U.S. Army Corps of Engineers

Galveston District
Southwestern Division

Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers and Galveston Counties, Texas

Economic Appendix

December 2019

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TABLES

List of Acronyms

AAEQ	Average Annual Equivalent
AEO	Annual Energy Outlook
BCC	Barbours Cut Ship Channel
BCT	Barbours Cut Container Terminal
BLT	Bulk Loading Tool
BNSF	BNSF Railway
BOP	Baytown Olefins Plant
BSC	Bayport Ship Channel
CBM	Cubic Meters
CLT	Container Loading Tool
DOE	U.S. Department of Energy
DWT	Dead Weight Tons
EJ	Environmental Justice
ETTC	Estimate Total Trip Cargo
FTZ	Foreign Trade Zone
FWOP	Future Without-Project
FWP	Future With Project
FY	Fiscal Year
HFOTCO	Houston Fuel Oil Terminal Company
HMST	HarborSym Modeling Suite of Tools
HSC	Houston Ship Channel
HSC ECIP	Houston Ship Channel Expansion Channel Improvement Project
HSCPDR	Houston Ship Channel Project Deficiency Report
HTRW	Hazardous, Toxic and Radioactive Waste
ITC	Intercontinental Terminals Company
IWR	Institute for Water Resources
LBC	Liquid Bulk Cargo
LFA	Loading Factor Analysis
LOA	Length Overall
LPG	Liquified Petroleum Gas
MLLW	Mean Lower Low Water
MLT	Mean Low Tide
NAAQS	National Ambient Air Quality Standards

NED	National Economic Development
OD	Origin-Destination
PDT	Project Delivery Team
PPX I	Post-Panamax Generation I
PPX II	Post-Panamax Generation II
PPX III	Post-Panamax Generation III
PPX IV	Post-Panamax Generation IV
PTRA	Port Terminal Railroad Association
PX	Panamax
RoRo	Roll-on Roll-off
SPX	Sub-Panamax
TEU	Twenty-Foot Equivalent Unit
TSP	Tentatively Selected Plan
UKC	Underkeel Clearance
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
WIS	World Industry Service
WTS	World Trade Service

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1 INTRODUCTION

This document presents the economic evaluations performed for the Houston Ship Channel (HSC) Expansion Channel Improvement Project (HSC ECIP). The study is being performed in response to the standing authority of Section 216 of the Flood Control Act of 1970, P.L. 91-611 dated December 31, 1970 (33 U.S.C. 569a), which authorizes studies to review the operation of completed Federal projects and recommend project modifications when found advisable due to significantly changed physical or economic conditions. The Galveston District, Southwestern Division, together with the Deep Draft Planning Center of Expertise performed the economic analyses contained within the Appendix in support of the feasibility study.

1.1 STUDY PURPOSE

The purpose of this study is to evaluate Federal interest in alternative plans (including the no-action plan) for reducing transportation costs and addressing navigation safety issues on the HSC and assess the effects of the alternatives on the natural system and human environment, including economic development.

Existing inefficiencies are a result of commercial vessel congestion along the waterway. The high volume of barge and deep-draft vessel traffic exacerbates congestion and results in increased delays and the potential for vessel related accidents. Channel deepening and/or widening may result in the deployment of larger and deeper drafting vessels, leading to fewer required trips and a reduction in waterway congestion. Furthermore, channel deepening and/or widening may alleviate congestion and safety concerns by enhancing the maneuverability and control of deep-draft vessels. Additional turning basins, moorings, and/or anchorages may also help reduce inefficiencies at HSC by alleviating congestion and reducing total vessel transit times. Safety issues on the HSC have already been established under the Houston Ship Channel Project Deficiency Report (Flare at the Intersection of the Houston Ship Channel and Bayport Ship Channel), Houston-Galveston Navigation Channels, Texas – Galveston District, March 2016 (HSCPDR). The HSCPDR, approved May 9, 2016, recommended an interim corrective action through a channel modification to make the project function in a safe, viable, and reliable manner. The ultimate fix was to be included in this study.

This study will evaluate improvements along the entire 52 miles of the HSC and two side channels—Bayport Ship Channel (BSC) and Barbours Cut Ship Channel (BCC). The HSC, Galveston Harbor and Channels, Galveston Entrance Channel, and Texas City Ship Channel are integrally connected to the overall navigation system of the Galveston Bay area. However, this feasibility study will focus solely and entirely on the HSC and the two side channels.

The study area has been divided into six project segments, as shown in **Figure 2-3.** Beginning at the most seaward end of the HSC, terminating at Bolivar Roads at the Galveston Entrance Channel, the study will examine possible anchorage and meeting and passing lanes in the Bay Reach, as well as improvements to the side channels—BSC and BCC. Additionally, the study will examine feasibility at the upper reach of the HSC between Boggy Bayou and the Main Turning Basin. The study also evaluates federalization of navigation features at Greens Bayou, Jacintoport, BSC, and BCC.

Figure 1-1: Study Segments or Reaches for the HSC ECIP Feasbility Study

1.2 STUDY AREA DELINEATION

The HSC provides access to numerous private and public docks and berthing areas including those associated with Port Houston. Bay Reach is the longest major navigation channel within the HSC system, spanning Harris, Chambers, and Galveston Counties, Texas. The HSC project consists of an existing 52-mile long navigation channel, and five tributary channels. Several other minor tributary channels also intersect the HSC, including South Boaters Cut, North Boaters Cut, and Five Mile Cut.

Although the Texas City Channel, Galveston Harbor and Channel, and the Cedar Bayou Channel Projects are located in the same bay system, they are not part of the HSC ECIP Feasibility Study. The Galveston Entrance Channel provides access from the Gulf of Mexico to the HSC and Galveston Harbor. Just beyond Galveston Harbor, the HSC and the Texas City Ship Channel intersect at Bolivar Roads. Additionally, on the northern end of the Atkinson Island Marsh, the HSC intersects with the Cedar Bayou (shallow draft) Federal channel. These channels are integrally connected to the overall navigation system of the Galveston Bay area; however, each has its own independent sponsor.

1.3 DOCUMENT LAYOUT

Section 2 details the existing conditions at the HSC. **Section 3** examines future without and with project conditions and includes an evaluation and description of terminal expansions, forecasted commodity trade, and vessel fleet operations at the harbor. **Section 4** presents the transportation cost savings benefit analysis. **Section 5** provides an overviews of the sensitivity analysis. **Section 6** summarizes the multi-port analysis. **Section 7** details updates to the economic analysis. **Section 8** describes the socioeconomics of the region surrounding the HSC and the potential impact regional impact of the recommended plan.

2 EXISTING CONDITIONS

The existing conditions are defined in this report as the project conditions that exist today (2017) plus any changes that are expected to occur prior to project year one, anticipated in 2029. The HSC extends 52 miles from its juncture with Texas City Channel at the entrance to Galveston Bay and terminates at a turning basin located within the city limits of Houston. From mile 0 to mile 38.5 (Boggy Bayou), the authorized channel depth is 46.5 feet, with a bottom width of 530 feet. The remaining channel depth from mile 40 to mile 52 (HSC Main Turning Basin) varies but generally is between 37.5 to 41.5 feet, with a bottom width of 300 feet. The latest improvement to the HSC to deepen the channel to −46.5 feet Mean Lower Low Water (MLLW) from the Gulf of Mexico up to Boggy Bayou was completed in June 2005. When the project was authorized in 1996, Sub-Panamax (SPX) and Panamax (PX) vessels made up about 80 percent of the container capacity in the world fleet and newbuild vessels. Since then, larger Post-Panamax classes of vessels are making up increasing percentages of newbuild vessels and the world fleet. Similarly, tanker vessel size has grown in the world fleet and at HSC with more Suezmax vessels transiting the waterway.

2.1 EXISTING CHANNEL AUTHORIZATIONS

The authorized channel dimensions within the HSC vary, as shown in **Table 2-1**. The original channel authorization was in Mean Low Tide (MLT). The Galveston District recently converted the HSC to the MLLW datum. In this report, MLLW is the standard datum used to report depth.

Table 2-1: Channel Dimensions for HSC and Tributaries

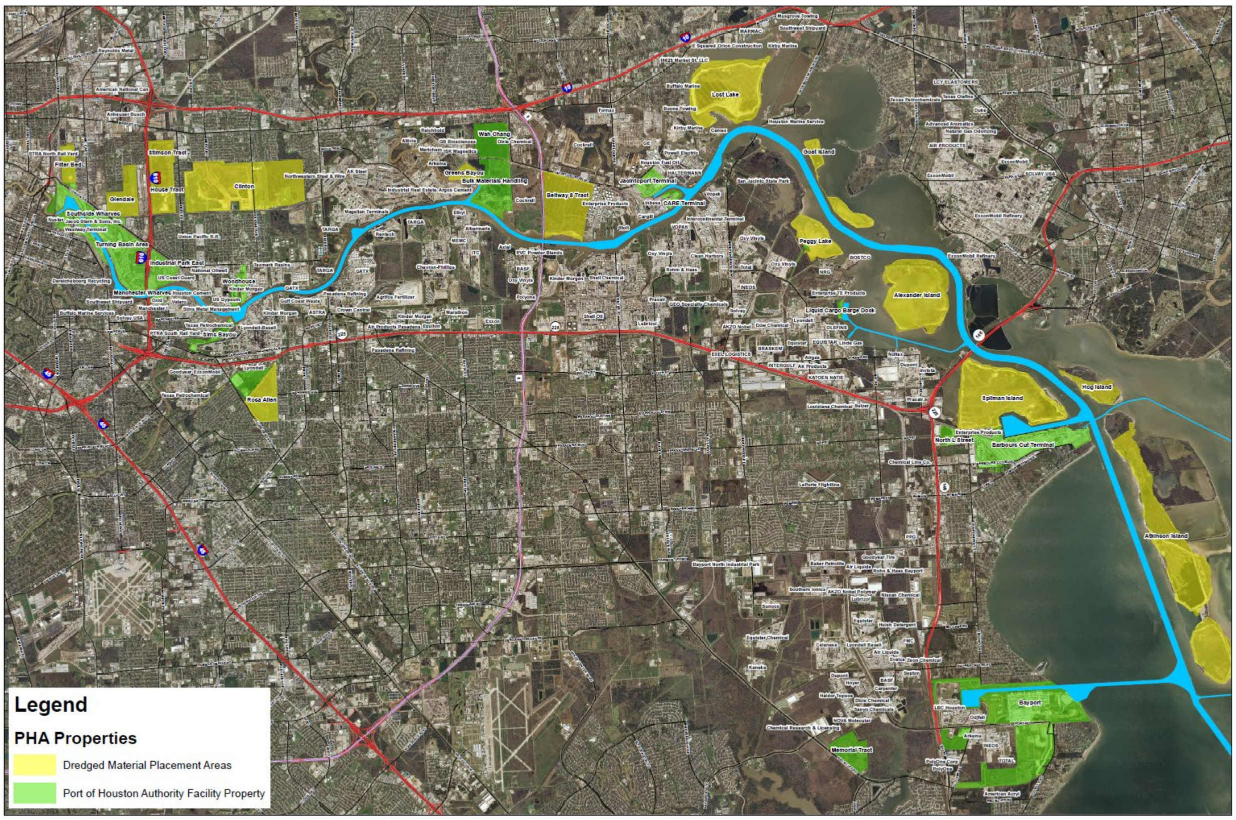
Houston Ship Channel Section of Waterway	Authorized Dimensions			
	Depth (feet)		Width (feet)	Length (miles)
	MLT	MLLW		
SEGMENT 1 – HSC-BAY REACH SAFETY AND EFFICIENCY ENHANCEMENTS				
Bolivar Roads (Mile 0) to Morgan's Point (Mile 26.2)[1]	45	46/46.5	530	26.2
Barge Lanes (adjacent to and on each side from Mile 0 to Mile 26.2)	12	13	125	26
Morgan's Point (Mile 26.2) to Boggy Bayou (Mile 38.5)	45	46.5	530-600	12.3
South Boaters Cut @ Mile 15.3	8	9	300	1.9
North Boaters Cut @ Mile 18.7	8	9	100	2.1
Five Mile Cut Channel @ Mile 20.9	8	9	125	1.9
SEGMENT 2 – BAYPORT SHIP CHANNEL				
Bayport Ship Channel (Mile 21.4 at intersection with HSC)[3]	40	41.5	300	3.8
Turning Basin	40	41.5	300-1,600	0.3
SEGMENT 3 – BARBOURS CUT CHANNEL				
Barbours Cut Channel (Miles 26.3 at intersection with HSC)[3]	45	46.5	300	1.1
Turning Basin	40	41.5	300-1,600	0.3
SEGMENT 4 – HSC-BOGGY BAYOU TO SIMS BAYOU				
Boggy Bayou (Mile 38.5) to Greens Bayou (Mile 42.0)	40	41.5	300	3.5
Jacintoport Channel	40	41.5	200	0.7
Greens Bayou (Mile 42.0) to Sims Bayou (Mile 47.5)	40	41.5	300	5.5
Hunting Bayou Turning Basin	40	41.5	948-1,000[2]	0.3
Clinton Island Turning Basin	40	41.5	965-1,070[2]	0.3
Greens Bayou Channel Mile 0.0 to Mile 0.36	40	41.5	175	0.4
Greens Bayou Channel Mile 0.36 to Mile 1.65	15	16.5	100	1.3
SEGMENT 5 – HSC-SIMS BAYOU TO I-610 BRIDGE				
Sims Bayou (Mile 47.5) to I-610 Bridge (Mile 48.3)	36	37.5	300	0.8
SEGMENT 6 – HSC-I-610 BRIDGE TO MAIN TURNING BASIN				
I-610 Bridge (Mile 48.3) to Houston (Main) Turning Basin (Mile 50.2)	36	37.5	300	1.9
Houston (Main) Turning Basin	36	37.5	400-932	0.6
Upper Turning Basin	36	37.5	150-527	0.2
Brady Island Channel	10	11	60	0.9
Brady Island Turning Basin	36	37.5	300-722	0.2

[1] *Per the MLT to MLLW Datum Conversion EDR, the split occurs at Beacon 76*
[2] *Includes 300-foot channel width*
[3] *PHA has approval to deepen channel to 45 feet (MLT)/ 46.5 feet (MLLW) and subsequent Federal assumption of maintenance under Section 408/204(f); BSC deepening was completed in fall 2016 and BCC was completed in August 2015*
[4] *City of Houston Improved in 1913 & 1914. Jensen Street Bridge to White Oak Bayou (Deauthorized – Sec12 of P.L. 93-251.)*

2.2 ECONOMIC STUDY AREA

Port Houston is a 25-mile-long complex of diversified public and private port facilities and is located in southeastern Texas. Port facilities extend from that located at Bayport Channel north and east to the Port's terminus on Boggy Bayou (i.e., at Main Street). The BSC and BCC are the two primary tributary channels to the HSC. **Figure 2-1** depicts the extent of PHA facilities along the HSC where green highlighted regions represent PHA Facility Property.

Figure 2-1: PHA Facility Property



2.2.1 Hinterland

The hinterland for Port Houston extends to every geographic region of the United States. It is the largest import and export port in the nation and is situated within the biggest foreign trade zone in terms of total import tonnage and eighth largest in terms of export tonnage. Port Houston accounts for 67 percent of seaport trade in Texas[1].

[1] Texas Comptroller, *Port of Entry: Houston – Port of Houston Impact to the Texas Economy,* (2015). https://comptroller.texas.gov/economy/docs/ports/overview-houston.pdf

The HSC is 192 miles from Austin, 227 miles from San Antonio, and 270 miles from Dallas/Fort Worth. **Table 2-2** provides population density by distance from Harris County[2].

Table 2-2: Study Area Population Density (2016)

Radius	Population
Harris County	4,589,928
50 miles	6,772,470
100 miles	7,823,209
200 miles	15,665,628
500 miles	43,062,221

2.2.2 Distribution Centers Development

With access to three Class 1 railroads (BNSF Railway (BNSF), Union Pacific Railroad (Union Pacific), TexMex/Kansas City Southern Railway (Kansas City Southern)) and a vast interstate system (including access to I-10 and I-45), HSC is well linked to the U.S. transportation network. The many distribution centers near HSC include Walmart's 500,000-square-foot facility and additional facilities owned by Home Depot, Xcel Energy, General Electric, Siemens, Cooper/T. Smith, Cargoways Logistics, Kuehne & Nagel, Empire Stevedoring, R Warehousing & Port Services, Jacintoport International, and Katoen Natie Gulf Coast.

2.2.3 Maritime Businesses

Service providers along the HSC facilitate the movement of imports/exports to and from port facilities for companies that ship or receive raw materials, component parts, and products. These firms are engaged in providing services such as freight forwarding, shipping agent services, and customs house brokering. In addition to the more than 150 private companies situated along Buffalo Bayou and Galveston Bay, Port Houston operates multiple facilities along the waterway including three container facilities and over 45 breakbulk and project cargo berths. Port Houston Authority, a cooperative entity with Port Houston, operates the major terminals along the HSC.

The Houston metropolitan statistical area employs 4,800 energy-related establishments and nearly one-third of the nation's jobs in oil and gas extraction[3].

The Port of Houston Authority is the grantee for Foreign Trade Zone (FTZ) No. 84, which is one of the largest FTZs in the country and is made up of various storage facilities and manufacturing facilities. FTZ 84 includes 13 special purpose subzones for use by individual companies for specific activities. FTZ 84 directly has 17,369 employees and 196 active firms[4]. Of the top 10 major U.S. cities for foreign direct investment in the future, Houston is ranked second for business

[2] statsamerrica.org
[3] http://www.houston.org/assets/pdf/business/HoustonRegionEconomicProfile.pdf
[4] http://gov.texas.gov/files/ecodev/TexasFTZs.pdf and http://porthouston.com/portweb/ftz/

friendliness, third for connectivity, fifth for human capital and lifestyle, and sixth for economic potential[5].

2.2.4 Cargo Profile

On average, 74 percent of cargo imported to HSC is petroleum or petroleum products. Other major imports include primary manufactured goods (12 percent), chemicals and chemical products (5 percent), and other crude materials (4 percent). Major exports from HSC are petroleum and petroleum products (61 percent), chemicals and chemical products (19 percent), food and farm products (10 percent), and manufactured equipment (4 percent).

Thirty-eight percent of all ships received enter the port after passing through the Panama Canal[6]. Port Houston is the nation's largest importer and exporter of petroleum and petroleum products. In 2014, the port's container terminals handled 67 percent of all U.S. Gulf Coast container traffic. Top origins and destinations for goods at HSC are China (9 percent) and Mexico (9 percent), but Port Houston and HSC has an expansive, worldwide trading network.

2.3 FACILITIES AND INFRASTRUCTURE

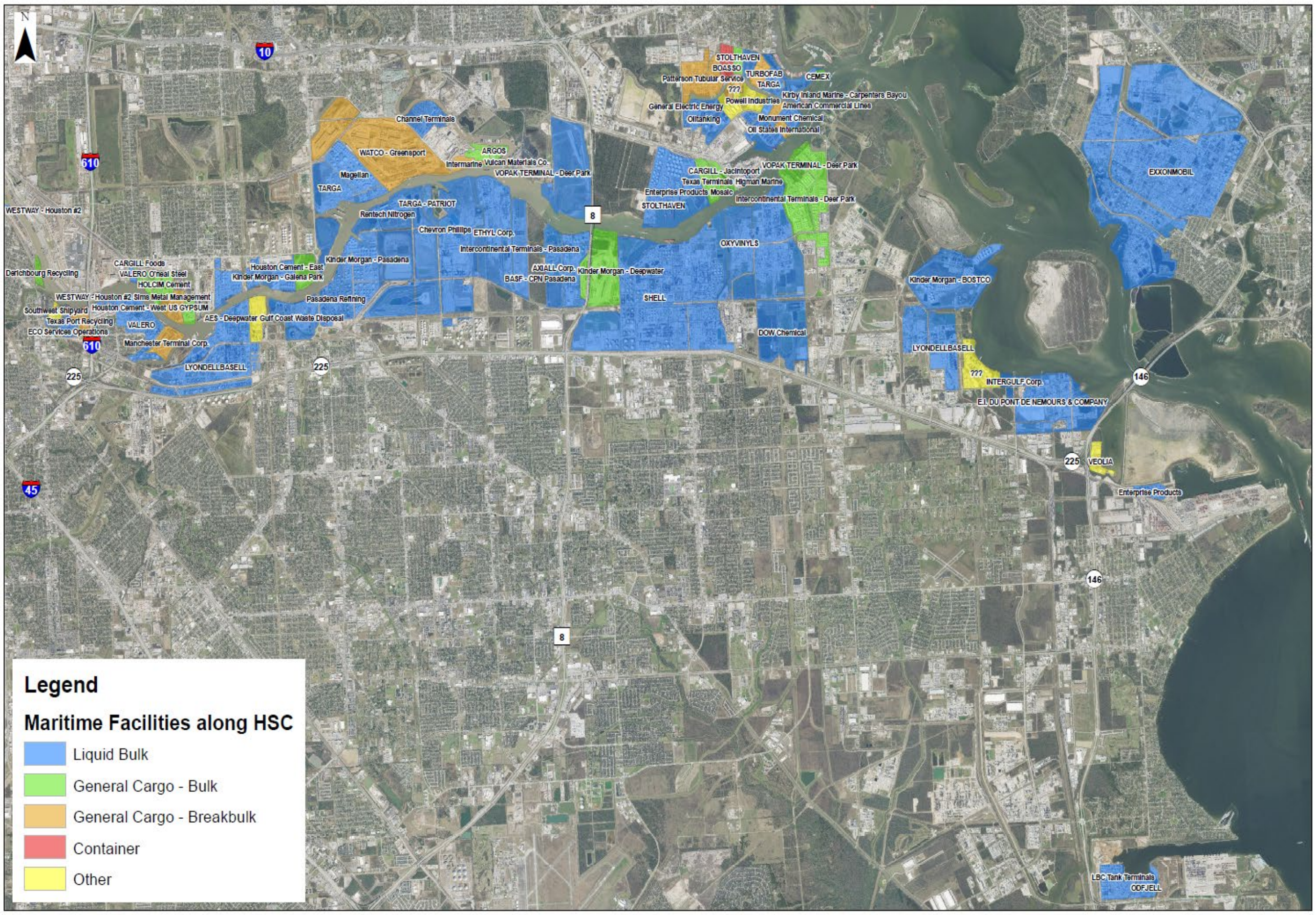
The HSC serves Port Houston as well as numerous privately owned terminals. The facilities and infrastructure described in this section account for approximately 85 percent of the total tonnage moving to docks along the HSC.

Port Houston, opened in November 1914, includes 25 miles of the HSC. Port Houston consists of not only eight public terminals owned, operated, managed or leased by Port Houston, but also more than 150 privately owned facilities along the upper half of the channel. In 2015, the HSC served 8,325 total oceangoing vessel arrivals including break bulk, bulk carrier, containers, roll-on/roll-off (RORO), tankers, tug tow, and vehicle carriers. While this overall total dropped slightly from 8,339 total vessel arrivals in 2014, the total number of tankers increased in 2015 by approximately 6 percent. Container cargo is primarily handled in the Barbours Cut Container Terminal (BCT) and Bayport Container Terminal (BPT), where a total of 1,935,444 twenty-foot equivalent units (TEUs) were handled in 2015, up 8.1 percent from the previous year. As of 2015, Port Houston is ranked first in the nation for foreign waterborne tonnage and second in terms of total tonnage. In 2015, Port of Houston Authority reported total revenue tonnage of 45,168,000 short tons (Port of Houston Authority, 2015).

A summary of facilities is provided in the following sections and depicted in **Figure 2-2**.

[5] https://texaswideopenforbusiness.com/sites/default/files/07/13/16/fdireport.pdf
[6] https://comptroller.texas.gov/economy/economic-data/text-only/houston.php

Figure 2-2: HSC Facilities



2.3.1 Bayport Container Terminal

The BPT is located on the BSC, which began with a series of agreements in 1964 between Humble Oil and Refining Company and the Harris County Navigation District (now the Port of Houston Authority) to dredge a new side channel to connect to the HSC in the present-day location of the BPT. A 10-foot-deep and 100-foot-wide barge channel was completed in 1966. It was later deepened to 12 feet in 1970 during the project's first phase.

The project's second phase began in 1972 and completed in 1977. It consisted of channel deepening and widening, construction of a turning basin, inclusion of aids to navigation, dredged material disposal, drainage structures, access roads, and railroad modifications on the port's property within the land cut on the south side of the channel[7]. During this phase of construction and pursuant to Department of the Army permit number 6140 (Section 408 approval and a Section

[7] The land cut is the portion of the channel that was created by cutting into the mainland to provide vessel access to facilities located in interior locations.

404/10 permit), the channel was deepened and widened to its current depth of −41.5 feet MLLW and width of 300 feet to accommodate a design vessel drafting 36 feet. Those improvements were completed in 1974. Planning for the BPT Cruise Terminal resulted in the *Final Environmental Impact Statement for Port of Houston Authority's Proposed Bayport Ship Channel Container/Cruise Terminal*, dated May 2003.

The BSC became a Federally-maintained channel when Federal maintenance of the BPT channel was authorized by an amendment to Section 819 of WRDA 1986, Public Law 99-662, which states:

> *"Federal maintenance of the Bayport Ship Channel, the channel, exclusive of berthing areas originally constructed at 40 feet in depth by the Local Sponsor pursuant to Department of the Army permit number 6140, to be perpetually maintained by the Government at a depth of 40 feet and width of 300 feet, from the Houston Ship Channel at mile 20.5 to the Bayport Turning Basin approximately 22,000 feet west; and the turning basin, to be perpetually maintained by the Government at a depth of 40 feet, a width of 1,600 feet and a length of 1,600 feet."*

The U.S. Army Corps of Engineers (USACE) assumed maintenance of the channel in April 1993 with a Local Cooperation Agreement authorized by the WRDA 1986 amendment.

The BSC is currently maintained by USACE to a depth of −41.5 feet MLLW and 300 feet wide with 2 feet of advanced maintenance and 2 feet of overdepth dredging along the entire channel length. The BSC Flare, the widened segment connecting the BPT Channel with the HSC is currently maintained at a depth of −41.5 feet MLLW plus 7 feet of advanced maintenance and 2 feet of overdepth dredging (i.e., from the confluence of the BSC Flare with the HSC to approximately station 214+00 on the BSC). Segments of the BSC are maintained on varying cycles: 17 months at the BSC Flare and 36 months for the channel and turning basin[8].

The BPT consists of three berths totaling 3,300 feet in length. Each berth is 40 feet in depth, 225 feet in width, and runs parallel to the BSC. The berths are serviced by 9 wharf cranes (6 Post-Panamax and 3 Super Post-Panamax) and 27 rubber tired gantry cranes. The terminal consists of 193 acres of developed land. The BPT is located near I-10, I-45, and I-69. The terminal has an

[8] Turner Collie & Braden Inc. and Gahagan & Bryant Associates, Inc. *Bayport Ship Channel Improvements Project, Draft Cost Estimate* (2013).

existing annual throughput capacity of 1.2 million TEUs, but improvements to be completed before the study base year (2029) will increase the terminal's annual capacity to 2.3 million TEUs.

2.3.2 Barbours Cut Container Terminal

Located in Morgan's Point, the BCT is the Port Houston's busiest terminal. Authorized by Section 107 of the Rivers and Harbors Act of 1960, the Barbours Terminal Channel Federal Project was authorized and originally constructed as a −17.5-foot-deep MLLW Federal project. Port Houston deepened the BCC and turning basin to −43.5 feet MLLW and constructed the container terminal along the southern limits of the channel. The terminal opened in 1977. The channel is currently authorized at a depth of −41.5 feet MLLW. The channel has been maintained historically at a 2- to 2.5-year interval, with 2 feet of advanced maintenance and 1 foot of overdepth dredging. Maintenance dredged sediments have been placed in the Spilman Island Placement Area, which is located adjacent to the northern limits of the BCC. The USACE assumed maintenance of the BCC in 1992.

In 2008, the USACE mined the BCC and most of the turning basin to −61.5 and −55.5 feet MLLW, respectively. The new work dredged material was beneficially utilized to construct levees at Atkinson Island for Cell M5/M6 and to repair levees at Spilman Island.

The BCT includes six, 1,000-foot berths, which run parallel to the BCC. Eleven wharf cranes ensure efficient and reliable handling of containers. The facility also includes a roll-on/roll-off platform, a LASH dock, 230 acres of paved marshaling area, 255,000 square feet of warehouse space, and an open marshaling and storage area. A computerized inventory control system tracks the status and location of individual containers. The terminal also features electronic data interchange capabilities. A comprehensive refrigerated food warehouse is located near the terminal. The terminal has an existing throughput capacity of 1.2 million TEUs, but improvements to be completed by the study base year (2029) will increase the terminal's annual capacity to 2 million TEUs.

The BCT is located in the proximity of I-10, I-45, and I-69. Additionally, there is an intermodal rail ramp near BCT with spurs leading to warehouses at the terminal. The rail facility is near the BCT dock (not on the dock side). The rail ramp consists of 42.1 acres with four working tracks (each approximately 2,700 feet in length), five storage tracks (each approximately 2,250 feet in length), and 730 wheeled container spaces. The entire facility is paved with concrete and sustains wheeled operations only. The container handling method is three Mi-Jack 1000R series overhead cranes, each capable of 30 moves per hour. The rail facility is currently operated by ITS Technologies on contract, and the primary railroad companies are BNSF, Union Pacific, and Port Terminal Railroad Association (PTRA).

2.3.3 Breakbulk and Project Terminals

2.3.3.1 Bulk Materials Handling Plant

The Bulk Materials Handling Plant is operated by Kinder Morgan and primarily handles dry bulk, petcoke, and coal. The plant contains two berths, which include an 800-foot ship dock and a 400-foot barge dock both with a water depth of approximately 40 feet. The plant is serviced by the PTRA and is conveniently located near I-10, Highway 225, and I-610 Loop[9].

2.3.3.2 Care Terminal

The Care Terminal is operated by Coastal Cargo of Texas and primarily handles breakbulk, project cargo, heavy lift, and bulk. The terminal is located on the north side of the HSC, near the City of Channelview and consists of two berths; berth 1 is 500 feet in length with a project depth of 37 feet and berth 2 is 618 feet in length with a project depth of 39 feet. Additionally, on-site there are 45,900 square feet of covered storage and 15 acres of paved storage. Care Terminal is serviced by the PTRA and is located within easy access to I-10[8].

2.3.3.3 Empire Terminal

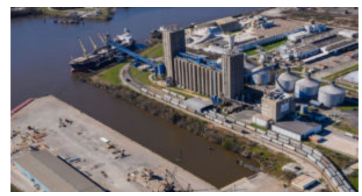
Empire Terminal is operated by Empire Stevedoring and primarily handles breakbulk, project cargo, heavy lift, and bulk. The facility has two berths – each 827 feet in length with a project depth of 35 feet. The terminal is serviced by Union Pacific and is located within easy access to I-10[8].

[9] Port Houston: http://porthouston.com/portweb/breakbulk-and-project-cargo/

2.3.3.4 Jacintoport Terminal

The Jacintoport Terminal, operated by Jacintoport International, primarily handles container, breakbulk, project cargo, and U.S. aid cargo. The terminal consists of three berths with a 40-foot project depth and lengths of 636 feet at berth 1 and 600 feet at berths 2 and 3. The site consists of several covered storage facilities including a shed, warehouse, and refrigerated facility and 7.5 acres of uncovered storage. Jacintoport Terminal is serviced by the PTRA and is located with easy access to I-10[8].

2.3.3.5 Public Elevator No. 2



Public Elevator No. 2 is operated by Louis Dreyfus and is utilized for loading export only of multi-grains. The project depth is 40 feet with an air draft of 48 feet and a 106-foot beam. The single berth is 600 feet in length. The terminal is serviced by Union Pacific and is easily accessible to I-10.

2.3.3.6 TGS Deepwater Terminal

The Trans-Global Solutions, Inc. (TGS) Deepwater Terminal was purchased by Kinder Morgan Energy Partners in 2005. This 136-acre site is located in Pasadena, Texas, and includes one 40-foot draft vessel dock. The terminal has a design system rate of 40,000 tons per day of petcoke loading with an annual tonnage of 4.5 million tons. Services include conveyor to storage, railcar to storage, and storage to vessel[10].

2.3.3.7 Turning Basin Terminal

The Turning Basin Terminal, located at the head of the HSC, is owned by the Port of Houston Authority of Harris County, Texas. This multipurpose complex consists of five liquid bulk wharves, one project cargo wharf (specially designed for handling project and heavy lift cargoes), and 36 general cargo wharves with substantial dockside facilities. General cargo and liquid bulk wharves berth lengths range from 376 to 600 feet at water depths from 27 to 36 feet (below mean tide). General cargo wharves consist of a paved

[10] https://www.kindermorgan.com/content/docs/terminalbrochures/p-deepwaterpasadena.pdf

marshalling area of 36 acres, while the project cargo wharf covers 20 acres with an 800-foot berth length and 37-foot water depth[11].

2.3.3.8 Woodhouse Terminal

Woodhouse Terminal is operated by C-PA and primarily handles breakbulk, project cargo, heavy lift, and roll-on/roll-off (RoRo). Project depths range from 35 to 39 feet at three berths ranging from 600 to 660 feet in length. The facility consists of 19,000 square feet of covered storage and 25 acres of uncovered storage and is serviced by Union Pacific, with easy access to I-10.

2.3.4 Liquid Bulk Cargo

2.3.4.1 Battleground Oil Specialty Terminal Company LLC (BOSTCO)

The BOSTCO Terminal is operated by Kinder Morgan and owned by Kinder Morgan, Inc, Tauber, and TransMontaigne Partners LP. The facility consists of 185 acres located at mile marker 43 on the HSC. Construction on the terminal began in 2011 with initial start-up of operations in 2013. There are two ship berths with 46.5-foot depth (MLLW) and 950-foot length with 12 barge loading and unloading spots. The facility is serviced by Union Pacific and easily accessible to Highways 225 and 146. There is also an on-site Exxon Baytown pipeline connection[12].

2.3.4.2 ExxonMobile Baytown

The ExxonMobil Baytown complex is a refining and petrochemical complex located on approximately 3,400 acres along the HSC. The refinery includes six berths with maximum drafts ranging from 38 to 43 feet and lengths of 410 to 820 feet.

The majority of crude oil for the refinery is supplied by tankers from the Persian Gulf, Africa, South America, and Mexico, supplementing pipeline crude from Texas and Louisiana. Crude capacity is currently 573,000 barrels per day, making it the largest refinery in the United States. The Baytown Complex produces a full range of petroleum products including lube oils, waxes, and hydrocarbon fluids as well as various blends and grades of these specialties' products. Gasoline is supplied to Texas and most states on the East Coast via pipeline. More than 7.2 billion pounds of petrochemical products are manufactured each year at the chemical plant. Basic chemicals purify refinery propylene and recover aromatics from refinery reformate and the

[11] Port of Houston Authority: http://208-110-207-161.biz.houston.comcastbusiness.net/general-terminals/terminals/turning-basin/
[12] http://www.bostco.net/pages/overview.aspx

Baytown Olefins Plant (BOP) naphthas, as well as butylene from BOP for butene-1 production. Seven percent of materials produced at the refinery are shipped by barge[13].

2.3.4.3 Houston Fuel Oil Terminal Company (HFOTCO)

HFOTCO is a leading marine terminal for storage of residual fuel oil and crude oil. The company owns and operates a 13.8-million-barrel storage terminal and is the largest provider of residual fuel oil storage in the Gulf Coast. HFOTCO's assets are strategically located on a 312-acre footprint at the widest point of the HSC, one of the largest trading centers for residual fuel oil and crude oil in the world. The facility includes four deepwater ship docks with dock infrastructure capable of loading and unloading Suezmax size vessels as well as six barge docks that can service 19 barges simultaneously[14].

2.3.4.4 ITC Deer Park

The Intercontinental Terminals Company (ITC) Deer Park terminal started in 1972 and currently has 12.8 million barrels (2 million cubic meters (cbm)) of capacity in 239 tanks. It stores all kinds of petrochemical liquids and gases, as well as fuel oil, bunker oil, and distillates. The terminal has five ship docks and 10 barge docks, rail and truck access, as well as multiple pipeline connections. The facility has five tanker berths, four of which range from 600 feet to 900 feet, with nominal draft of 40 to 45 feet. An additional tanker berth is 520 feet with a 28-foot draft and 80-foot beam. There are also 10 barge docks allowing for a total of up to five oceangoing tankers and 15 barges to be accommodated simultaneously[15].

2.3.4.5 ITC Pasadena

The ITC Pasadena terminal opened with 1 million barrels capacity in May 2015 and will have over 3 million barrels of storage available once the current construction is completed. The products handled are petrochemicals and petroleum products. The facility has two ship docks and four barge docks, as well as rail and truck. The terminal will be connected to the Explorer and Colonial pipeline systems, as well as to multiple refineries and plants in the area[12].

[13] http://corporate.exxonmobil.com/en/company/worldwide-operations/locations/united-states/baytown-area-operations/about
[14] http://www.hfotco.com/facilities.html
[15] http://www.iterm.com/

2.3.4.6 Jacob Sterns & Sons

The Jacob Sterns & Sons terminal is operated by Jacob Sterns & Sons and primarily handles liquid cargo. The facility serves vessels, barges, trucks, and rail car. There is a total of three berths with a project depth of 34 feet. The terminal is served by the PTRA and is located with easy access to I-10[16].

2.3.4.7 LBC Houston

The LBC Houston terminal provides storage, transfer, and distribution services for chemicals, petroleum products, and oils. LBC Houston has 186 tanks with liquid storage capacity of 6.5 million barrels. The facility operates year-round and is serviced by ship, barge, truck, and rail, with direct transfers available between ships/barges to and or from rail and truck. Its current berthing capacity includes three berths for deep draft vessels (with maximum draft of 40 feet) and five for barge traffic[17].

2.3.4.8 Odfjell Terminals

Odfjell Terminals (Houston) is a 76-acre facility located on the southeastern boundary of the Bayport Turning Basin near the entrance of the HSC. The Houston facility has 119 tanks with a total capacity of just over 2.28 million barrels. The terminal provides storage, transfer, and distribution services for liquid chemicals including chemicals, petroleum, acids, edible oils, and liquified petroleum gas (LPG). The Bayport facility can store and transfer over 700 chemicals with simultaneous distribution to any combination of ships, barges, rail cars, tank trucks, banks, or ISO containers. The terminal is linked to the North American rail network for distribution throughout the United States, Canada, and Mexico. From a single vessel, up to 25 different chemicals can be simultaneously loaded and discharged. Direct transfer from rail to ship or barge can be handled at rates up to 3,500 barrels per hour.

The facility has two deepwater berths that can accommodate vessels up to 650 feet in length and 40 feet in draft. Barge traffic is handled at four berths (i.e., length overall up to 300 feet and drafts

[16] http://www.jacobstern.com/bls/
[17] https://www.lbctt.com/locations/lbc-houston/

of 12 feet). There are also eight rail tracks with the capacity of unloading up to 110 rail cars and 14 truck stations located on site[18].

2.3.4.9 Old Manchester Terminal

The Old Manchester Terminal is operated by Westway Terminals with primary cargo handling of liquids. The facility consists of two berths with a depth of 36 feet. Vessels, barges, tank truck, ISO containers, flexitank, and railcar containers can be serviced, and the facility is connected to BNSF, Kansas City Southern, and Union Pacific with easy access to I-10.

2.3.4.10 Oiltanking Houston

Oiltanking Houston, L.P. provides oil warehousing and storage facilities. Their Texas City terminal is located in Galveston Bay. The terminal is located in the middle of an industrial complex including three world-scale refineries and three major chemical plants. The storage capacity of 555,000 cbm can be separated into petroleum products, gases, and chemicals. The Texas City terminal includes nine berths for barges and tankers up to 38 feet draft. The facility has connections to the highway and railway network, provides good pipeline access, and has an excellent marine configuration[19].

2.3.4.11 Shell Oil Co Deer Park

Shell Deer Park, located in Deer Park, Texas, originated in 1929, and currently covers 2,300 acres. It is a fully integrated refinery and chemical plant that operates 24 hours a day. Shell Deer Park's location near major crude oil and products pipelines, in addition to extensive dock facilities, is an important asset. This provides the site with numerous transportation advantages and significantly increases efficiency when delivering or receiving products. Annually, an average of more than 2,500 vessels are loaded or off-loaded at the site, which represents about 100 million barrels (4 billion gallons) of crude oil and products for the refinery and chemical plant. The dock facility ranks (in volume of materials) as one of the 25 largest ports nationwide and has the capability to handle tankers as large as 80,000 tons. Annually, an average of 2,500 to 2,700 vessels are loaded or offloaded at the docks, representing about 100 million barrels of products for the chemical plant and refinery. The facility consists of five berths, three of which are dual purpose[20].

[18] http://www.odfjell.com/Terminals/HoustonTerminalUSA/Pages/default.aspx
[19] http://www.oiltanking.com/Oiltanking/en/services/terminals/oil_storage/north_america/oiltanking_texascity.php
[20] http://www.shell.us/about-us/projects-and-locations/deer-park-manufacturing-site/about-shell-deer-park.html

2.3.4.12 Sims Terminal

The Sims Terminal is operated by TPC group and consists of two ship berths and one barge dock with a project depth of 40 feet. The facility primarily handles liquid cargo and services vessels, barges, trucks, and railcars. Sims is serviced by the PTRA and is conveniently located near I-10.

2.3.4.13 Vopak Terminal Deer Park

The Vopak Terminal consists of eight barge berths and four vessel berths. The terminal stores and transports biofuels, chemicals, petroleum products, base oils, and lubricants[21].

2.4 HISTORICAL COMMERCE

The following section summarizes historical import and export trade at the HSC. The analysis establishes the baseline for commodity forecasting presented in Section 3. **Figure 2-3** provides a summary of commodity growth from 2005 for both import and export[22].

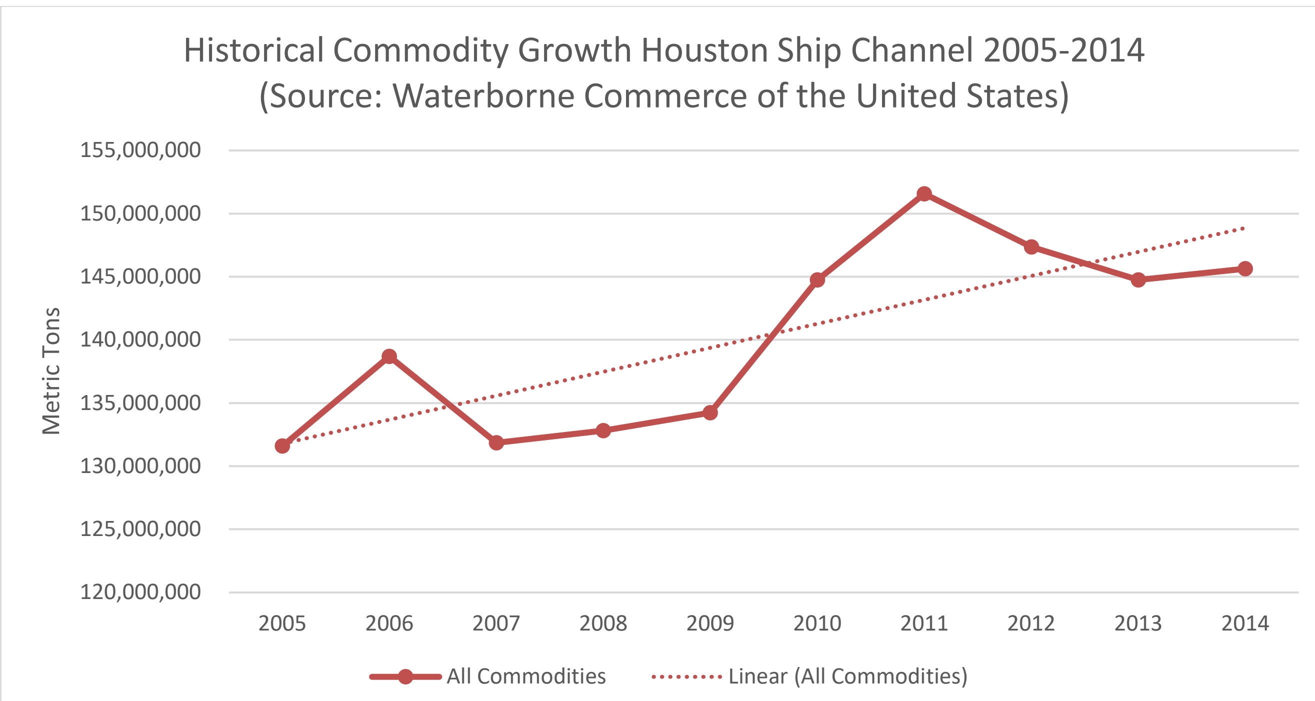


Figure 2-3: Historical Commodity Growth at HSC from 2005 to 2014

[21] https://www.vopak.com/terminals/vopak-terminal-deer-park-houston
[22] http://www.navigationdatacenter.us/wcsc/webpub14/Part2_Ports_tonsbyTT_Dr_Yr_comm2014-2010.htm

2.4.1 Imports

Table 2-3 summarizes historical imports moved through the HSC from 2010 to 2015. Over that time, imports fell by 15.5 million tons. Petroleum and petroleum products imports fell by 27.7 million tons from 2010 to 2015, leading to the overall decline in tonnage. Per the Department of Energy, this significant drop is part of a national trend of lower levels of consumption, increased use of domestic biofuels, and increased domestic production of crude oil and hydrocarbon gas liquids (due largely to the widespread application of advanced techniques combining horizontal drilling and hydraulic fracturing)[23].

Table 2-3: Historical Imports (1,000 Metric Tons)[24]

Commodity	2010	2011	2012	2013	2014
Chemicals	3,345	3,695	3,727	4,040	3,902
Coal	1	-	1	2	1
Crude Materials	2,993	2,426	2,396	2,658	3,915
Food and Farm Products	1,241	1,417	1,460	1,615	1,616
Manufactured Equipment, Machinery	1,553	1,816	2,038	2,285	2,972
Other	228	287	309	583	1,575
Petroleum and Petroleum Products	64,802	63,065	56,619	49,068	44,164
Primary Manufactured Goods	6,131	7,932	9,487	9,102	11,424
Total	**80,293**	**80,639**	**76,037**	**69,353**	**69,568**

2.4.2 Exports

Table 2-4 summarizes exports moved through the HSC from 2010 to 2015. Over that time, exports grew by 19 million tons. Petroleum and Petroleum Products exports grew by 19.4 million tons, leading to the overall growth in tonnage. This was led primarily by an increase in exports of hydrocarbon and petroleum gases, naphtha and solvents, and other petroleum products. The significant growth in domestic production coupled with stable consumption led to the export growth between 2010 and 2015[25]. Coal, crude materials, manufactured equipment, and other commodities grew from 2010 to 2015. Chemicals, food and farm products, and primary manufactured goods declined in the same time period.

Table 2-4: Historical Exports (1,000 Metric Tons)[26]

Commodity	2010	2011	2012	2013	2014
Chemicals	13,805	13,476	13,973	14,016	11,859
Coal	3	499	2,154	2,738	1,927
Crude Materials	882	1,404	1,474	1,570	1,304
Food and Farm Products	8,504	7,727	4,946	7,315	7,210
Manufactured Equipment	2,354	2,712	2,736	2,725	2,755

[23] https://www.eia.gov/energyexplained/index.cfm?page=oil_imports
[24] http://www.navigationdatacenter.us/wcsc/webpub14/Part2_Ports_tonsbyTT_Dr_Yr_comm2014-2010.htm
[25] https://www.eia.gov/energyexplained/index.cfm?page=oil_imports
[26] http://www.navigationdatacenter.us/wcsc/webpub14/Part2_Ports_tonsbyTT_Dr_Yr_comm2014-2010.htm

Commodity	2010	2011	2012	2013	2014
Other	579	463	579	986	1,738
Petroleum & Petroleum Products	37,279	43,686	44,341	45,084	48,416
Primary Manufactured Goods	1,053	964	1,089	956	856
Total	**64,458**	**70,931**	**71,291**	**75,389**	**76,066**

2.5 CONTAINER SERVICES

In 2016, 22 container services called at HSC (BPT, BCT, and the Jacintoport Container Terminal). **Table 2-5** provides the operator, service, vessel TEU capacity, and trade area for all services ordered largest to smallest by vessel TEU capacity. Services only using vessels of 4,000 TEU capacity and under are excluded from this table.

Table 2-5: Houston Ship Channel Container Services (May 2016)

Operator	Service	Vessel TEU's	Trade Areas
Maersk	TA-6	6,600	Mexico • Houston • New Orleans • Miami • Mediterranean • Port Everglades
Maersk	MECL 1	6,400	Savannah • Norfolk • New York • Mediterranean • Middle East •Mediterranean • Charleston • Houston
Hamburg Sud	UCLA 1	5,500 - 6,500	Mexico • Houston • East Coast South America
Hapag-Lloyd	GS1	5,500 - 6,000	Mexico • Houston • New Orleans • East Coast South America
Hapag-Lloyd	AX2	5,000	Northern Europe • Mexico • Houston • New Orleans • Charleston
CMA CGM	PEX3	5,000	China • *Panama Canal* • Houston • Mobile • Miami • Jacksonville • South Africa • Singapore
Maersk	TA-1	4,800	Mediterranean • Norfolk • Charleston • Miami • Houston
Maersk	TP-18	4,000 - 5,000	Houston • Mobile • Miami • *Panama Canal* • East Asia
Hapag-Lloyd	MGX	4,200 - 4,400	Mediterranean • Caribbean • Port Everglades • Mexico • Houston • New Orleans
COSCO/CS	GME	4,250	China • *Panama Canal* • Houston • Mobile
CMA CGM	VICTORY	4,200	Mediterranean • Northern Europe • Charleston • Savannah • Miami • Houston • New Orleans

2.5.1 Existing Container Terminals and Capabilities

As discussed in Section 2.3.1, Port Houston's container operations are primarily handled at Bayport Container Terminal and Barbours Cut Container Terminal with some smaller services handled at Jacintoport Terminal. When fully developed, Bayport Container Terminal will have seven container berths with the capacity to handle 2.3 million TEUs annually. Barbours Cut Container Terminal's six berths will have capacity for 2 million TEUs annually when fully developed.

2.5.2 Carriers and Trade Lanes

Data from Port Houston shows that between 2016 and 2017, the port maintained approximately 22 regularly calling container services. Routes include services to the Far East, Northern Europe, the Mediterranean, South America, Central America, the Middle East, and the Caribbean. Major lines and consortia calling Bayport and Barbours Cut Container Terminals include COSCO, CMA-CGM, Hapag-Lloyd, MSC, Maersk, and Hamburg Sud.

2.5.3 TEU Weight by Container

Data for all container vessel calls detailing loaded and unloaded TEU and metric tons from 2010 to 2016 from PIERS database were used to calculate the average metric tons per TEU by route group. Results are shown in **Table 2-6**. The assumed two-ton tare weight for all boxes was not included in this total.

Table 2-6: Tons per TEU by Route

Route Group	Description	TEU Weight
NEU-NA	Northern Europe to North America	9.27
ECSA-NA	East Coast South America to North America	12.01
FE-NA-PAN	Far East to North American via Panama Canal	8.72
MED-NA	Mediterranean to North America	9.24
FE-NA-SUEZ	Far East to North America via Suez Canal	9.79
CAR-CA-NCSA	Caribbean, Central America, and North Coast South America to North America	10.89

2.6 LIQUID AND DRY BULK SERVICES

Itinerary data from the Waterborne Commerce Statistics Center (WCSC) indicates that bulk traffic follows both pendulum routes (back-and-forth to-and-from HSC) as well as multi-port services depending on cargo, vessel type, and vessel size. Primary benefitting vessels of this study are bulk cargo carriers and tankers. These vessels primarily follow routes between HSC and the following regions:

- Caribbean, Central America, and Mexico
- East Asia
- East Coast South America
- Northern Europe
- Mediterranean
- West Coast South America
- West Coast Africa
- Middle East
- Canada
- Southeast Asia

This study assigned future traffic route groups based on historical route groups by vessel class gathered from the Entrances and Clearances Database from the Navigation Data Center.

2.6.1 Container Fleet

From 2011 to 2015, the containership fleet calling at the HSC consisted of Sub-Panamax (SPX) (33 percent), Panamax (PX) (52 percent), Generation I Post-Panamax (PPX I) (15 percent), and Generation II Post-Panamax (PPX II) (less than 1 percent). Over this time, the percent of Post-Panamax calls has increased from nine percent to 21 percent of total calls while the percent of Panamax and Sub-Panamax calls has fallen from 91 percent to 79 percent of total calls. **Figure 2-4** provides an overview of vessel calls by class at the HSC from 2011 through 2015.

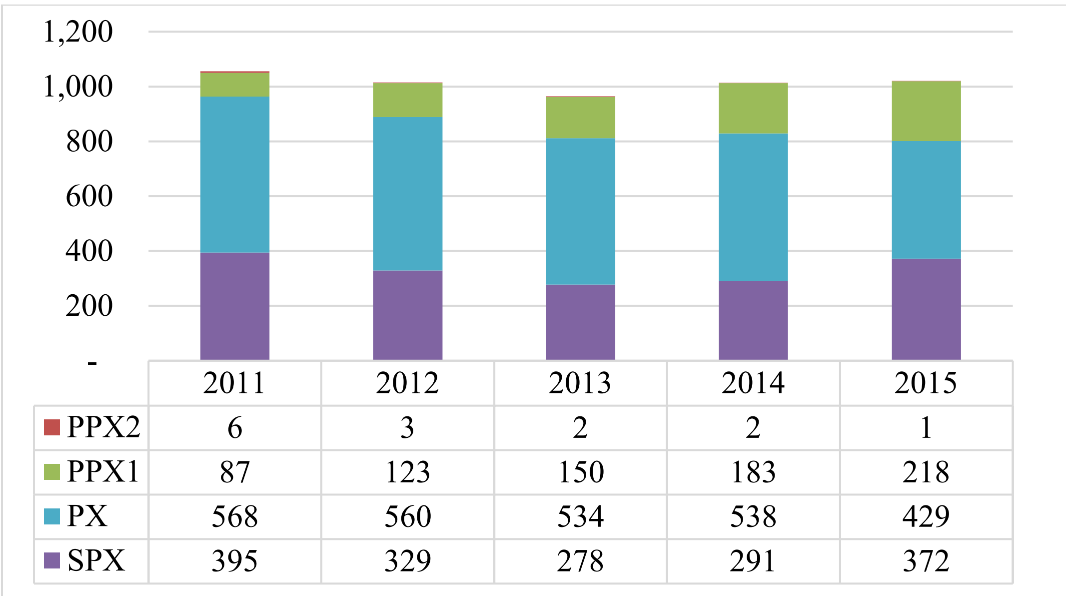


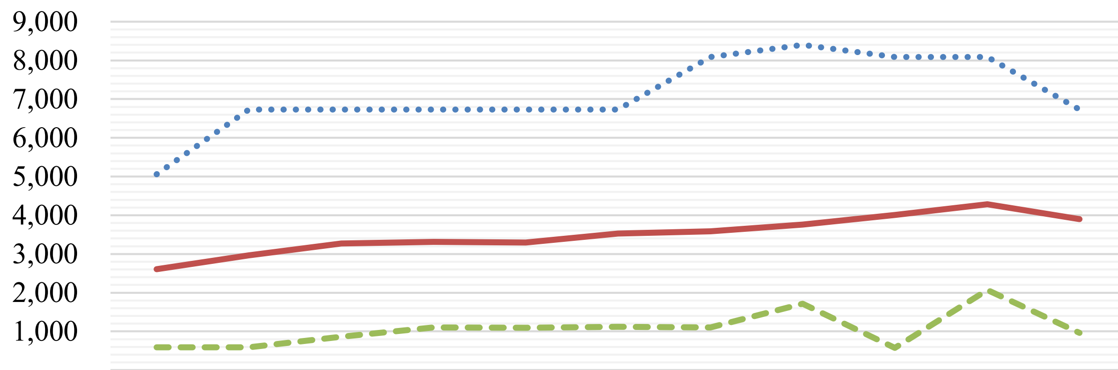
Figure 2-4: Houston Ship Channel Containership Fleet 2011-2015

The largest containership by deadweight tonnage to call at HSC was the *MSC Rania* in 2012; however, this vessel no longer calls the port. As of 2015, the largest vessel to call HSC was the *Cap Andreas*. The dimensions of the *MSC Rania* and *Cap Andreas* are given in **Table 2-7**. Currently, the largest vessel calling at HSC has a nominal capacity of 6,500 TEUs. Over the past five years, four calls at HSC have exceeded a breadth of 140 feet.

Table 2-7: Largest Vessel Calls 2011–2015

Vessel Name	Beam	Draft	LOA	DWT	TEU Capacity
MSC Rania	141.7	47.6	1,083	108,000	8,400
Cap Andreas	140	47.8	889	80,547	6,612

From 2005 to 2015, the average vessel's TEU capacity calling at HSC (BPT, BCT, and Jacintoport) grew at a 3.7 percent compound annual growth rate from 2,608 nominal TEUs to 3,902 TEUs in 2014, with the largest average vessel size of 8,089 nominal TEUs in 2014. **Figure 2-5** provides the minimum, average, and maximum nominal TEU capacity of vessels calling at HSC from 2005 to 2015.

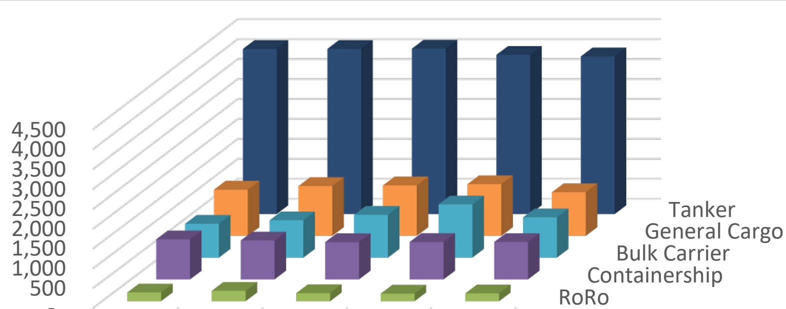


	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Min TEU	591	591	862	1,104	1,092	1,118	1,102	1,713	575	2,070	966
Avg TEU	2,608	2,969	3,267	3,309	3,297	3,526	3,586	3,759	4,008	4,284	3,902
Max TEU	5,059	6,732	6,732	6,732	6,732	6,732	8,089	8,401	8,089	8,089	6,732

Figure 2-5: Houston Ship Channel Vessel Nominal TEU Capacity 2005–2015

2.6.2 Bulk Fleet

Nearly 90 percent of all deep-draft vessel traffic at HSC is non-containerized. This includes bulk carriers, chemical tankers, general cargo vessels, RoRo vessels, and tankers. **Figure 2-6** provides an overview of total calls by vessel type at the HSC. This does not include interport movements. All tanker types are grouped.



	2011	2012	2013	2014	2015
RoRo	221	264	205	193	198
Containership	1,015	985	944	948	946
Bulk Carrier	858	946	1,083	1,344	1,020
General Cargo	1,163	1,254	1,271	1,301	1,099
Tanker	4,139	4,140	4,146	3,990	3,952

Figure 2-6: Calls by Vessel Type from 2011–2015

2.7 SHIPPING OPERATIONS

Most container vessels calling at HSC are part of scheduled liner services that call at multiple U.S. ports in conjunction with the HSC. Consequently, shippers engage in the practice of "just-in-time" deliveries of cargo and avoid schedule disruptions whenever possible. Today, there are three container yard operations at the harbor – two main container terminals, BCT and BPT, and one container and dry bulk facility, Jacintoport Terminal. Once reaching HSC at Bolivar Roads, an inbound vessel transiting to BSC will voyage approximately 2.5 hours to BSC. A vessel transiting to BCT will voyage an additional hour. A vessel transiting to Jacintoport Terminal will transit an additional 2 hours from BSC.

Houston pilots maintain two-way traffic for all vessels in the main channel. Widebody containerships (120-foot beam and larger) face some restrictions pertaining to meeting other widebody vessels. No vessel with a beam beyond 150 feet or length overall greater than 900 feet can transit the channel at night. This restricts most Post-Panamax containerships. BSC and BCC are both one-way channels for all vessels.

Non-container vessels make berth along all 50 miles of the HSC. The most significant tanker operations take place near the entrance to Buffalo Bayou in Segment 1 and throughout Segments 5 and 6. More bulk carrier and general cargo traffic takes place in Segments 5 and 6. Chemical tanker traffic transit throughout Segments 1, 2, and 4; however, most non-container vessels call locations throughout the HSC.

2.7.1 Underkeel Clearance

The measure of underkeel clearance (UKC) for economic studies is applied according to planning guidance. According to this guidance, UKC is evaluated based on actual vessel operator and pilot practice within a harbor and subject to present conditions, with adjustment as appropriate or practical for with-project conditions. Generally, practices for UKC are determined through review of written pilotage rules and guidelines, interviews with pilots and vessel operators, and analysis of actual past and present practices based on relevant data for vessel movements. Typically, UKC is measured relative to immersed vessel draft in the static condition (i.e., motionless at dockside). When clearance is measured in the static condition, explicit allowances for squat, trim, and sinkage are unnecessary. Evaluation of when the vessel is moved or initiates transit relative to immersed draft, tide stage, and commensurate water depth allows reasonable evaluation of clearance throughout the time of vessel transit.

Evaluation of all movements renders a distribution of UKC requirements. Evaluation of minimal clearance (i.e., some level of clearance below which operators or pilots will not move a vessel due to concerns for insufficient safety) helps to quantify the period of time each day a given vessel with a specified immersed draft can be moved relative to tide.

At HSC, an existing pilot rule states:

> *"Maximum permitted draft for vessels transiting the Houston Ship Channel shall not exceed 45 ft. (fresh water). Maximum draft shall be adjusted in accordance with the state of the tide and current to allow one-foot under keel clearance. 45 ft. is allowed at 0 tide. Height of tide shall be measured by the tide gauge system adopted by the Houston Pilots."*[27]

Economics analysis assumed the 1 foot UKC rule in evaluation of deepening measures for both without and with project scenarios.

2.7.2 Tidal Range

The variability of sea level must be considered when determining the level of water needed for navigation **(Figure 2-7)**. At the entry to the HSC at the Galveston Bay tidal station, an applied tide range from the 46.5 project depth of approximately 1.4 feet is experienced. Extreme low tidal variation can reach −1.24 feet. The average tide cycle duration is 12.4 hours.

Currently, the HSC has 100 percent access for vessels drafting 45.2 feet and less. For vessels drafting at 46.8 feet this drops to 80 percent reliability. Depths of 47.6 feet are available 20 percent of the time. As larger vessels with potentially deeper sailing drafts call at the HSC in larger numbers, the percent of reliable access depth and the width of the tide window will become a constraint on vessel operations.

[27] Houston Pilot Working Rules (April 26, 2017): https://www.google.com/search?q=houston+ship+channel+pilot+working+rules&ie=utf-8&oe=utf-8

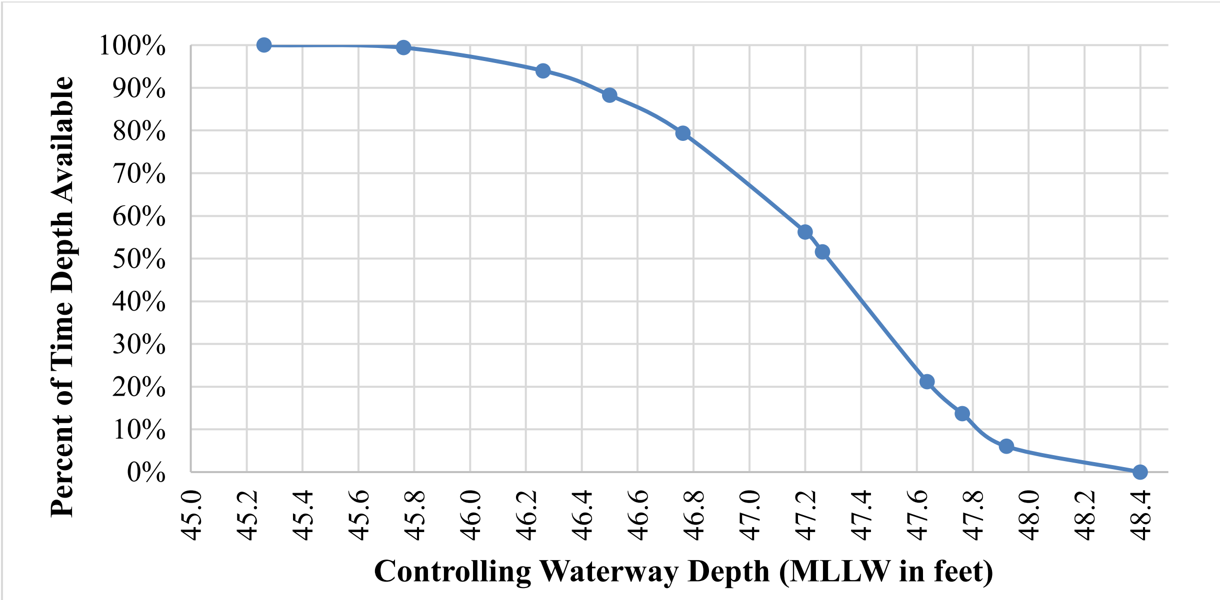


Figure 2-7: Water Depth Availability Relative to Tidal Stage Galveston Reference Station (3277)

2.7.3 Sailing Practices

The following tables were prepared using arrival draft data from the Houston Pilots between 2011 and 2015.

Figure 2-8 provides the sailing draft of vessel transits along Segment 1 (2011–2015), including arrivals and departures. Bay Reach has the most vessel transits with an average of 8,277 per year. On average, 66 percent of those vessels are drafting at 30 feet or less. The number of vessels drafting over 42 feet peaked in 2011 but has since declined.

Figure 2-9 provides the sailing draft of vessel transits along Segment 2 (2011–2015), including arrivals and departures. BSC has an average of 2,103 vessel transits annually with 53 percent drafting at 30 feet or less.

Figure 2-10 provides the sailing draft of vessel transits along Segment 3 (2011–2015), including arrivals and departures. BCC, leading to the container terminal, has an average of 1,249 vessel transits annually with approximately 11 percent drafting between 38–41 feet.

Figure 2-11 provides the sailing draft of vessel transits along Segment 4 (2011–2015), including arrivals and departures. The segment moving from Boggy Bayou to Sims Bayou has an average of 3,141 vessel transits annually with 67 percent drafting at 30 feet or less.

Figure 2-12 provides the sailing draft of vessel transits along Segment 5 (2011–2015), including arrivals and departures. The segment moving from Sims Bayou to the I-610 bridge has an average of 702 vessel transits annually with 87 percent drafting at 30 feet or less. With an authorized depth of 37.5 feet, approximately 1 percent of vessels are taking advantage of tide to draft beyond 37.5 feet.

Figure 2-13 provides the sailing draft of vessel transits along Segment 6 (2011–2015), including arrivals and departures. The segment moving from the I-610 bridge to the main turning basin has an average of 1,506 vessel transits annually with 80 percent drafting at 30 feet or less.

Figure 2-14 summarizes all transit drafts from 2011 through 2015 based on Pilot Logs by vessel type. This table includes calls to all segments of the channel.

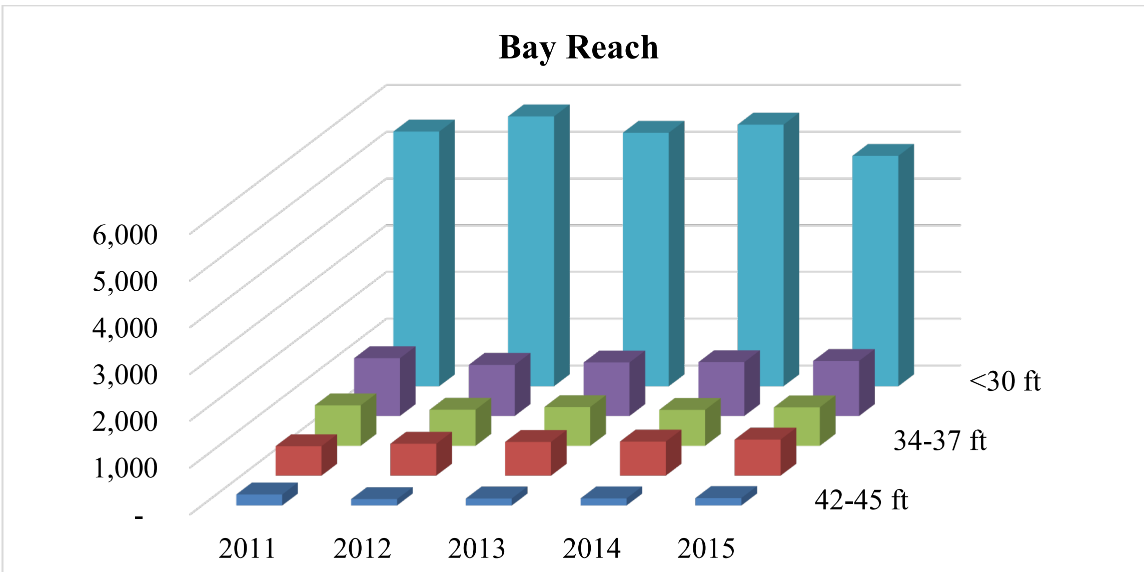


Figure 2-8: Segment 1 – Bay Reach – Vessel Transits by Draft

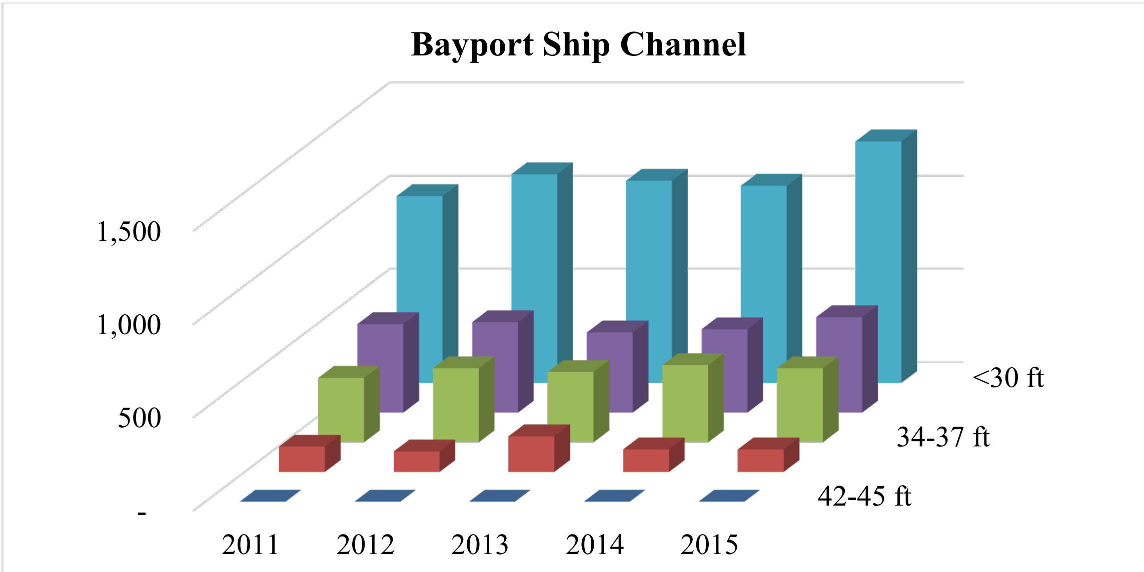


Figure 2-9: Segment 2 – Bayport Ship Channel – Vessel Transits by Draft

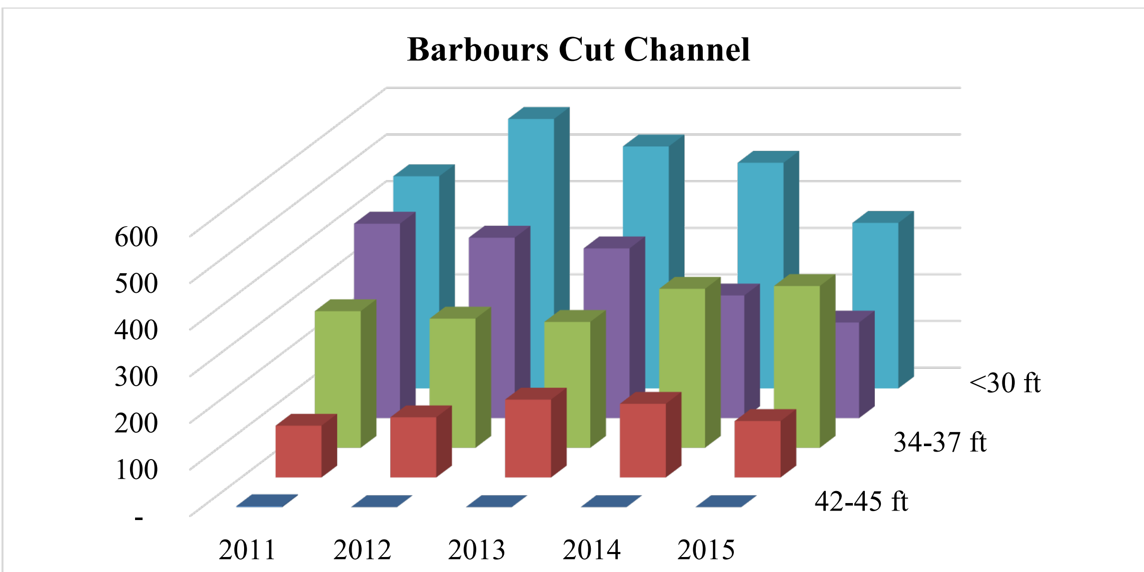


Figure 2-10: Segment 3 – Barbours Cut Channel – Vessel Transits by Draft

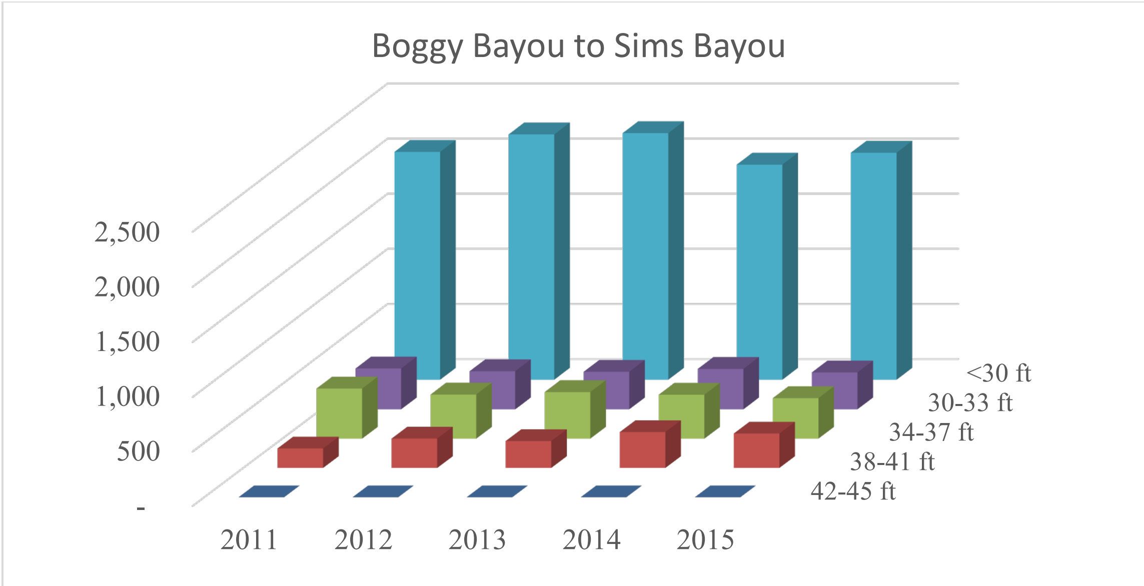


Figure 2-11: Segment 4 – Boggy Bayou to Sims Bayou – Vessel Transits by Draft

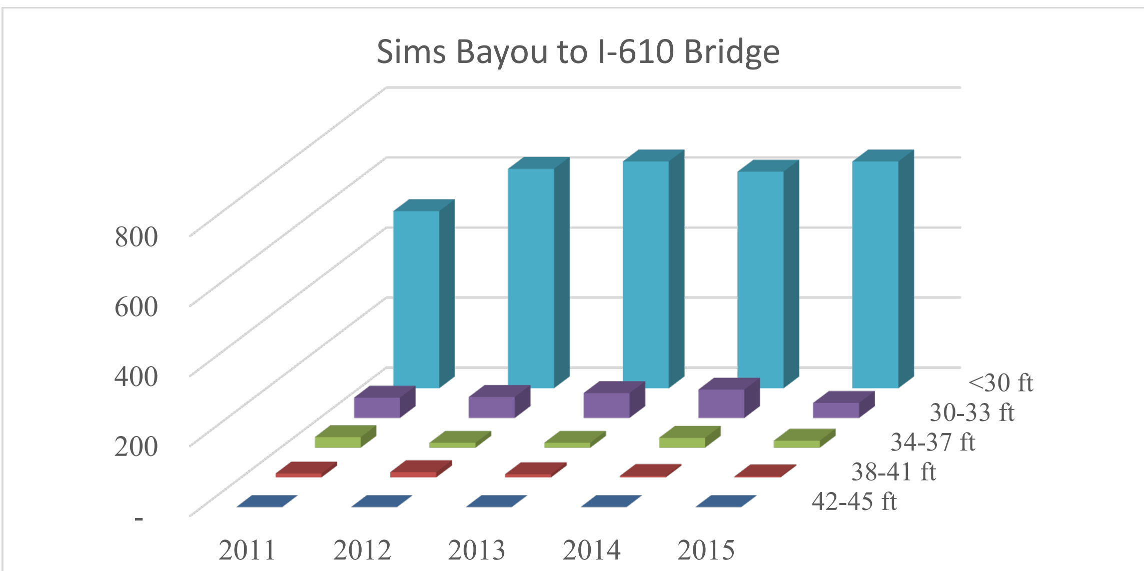


Figure 2-12: Segment 5 – Sims Bayou to I-610 Bridge – Vessel Transits by Draft

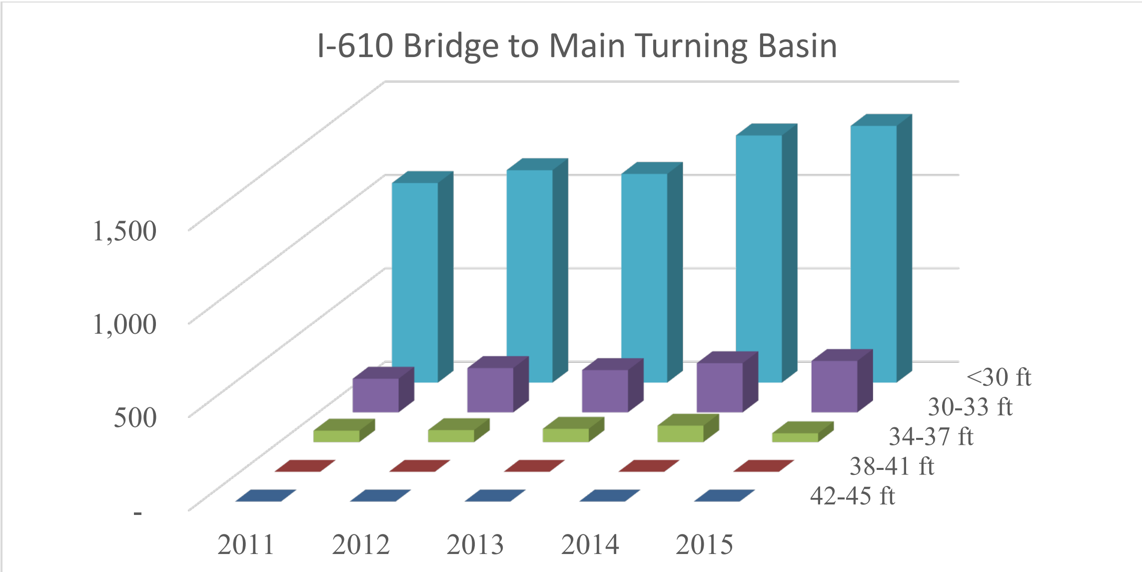
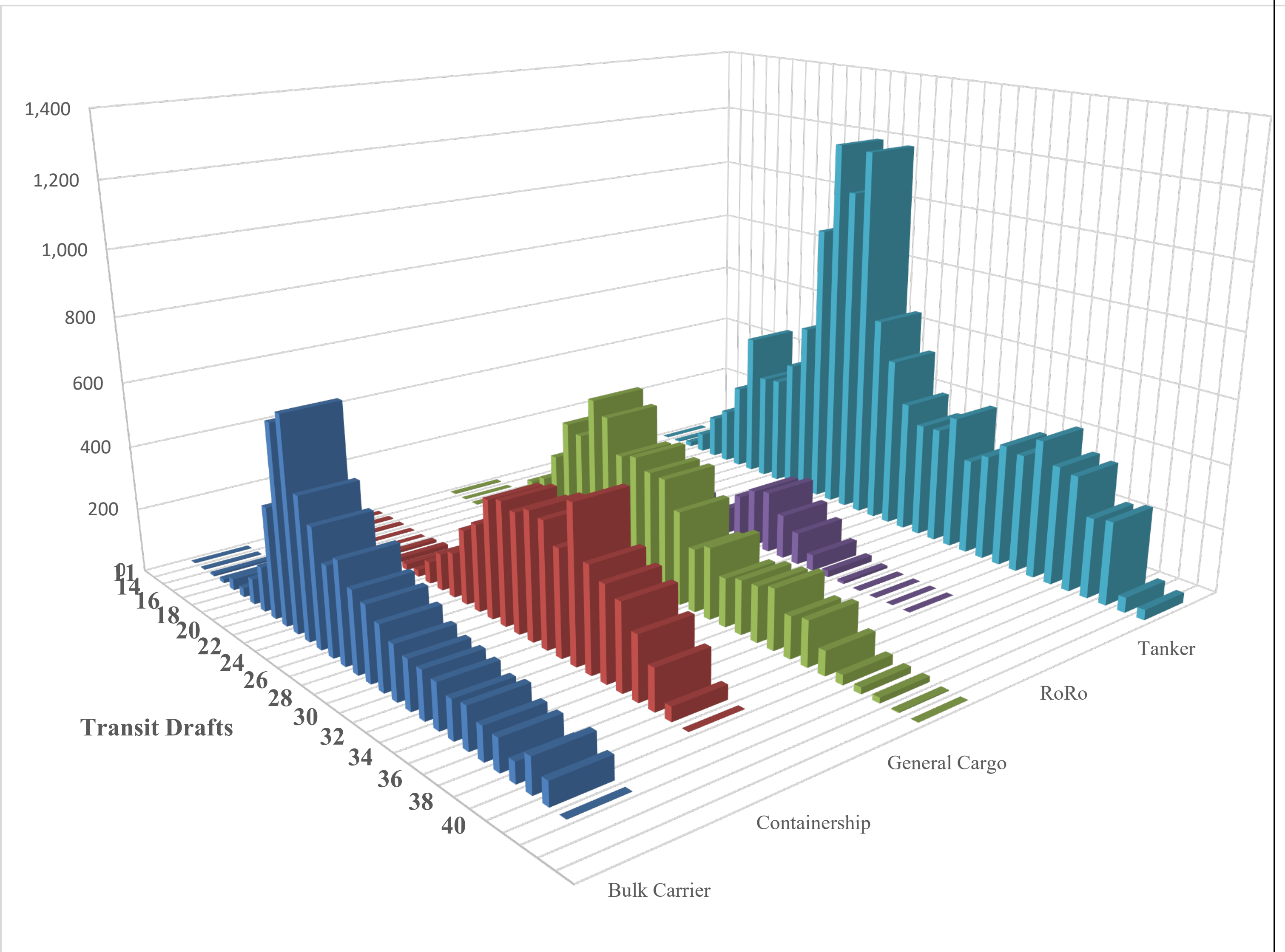


Figure 2-13: Segment 6 – I-610 Bridge to Main Turning Basin – Vessel Transits by Draft

Figure 2-14: Transit Drafts by Vessel Type (2011-2015)



2.8 DESIGN VESSELS

The selection of vessel specifications for fleet service forecasts sometimes poses unique concerns given requirements to evaluate design and improvements for waterway systems over time. Generally, waterway improvements should be designed to be optimized across the entire forecasted fleet. In this case, it would include service by several forms or types of vessels (i.e., tankers and dry cargo carriers, etc.). Where vessel designs are relatively mature (tankers and dry bulk carriers), the task is straightforward. However, fully cellular containership designs are evolving. On a world fleet basis, containership designs continue to change with respect to size and cargo carrying capacity and have not reached a limiting threshold.

The design vessels are defined per USACE guidance from EM 1110-2-1613 stating:

> "*…the design ship or ships are selected on the basis of economic studies of the types and sizes of the ship fleet expected to use the proposed navigation channel over the project life…*" The design ship is defined by EM 1110-2-1613 as "*…the largest ship of the major commodity movers expected to use the project improvements on a frequent and continuing basis…*"

2.8.1 Segment 1, 2, and 3

The Deep Draft Navigation Planning Center of Expertise in coordination with the Institute for Water Resources (IWR) recommend the use of two containership design vessels in the bay reaches leading to the BPT and BCT. **Table 2-8** provides the specifications of the selected containership design vessels. Two containership design vessels were selected for this study to address concerns over both vessel beam and length overall on the HSC. These vessels are expected to transit the channel under With-Project Scenarios.

Table 2-8: Containership Design Vessel

Vessel Type	DWT	TEU	LOA	Beam	Draft
Containership	115k-125k	10k-11k	1,100	158	49
Containership	115k-125k	10k-11k	1,200	140	49

Consideration of non-containership design vessels are necessary for each study reach. A Suezmax tanker will serve as the design vessel selection for the Bay Reach (Galveston to Boggy Bayou). **Table 2-9** provides the dimensions of the Suezmax tanker.

Table 2-9: Non-Containership Design Vessel for Bay Reach

Type	DWT Range	LOA	Beam	Draft
Tanker	157.5k-215k	935	164	54

2.8.2 Segment 4

From Boggy Bayou to Sims Bayou, the PHA recommends use of an Aframax tanker with the dimensions provided in **Table 2-10**.

Table 2-10: Design Vessel for Boggy Bayou to Sims Bayou (initial)

Type	DWT Range	LOA	Beam	Draft
Tanker	100k-157.5k	850	138	54
Bulk Carrier	70k-110k	810	106	44

2.8.3 Segment 5

Table 2-11 provides the design vessels selected for Sims Bayou to the I-610 bridge segment.

Table 2-11: Design Vessels for Sims Bayou to the I-610 Bridge

Type	DWT Range	LOA	Beam	Draft
Vehicles Carrier	15.9k-20.9k	640	106	34
Tanker	55k-75k	610	106	44

2.8.4 Segment 6

In addition to the vehicles carrier described for Segment 5, the I-610 bridge to main turning basin segment will model for a bulk carrier. **Table 2-12** describes the design vessels for the I-610 bridge to main turning basin segment.

Table 2-12: Design Vessels for I-610 Bridge to Main Turning Basin

Type	DWT Range	LOA	Beam	Draft
Vehicles Carrier	15.9k-20.9k	640	106	34
Bulk Carrier	55k-75k	750	106	45

3 FUTURE CONDITIONS

3.1 TERMINAL EXPANSIONS

The major expansion of the Panama Canal has accelerated expansions within the HSC to allow for larger containerships and faster movement of goods between the Gulf Coast and Asia markets.

3.1.1 Container Terminals

Over the period from 2015 through 2020, the Port of Houston Authority plans to spend $1.6 billion to expand its BCT and BPT. The expansion includes deepening the channels to 46.5 feet to allow for larger container ships. To accommodate these vessels, Port Houston recently added four Super Post-Panamax cranes. These preparations for the recent Panama Canal expansion resulted in two shipping lines announcing service from Asia to Houston through the expanded canal[28]. Terminal improvements at Bayport and Barbours Cut Container Terminals will occur before the study base year with or without project implementation; therefore, they are included as part of the FWOP condition.

3.1.1.1 Bayport Container Terminal

When fully developed in 2023, the BPT will have a total of seven container berths totaling 7,000 linear feet of berthing space[29]. Additionally, there will be a total of 21 Super Post-Panamax cranes for vessel loading and unloading. The 376-acre container yard and 123-acre intermodal facility will provide an annual throughput capacity of 2.3 million TEUs.

3.1.1.2 Barbours Cut Container Terminal

Plans are also underway to modernize the BCT by 2023. The $700 million investment will result in a total of 18 Post-Panamax cranes, new lighting, and dock improvements. Upon completion, the six-berth facility, offering 6,000 linear feet of berthing, will provide an annual throughput of 2 million TEUs.

3.1.2 Liquid Bulk Cargo Terminals

Improvements planned at the LBC Houston terminal include installation of more tanks and another dock to the north end of the existing complex. Increasing tank capacity by 3.3 million barrels of storage is anticipated to result in a 60 percent increase in throughput capacity at LBC Houston[30]. Additionally, LBC Houston is currently constructing an additional Aframax capable dock, which can handle vessels up to a 45-foot draft and two additional barge docks[31]. In addition, LBC Tank

[28] Port of Houston Authority, https://comptroller.texas.gov/economy/docs/ports/overview-houston.pdf
[29] http://www.portofhouston.com/container-terminals/bayport/
[30] Personal communication with C. Harmon, ODFJELL Operations, May 2013.
[31] https://www.lbctt.com/locations/lbc-houston/

Terminals, LLC (LBC) and Magellan Midstream Partners, L.P. (Magellan) are currently proposing a joint venture to construct up to a 4-million-barrel storage facility adjacent to the LBC Houston terminal[29]. This storage would be connected to Magellan's Houston crude oil distribution system with a 24-inch pipeline.

Additional expansion projects are underway across the ship channel. Petroleum product facilities in particular are constantly updating facilities and adding capacity. Perhaps the most significant increase to expansion is taking place in Segment 4 where Texas Deepwater Industrial Port and other partners are planning to construct multiple new dock facilities along the ship channel capable of accommodating Aframax tankers. Other projects include dock expansion by HFOTCO and ITC. The study assumes the significant expansion along the ship channel will keep pace with the commodity growth forecast over the study period.

3.1.3 Bulk Cargo Terminals

Magellan plans to build a marine terminal on nearly 200 acres along the HSC in Pasadena with expected completion in early 2019. The terminal will handle various grades of gasoline and diesel fuel as well as renewable fuels. The project includes 1 million barrels of storage for refined petroleum products and ethanol, as well as a new marine dock that can accommodate Panamax-sized ships or barges with up to a 40-foot draft. Magellan could eventually expand the facility to include up to 10 million barrels of storage and up to five docks, some of which potentially could accommodate Aframax-sized vessels with a draft up to 45 feet, depending on demand[32].

3.1.4 Panama Canal Expansion and Impact to the HSC

In June 2016, the Panama Canal Expansion was completed and opened a new set of locks with chambers of 1,400 feet long, 180 feet wide, and 60 feet deep, creating a third lane of traffic. The lock expansion provides the capacity to accommodate vessels up to 1,200 feet long, 161 feet wide and 50 feet deep. This amounts to containerships with cargo volumes up to 120,000 deadweight tonnage (DWT) and 13,000 TEU. The Panama Canal's expansion paves the way for larger ships to be deployed to the U.S. Gulf Coast and East Coast from Asia, Oceana, and West Coast of South America. Previously, the Panama Canal was restricted to container traffic shipments to vessels drafting less than 39.5 feet. This essentially prevented any Far East/Gulf Coast/East Coast U.S. shipments from taking advantage of the economies of scale of loading larger ships to deeper sailing drafts.

In the first seven months of fiscal year (FY) 2017 (October 2017 – April 2017), over 1,000 vessels of the new Panamax dimensions transited the new locks. Tonnage through the Panama Canal increased by 22 percent in the first seven months of FY 2017 over FY 2016. The HSC expansion study assumes these new locks allow the port to attract these larger fleets transporting commodities

[32] http://www.bizjournals.com/houston/news/2016/07/14/midstream-company-to-build-houston-ship-channel.html

to and from the U.S. Gulf Coast and Asia, Oceana, and West Coast of South America. **Table 3-1** displays a comparison lock and vessel size capacities of the original and new locks.

Table 3-1: Comparison of Panama Canal Lock and Vessel Dimensions

Dimension	Original Locks	Panamax Vessel	3rd Locks	Neo-Panamax Vessel
Length (ft)	1,050	965	1,400	1,200
Width (ft)	110	106	180	168
Draft (ft)	41.2	39.5	60	50
TEUs		5,000		13,000
Tonnage (DWT)		52,500		120,000

Source: Panama Canal Authority

3.2 COMMODITY FORECAST

The import and export commodity forecast for the HSC ECIP was developed in three steps. First, the baseline was established. The baseline is an average of the previous three years of available data. Second, growth rates for each commodity were found using sources such as the U.S. Department of Energy (DOE) and U.S. Department of Agriculture (USDA), a well as a contracted forecast for the HSC conducted by IHS Global Insight (Global Insight). Third, growth rates were applied to the baseline to determine total import and export trade for the HSC. The commodity forecast was then separated between containerized and non-containerized tonnage. This study will use the non-containerized forecast for all bulk cargo. The Houston 204 Assumption of Maintenance[33] Report provides an in-depth container and vessel fleet forecast for Bayport Ship Channel and Barbours Cut. This study will use the growth rates developed in coordination with MSI for the 204(f) Assumption of Maintenance Report Container Forecast for all containerized cargo. **Figure 3-1** describes the process used to reach the final commodity forecast.

[33] Bayport Ship Channel Improvements and Barbour's Cut Channel Improvement Projects, Section 204(f) Assumption of Maintenance Assessment Report for Harris and Chambers Counties, Texas, dated 23 December 2013.

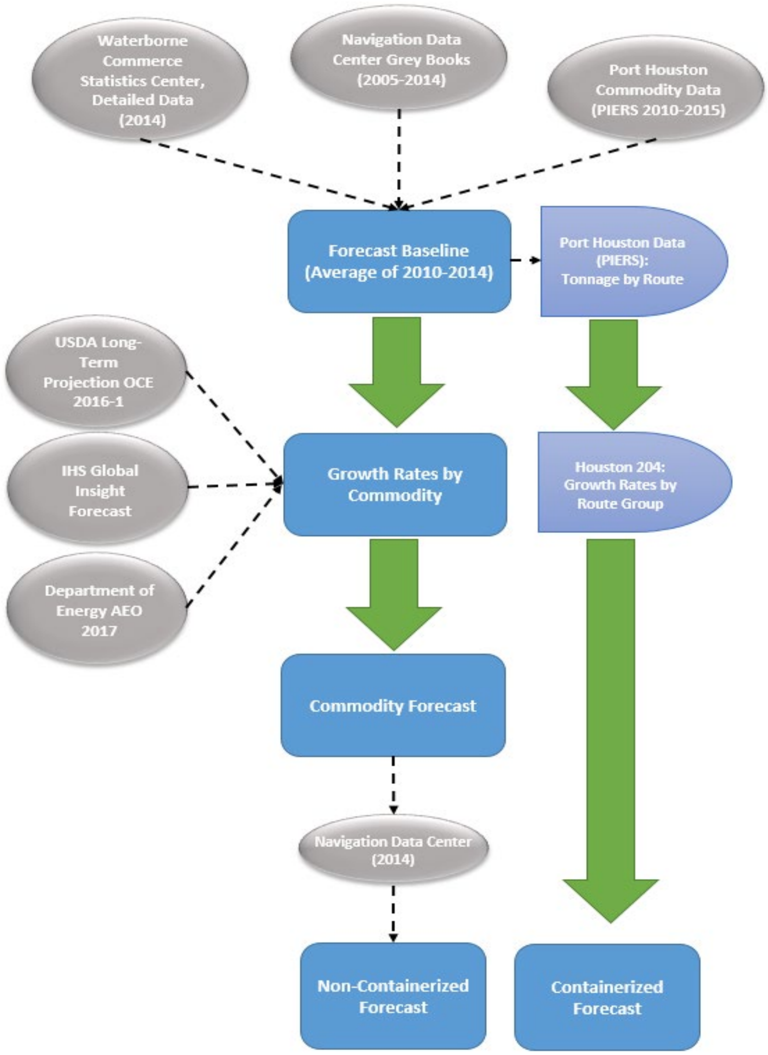


Figure 3-1: Forecast Methodology

3.2.1 Non-containerized Trade

3.2.1.1 Baseline

An essential step when evaluating navigation improvements is to analyze the types and volumes of cargo moving through the port. Trends in cargo history can offer insights into a port's long-term trade forecasts and thus the estimated cargo volume upon which future vessel calls are based. Under future without and future with project conditions, the same volume of cargo is assumed to move through the HSC. However, a deepening project will allow shippers to load their vessels more efficiently or take advantage of larger vessels. Similarly, widening and other modifications evaluated at the HSC will potentially reduce inefficiencies related to transit of all cargo. These efficiencies translate to transportation cost savings and NED.

To minimize the impact of potential anomalies in trade volumes on long-term forecast, the most recent three years of available detailed tonnage data was used to establish the baseline for the commodity forecast. Empirical data from 2012–2014 were used to develop a baseline, allowing the forecast to capture both economic prosperity and downturn that occurred over that time frame.

Using the data presented in Section 2.4, Historical Commerce, the three-year average of imports and exports are used to develop the baseline for the commodity forecast, as shown in **Table 3-2**. This includes potentially benefitting bulk and containerized commodities.

Table 3-2: Houston Ship Channel Baseline Commodity Forecast (1,000s of Metric Tons)

Commodity	Imports	Exports
Chemicals	3,890	13,283
Coal	1	2,273
Crude Materials	2,990	1,449
Food and Farm Products	1,564	6,490
Manufactured Equipment	2,432	2,739
Other	823	1,101
Petroleum & Petroleum Products	49,950	45,947
Primary Manufactured Goods	10,004	967
Total	**71,653**	**74,249**

3.2.2 Growth Rates

3.2.2.1 Background

The long-term trade forecast for the HSC ECIP used forecast data from DOE, USDA, and Global Insight. The forecast applied the growth rates from these sources for each commodity's baseline. This methodology is consistent with the approach used to perform a long-term commodity forecast for other USACE deep-draft analyses. The next section presents the methodology employed to develop a long-term trade forecast for HSC.

3.2.2.1.1 U.S. Department of Energy Forecast

The forecast used the Annual Energy Outlook 2017 (AEO) growth rates for forecasting petroleum and petroleum products and coal at the HSC, which account for 74 percent and 63 percent of imports and exports, respectively. The AEO uses the National Energy Modeling System, an integrated model that aims to capture various interaction of economic changes and energy supply, demand, and prices. The AEO provides multiple forecast cases based on different scenarios through 2050. This forecast used the "reference" case, which assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central view of leading economic forecasters and demographers.

3.2.2.1.2 U.S. Department of Agriculture

The forecast used growth rates from the USDA's Long-term Projections Report OCE-2016-1 to develop forecasts for food and farm products. This commodity group accounts for 2 percent of imports and 10 percent of exports. The USDA uses specific assumptions about macroeconomic conditions, policy, weather, and international developments, with no domestic or external shocks to global agricultural markets to compile a forecast through 2025 by major commodity. The projections are one representative scenario for the agricultural sector for the next decade and reflect a composite of model results and judgment-based analyses. The reference case, used for this study, reflects relatively sluggish economic growth in developing countries, a strong dollar, and low oil prices in the near term, with stronger developing country growth, a somewhat weaker dollar, and rising oil prices in the longer term.[34] The USDA's Long-term Projections Report OCE-2016-1 summarizes future food and farm trade as follows:

> *Steady world economic growth is projected over the next decade, despite a near-term slowdown in many developing countries. Projected global demand for agricultural products will rise, but at a slower rate than in the past decade. At the same time, world agricultural production is projected to increase more rapidly than world population, enabling a small increase in global per capita use of most agricultural products. Growth in world agricultural trade is projected to continue, albeit at a slower rate than in recent years. Together, these trends result in continued declines in the projected prices of agricultural commodities over the short term and the persistence of low prices throughout the projection period.* [35]

3.2.2.1.3 IHS Global Insight Trade Forecast

Global Insight's trade forecast informed the growth rates for chemicals, primary manufactured goods, manufactured equipment, and crude materials. These commodity groups account for 23 percent of imports and 26 percent of exports. The model is based on the IHS World Trade Service (WTS) model. Conceptually, the WTS real value trade model uses a three-level process, shown in **Figure 3-2** provides a schematic of the WTS forecasting process. This multi-stage forecasting uses a combination of bottom-up and top-down approaches. Global Insight combines both approaches to increase forecast accuracy.

[34] https://www.ers.usda.gov/webdocs/publications/37809/56729_oce-2016-1.pdf?v=42508
[35] https://www.ers.usda.gov/webdocs/publications/37809/56729_oce-2016-1.pdf?v=42508

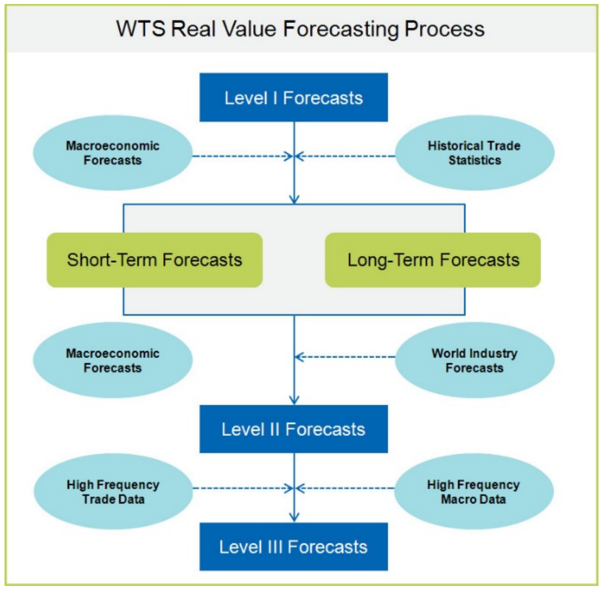


Figure 3-2: WTS Real Value Forecasting Process

Level I forecasts a country's imports of a commodity individually, without any exporter-level detail. The forecast at this stage is a bottom-up approach, which reflects heterogeneous behaviors of countries importing goods in each commodity group.

Level II forecasts a country's imports of a commodity from an exporting country under the assumption that the country's aggregated imports of the commodity from all the exporting countries is controlled by this country's imports of the commodity forecasted at Level I. The second stage forecast can be described as a top-down controlled approach and conforms to the WTS demand-driven approach to trade. The IHS World Industry Service (WIS) and IHS other sectoral forecasts are utilized at this level to address the competitiveness and supply capacity of an exporting country. The WIS provides both historical and forecasted industry data by Standard Industrial Classification category across 78 countries.

Level III forecasts and makes adjustments to individual commodity flows between importing and exporting countries given the most updated monthly and quarterly trade statistics collected from a variety of national and international sources, including the U.S. Census Bureau and Eurostat, to capture the most recent trade developments during the current year. At this stage, Global Insight also takes into account the most up-to-date high-frequency macro data. After the adjustments, the forecasting procedures produce final globally consistent commodity-level trade forecasts between 106 countries/regions for 201 commodity categories.

3.2.2.2 Commodity Grouping for Growth Rates

The following section outlines the growth rates by commodity for the HSC. The forecast applies these growth rates to the base forecast presented in **Table 3-2** to develop a final forecast by commodity, organized by import and export. **Table 3-3** lists the major commodities in the study area and groups them by the data source and commodity growth rate used to develop the forecast for the HSC. Compound Annual Growth Rates (CAGR) were used for organic chemical growth rates. These estimates were adjusted to be more conservative compared Global Insights Forecast given facility capacity constraints a lower forecasted growth rates from sources such as the Department of Energy. For commodities without significant forecasting information (such as Pulp and Waste Paper, Sulphur, and Slag) the baseline forecast was held constant. These commodities are not potentially benefitting and do not alter benefits or the selected plan.

Table 3-3: Commodity Sources

WCSC Commodity Name	Forecast Source*	Source Commodity Group
10 Coal,Lignite and Coal Coke	AEO	Coal
21 Crude Petroleum	AEO	Crude Petroleum
22-29 Petroleum Products	AEO	Petroleum and other liquids
3110 Nitrogenous Fert.	GI	Fertilizers
3120 Phosphatic Fert.	GI	Fertilizers
3130 Potassic Fert.	GI	Fertilizers
3190 Fert. & Mixes NEC	GI	Fertilizers
3211 Acyclic Hydrocarbons	CAGR	Organic Chemicals
3212 Benzene & Toluene	CAGR	Organic Chemicals
3219 Other Hydrocarbons	CAGR	Organic Chemicals
3220 Alcohols	GI	Petroleum and other liquids
3230 Carboxylic Acids	CAGR	Organic Chemicals
3240 Nitrogen Func. Comp.	CAGR	Organic Chemicals
3250 Organo - Inorg. Comp.	GI	Other Chemicals
3260 Organic Comp. NEC	CAGR	Organic Chemicals
3271 Sulphur (Liquid)	CAGR	Organic Chemicals
3272 Sulphuric Acid	GI	Inorganic Chemicals
3273 Ammonia	GI	Inorganic Chemicals
3274 Sodium Hydroxide	GI	Inorganic Chemicals
3275 Inorg Elem., Oxides, Halogen Salts	GI	Inorganic Chemicals
3276 Metallic Salts	GI	Other Chemicals
3279 Inorganic Chem. NEC	GI	Inorganic Chemicals
3281 Radioactive Material	GI	Other Chemicals
3282 Pigments & Paints	GI	Paints
3283 Coloring Mat. NEC	GI	Paints
3284 Medicines	GI	Other Chemicals
3285 Perfumes & Cleansers	GI	Other Chemicals
3286 Plastics	GI	Plastics
3291 Pesticides	GI	Other Chemicals
3292 Starches, Gluten, Glue	GI	Other Chemicals
3293 Explosives	GI	Other Chemicals
3297 Chemical Additives	GI	Other Chemicals

WCSC Commodity Name	Forecast Source*	Source Commodity Group
3298 Wood & Resin Chem.	GI	Other Chemicals
3299 Chem. Products NEC	GI	Other Chemicals
3220 Alcohols	AEO	Petroleum and other liquids
4110 Rubber & Gums	GI	Natural Rubber
4150 Fuel Wood	GI	Cork and Wood
4161 Wood Chips	GI	Cork and Wood
4170 Wood in the Rough	GI	Cork and Wood
4189 Lumber	GI	Cork and Wood
4190 Forest Products NEC	GI	Cork and Wood
4225 Pulp & Waste Paper	N/A	Baseline held constant
43 Soil, Sand, Gravel, Rock and Stone	GI	Stone, Clay Other Crude Materials
44 Iron Ore and Scrap	GI	Ores and Scrap
46 Non-Ferrous Ores and Scrap	GI	Ores and Scrap
47 Sulphur, Clay and Salt	N/A	Baseline held constant
48 Slag	N/A	Baseline held constant
49 Other Non-Metal. Min.	N/A	Baseline held constant
51 Paper Products	GI	Paper and Paperboard Products
52 Lime, Cement and Glass	GI	Glass and Products
53 Primary Iron and Steel Products	GI	Iron and Steel
54 Primary Non-Ferrous Metal Products	GI	Non-ferrous metals
55 Primary Wood Products; Veneer	GI	Wood Products
61 Fish	USDA	Fish and Seafood
6241 Wheat	USDA	Wheat
6344 Corn	USDA	Corn
6442 Rice	USDA	Rice
6443 Barley & Rye	USDA	Barley
6445 Oats	USDA	Animal Feed
6447 Sorghum Grains	USDA	Sorghum
6521 Peanuts	USDA	Oilseeds
6522 Soybeans	USDA	Soybean Oil
6534 Flaxseed	USDA	Oilseeds
6590 Oilseeds NEC	USDA	Oilseeds
6653 Vegetable Oils	USDA	Oilseeds
6654 Vegetables & Prod.	USDA	Vegetable Products
67 Processed Grain and Animal Feed	USDA	Animal Feed
6811 Meat, Fresh, Frozen	USDA	Meat
6817 Meat, Prepared	USDA	Meat
6822 Dairy Products	USDA	Dairy
6835 Fish, Prepared	USDA	Fish and Seafood
6838 Tallow, Animal Oils	USDA	Oilseeds
6839 Animals & Prod. NEC	USDA	Animal and Vegetable Oils
6856 Bananas & Plantains	USDA	Vegetable Products
6857 Fruit & Nuts NEC	USDA	Vegetable Products

WCSC Commodity Name	Forecast Source*	Source Commodity Group
6858 Fruit Juices	USDA	Vegetable Products
6861 Sugar	USDA	Sugar
6865 Molasses	USDA	Other Agriculture and Food
6871 Coffee	USDA	Other Agriculture and Food
6872 Cocoa Beans	USDA	Other Agriculture and Food
6885 Alcoholic Beverages	USDA	Beverages
6887 Groceries	USDA	Other Agriculture and Food
6888 Water & Ice	USDA	Other Agriculture and Food
6889 Food Products NEC	USDA	Other Agriculture and Food
6891 Tobacco & Products	USDA	Other Agriculture and Food
6893 Cotton	USDA	Cotton
6894 Natural Fibers NEC	USDA	Other Agriculture and Food
6899 Farm Products NEC	USDA	Other Agriculture and Food
7110 Machinery (Not Elec)	GI	Machinery
7120 Electrical Machinery	GI	Machinery (not electrical)
7210 Vehicles & Parts	GI	Vehicles and Parts
7220 Aircraft & Parts	GI	Aircraft & Parts
7230 Ships & Boats	GI	Ships & Boats
7300 Ordnance & Access.	GI	Manufac. Prod. NEC
7400 Manufac. Wood Prod.	GI	Manufac. Prod. NEC
7500 Textile Products	GI	Textiles
7600 Rubber & Plastic Pr.	GI	Rubber & Plastic Pr.
7800 Empty Containers	N/A	HarborSym Calculation
7900 Manufac. Prod. NEC	GI	Manufac. Prod. NEC
90 Unknown or Not Elsewhere Classified	N/A	Baseline held constant

** AEO = Annual Energy Outlook; GI = Global Insight Forecast; USDA = US Department of Agriculture; CAGR = Compound Annual Growth Rate*

3.2.2.2.1 Import Growth Rates

Table 3-4 provides the import forecast rate of change between each year as calculated from the DOE's AEO, USDA's Long-term Projections Report, and Global Insight's WTS. The forecast extends the USDA's projection from 2025 using the average of 2023 through 2025 growth rates. This is meant to be an estimate of growth after 2025 and is considered reasonably conservative and matches a separate forecast completed by Global Insight. Actual growth rates from each source were used for the years 2015 and 2016 since this data was not available at the Port-level as of the writing of this appendix.

Table 3-4: Import Rates of Change

Source	Commodity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
AEO	Coal	15%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
AEO	Crude Petroleum	0%	7%	1%	-3%	-3%	-3%	1%	1%	-1%	1%	1%	-1%	-2%	-2%	2%	2%	0%	1%	0%	1%	1%	0%
AEO	Petroleum and other liquids	10%	-2%	2%	3%	-2%	-2%	0%	2%	1%	0%	-1%	-1%	0%	-3%	-1%	0%	0%	0%	-1%	0%	0%	0%
GI	Fertilizers	-1%	0%	0%	-1%	-1%	-1%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
CAGR	Organic Chemicals	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Other Chemicals	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Inorganic Chemicals	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	2%	2%	2%
GI	Paints	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Plastics	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
N/A	Natural Rubber	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Cork and Wood	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Stone Clay and Other Crude Materials	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Ores and Scrap	3%	0%	-1%	-1%	-1%	-1%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
GI	Paper and Paperboard Products	4%	4%	4%	5%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Glass and Products	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Iron and Steel	2%	3%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Metal Products	4%	4%	3%	4%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Wood Products	3%	3%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Fish and Seafood	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
USDA	Wheat	-16%	0%	4%	4%	4%	3%	3%	3%	3%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
USDA	Corn	-5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Rice	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
USDA	Barley	-6%	-11%	-1%	0%	1%	0%	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
USDA	Animal Feed	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

Source	Commodity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
USDA	Sorghum	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Oilseeds	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
USDA	Soybean Oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Vegetable Products	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
USDA	Meat	15%	-11%	-2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
USDA	Dairy	20%	0%	-8%	-4%	-2%	-2%	-1%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Animal & Vegetable Oils	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
USDA	Sugar	-5%	7%	-4%	-6%	-2%	2%	2%	3%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Other Agriculture & Food	4%	5%	4%	5%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Beverages	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
USDA	Cotton	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Machinery	4%	3%	3%	3%	3%	3%	3%	3%	3%	4%	3%	4%	4%	4%	3%	3%	3%	3%	4%	4%	4%	4%
GI	Machinery (not electrical)	5%	4%	4%	4%	4%	4%	4%	4%	5%	5%	5%	5%	5%	5%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Vehicles and Parts	5%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Aircraft & Parts	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Ships & Boats	6%	6%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
GI	Manufac. Prod. NEC	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Textiles	4%	5%	4%	4%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Rubber & Plastic Pr.	4%	4%	4%	4%	4%	4%	4%	5%	4%	5%	5%	5%	5%	5%	4%	4%	4%	4%	4%	4%	5%	5%

Table 3-5 provides a summary of weighted rates of change by import commodity group.

Table 3-5: Imports Weighted Rates of Change by Commodity Group

Commodity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Chemicals	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Coal	9%	-18%	8%	1%	-13%	0%	-4%	-5%	-5%	-5%	-5%	-4%	-6%	-4%	-3%	-1%	-6%	-3%	-3%	-2%	-1%	-1%
Crude Materials	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Food and Farm Products	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Manufactured Equipment	4%	3%	3%	3%	3%	3%	3%	3%	3%	4%	3%	4%	4%	4%	3%	3%	3%	3%	3%	3%	4%	4%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Petroleum & Petrol. Products	2%	5%	1%	-2%	-3%	-3%	1%	1%	0%	0%	0%	-1%	-1%	-2%	1%	1%	0%	0%	0%	1%	0%	0%
Primary Man. Goods	-1%	3%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%

3.2.2.2.2 Export Growth Rates

Table 3-6 provides the export forecast rate of change between each year as calculated from the DOE's AEO, USDA's Long-Term Projections Report, and Global Insight's WTS. The forecast extends the USDA's projection from 2025 using the average of the last three years' growth rates. Actual growth rates from each source were used for the years 2015 and 2016 since this data was not available at the Port-level as of the writing of this appendix.

Table 3-6: Export Rates of Change

Source	Commodity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
AEO	Coal	-21%	-26%	-5%	6%	4%	4%	4%	4%	1%	-5%	-1%	0%	0%	1%	2%	3%	2%	3%	6%	-5%	3%	4%
AEO	Crude Petroleum	12%	11%	3%	8%	4%	1%	6%	4%	3%	3%	3%	2%	0%	-2%	3%	3%	-1%	0%	-2%	1%	0%	0%
AEO	Petroleum and other liquids	12%	11%	3%	8%	4%	1%	6%	4%	3%	3%	3%	2%	0%	-2%	3%	3%	-1%	0%	-2%	1%	0%	0%
GI	Fertilizers	-1%	0%	0%	-1%	-1%	-1%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
CAGR	Organic Chemicals	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
GI	Other Chemicals	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Inorganic Chemicals	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Paints	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Plastics	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%
N/A	Natural Rubber	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Cork and Wood	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%
N/A	Pulp and Waste Paper	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Stone Clay & Other Crude Materials	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Ores and Scrap	3%	0%	-1%	-1%	-1%	-1%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
GI	Paper & Paperboard Products	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Glass and Products	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Iron and Steel	2%	3%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Metal Products	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	5%	4%	4%	4%	4%	4%
GI	Wood Products	3%	3%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
GI	Fish and Seafood	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
USDA	Wheat	-6%	12%	6%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
USDA	Corn	-3%	6%	1%	3%	3%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

Source	Commodity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
USDA	Rice	-3%	12%	2%	2%	1%	1%	1%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
USDA	Barley	-16%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Animal Feed	4%	5%	4%	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
USDA	Sorghum	-8%	-38%	-13%	-6%	-3%	-3%	-3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Oilseeds	7%	7%	7%	8%	7%	8%	8%	8%	9%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
USDA	Soybean Oil	14%	13%	3%	2%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Vegetable Products	3%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
USDA	Meat	-9%	8%	4%	3%	3%	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
USDA	Dairy	-9%	5%	7%	2%	2%	4%	2%	3%	3%	4%	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
USDA	Animal & Vegetable Oils	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
USDA	Sugar	8%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Other Agriculture and Food	4%	5%	4%	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Beverages	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
USDA	Cotton	-9%	0%	1%	1%	0%	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
GI	Machinery	4%	3%	3%	3%	3%	3%	3%	3%	3%	4%	3%	4%	4%	4%	3%	3%	3%	3%	8%	4%	4%	4%
GI	Machinery (not electrical)	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
GI	Vehicles and Parts	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Aircraft & Parts	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
GI	Ships & Boats	6%	6%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
GI	Manufac. Prod. NEC	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
GI	Textiles	5%	5%	5%	6%	6%	6%	6%	6%	5%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
GI	Rubber & Plastic Pr.	4%	4%	4%	4%	4%	4%	4%	5%	4%	5%	5%	5%	5%	5%	4%	4%	4%	4%	4%	4%	5%	5%

Table 3-7 provides the rates of change by commodity group.

Table 3-7: Export Rates of Change by Commodity Group

Commodity	2105	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Chemicals	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Coal	-41%	-5%	6%	4%	4%	4%	4%	1%	-5%	-1%	0%	0%	1%	2%	3%	2%	3%	6%	-5%	3%	4%	1%
Crude Materials	4%	1%	1%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Food and Farm Products	-4%	3%	3%	1%	2%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Manufactured Equipment	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Petroleum & Petrol. Products	12%	11%	3%	8%	4%	1%	6%	4%	3%	3%	3%	2%	0%	-2%	3%	3%	-1%	0%	-2%	1%	0%	0%
Primary Manufactured Goods	-1%	3%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%

3.2.3 Forecasts

Using the baseline, the forecast applied the growth rates determined in the preceding section to forecast total import and export tonnage to the HSC over the study period. The forecast applied these growth rates at the most disaggregated level possible before summarizing commodity totals by commodity group. The following sections summarize the forecast by import and export.

3.2.3.1 Imports

The forecast uses the rates of change in the preceding section to forecast from the baseline in **Table 3-8** summarizes the unconstrained import commodity forecast. The totals are for bulk commodities only. Containerized tonnage is excluded.

Table 3-8 : Import Forecast(metric tons)

Commodity Name	Baseline	2029	2034	2039
Chemicals and Related Products	3,300,000	4,652,000	5,217,000	5,794,000
Coal	-	-	-	-
Crude Materials	2,502,000	3,252,000	3,524,000	3,832,000
Food and Farm Products	538,000	819,000	943,000	1,089,000
Manufactured Equipment, Machinery	951,000	1,565,000	1,844,000	2,101,000
Other	578,000	578,000	578,000	578,000
Petroleum and Petroleum Products	49,885,000	49,547,000	50,687,000	50,896,000
Primary Manufactured Goods	7,942,000	11,361,000	13,034,000	14,537,000
Grand Total	**65,696,000**	**71,774,000**	**75,828,000**	**78,827,000**

Petroleum and petroleum products on average comprise 69 percent of all imports to the HSC. On average, the HSC handles roughly 10 percent of national waterborne petroleum trade. The DOE projects that petroleum consumption in the United States will remain below 2005 levels through 2050. Coupled with higher refinery inputs and levels of U.S. crude oil production, imports of petroleum and crude oil will likely see limited growth[36].

Primary manufactured goods account for 12 percent of all imports. Iron and steel products make up about 67 percent of primary manufactured goods. This is likely the result of new infrastructure projects along the waterway and in the Houston area – construction contract value over this time has grown by nearly 10 percent[37].

Chemical imports make up 5 percent of total imports. Plastics, organic compounds, and hydrocarbons represent the majority of chemical imports. With increased domestic production and relatively flat domestic consumption, chemical imports will likely grow slowly[38].

[36] http://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf
[37] http://www.dallasfed.org/assets/documents/research/indicators/tei/2016/tei160328.pdf
[38] https://www.americanchemistry.com/Policy/Trade/Fueling-Export-Growth-US-Net-Export-Trade-Forecast-for-Key-Chemistries-to-2030.pdf

3.2.3.2 Exports

Table 3-9 provides the unconstrained export forecast by commodity. The totals include bulk commodities only. The containerized tonnage is excluded.

Table 3-9: Export Forecast (metric tons)

Commodity Type	Base Year	2029	2034	2039
Chemicals and Related Products	10,045,000	11,950,000	12,687,000	13,795,000
Coal	2,272,000	1,595,000	1,741,000	1,871,000
Crude Materials	825,000	1,074,000	1,184,000	1,307,000
Food and Farm Products	5,541,000	6,862,000	7,528,000	8,316,000
Manufactured Equipment	1,070,000	1,879,000	2,272,000	2,618,000
Other	607,000	607,000	607,000	607,000
Petroleum and Petroleum Products	45,689,000	83,614,000	84,819,000	84,030,000
Primary Manufactured Goods	474,000	684,000	794,000	889,000
Grand Total	**66,522,000**	**108,263,000**	**111,633,000**	**113,432,000**

Petroleum and petroleum products account for 74 percent of all exports from the HSC. Distillate fuel oils and hydrocarbons make up over 50 percent of this commodity group. The AEO 2017 reports that nationally the export of petroleum and petroleum products will increase significantly given slow growth in consumption and higher levels of production. Exports of petroleum and petroleum products in this forecast will see the greatest levels of growth. A simple linear regression analysis confirmed the relationship between historical growth in petroleum and petroleum product exports nationally and at the HSC. The regression results indicate that 95 percent of the variation in HSC exports between 1995 and 2015 were predicted from national exports. The results of the linear regression are in **Table 3-10**. The HSC alone accounts for 29 percent of total waterborne trade of national petroleum and petroleum products.

Table 3-10: Resgression output

Regression Statistics	
Multiple R	0.98
R Square	0.95
Adjusted R Square	0.95
Standard Error	3,067,142
Observations	20

Chemical exports comprise 19 percent of all exports from the HSC. Organic chemicals make up the most tonnage within this group. Global Insight forecasts 7 percent compound annual growth, the fastest growth of any chemical product. Global Insight forecasts all other chemicals to grow at approximately 2 percent compound annual growth. This growth rate is slightly less than that of the American Chemistry Council, which forecasts a growth rate of approximately 4 percent for national chemical exports brought on by rapidly growing production unmatched by domestic consumption[39].

Exports of food and farm products make up 10 percent of all exports. Wheat is the largest commodity in the food and farm products category, accounting for over 50 percent of all food and farm exports from the HSC. The USDA's Long-Term Projections OCE-2016-1 anticipate a slight drop in exports in the short-term due to a stronger dollar before long-term export growth due to long-run global economic growth and growing demand for biofuel feedstocks[40].

3.2.4 Containerized Trade

This study used the containerized trade forecast initially developed for the 204(f) Assumption of Maintenance Report. The following section describes the methodology and data sources used to forecast container traffic for the HSC ECIP.

3.2.4.1 Baseline

The forecast established a baseline as the average of 2013–2015 containerized data and applied growth rates from a 2010 Global Insight long-term trade forecast for the Gulf Coast Region. **Table 3-11** provides total TEUs for years 2011 through 2015.

Table 3-11: TEU Totals at HSC (2010-2015)

Direction	2010	2011	2012	2013	2014	2015
Import	526,945	566,492	626,031	655,093	753,660	842,088
Export	842,155	873,898	890,623	917,187	880,344	920,462
Total	1,369,100	1,440,390	1,516,654	1,572,279	1,634,004	1,762,550

To back-check the commodity forecast for Houston Ship Channel, the study compared TEU totals recorded in 2016 by Port Houston to this study's forecast. **Table 3-12** shows an approximate 3 percent difference in imports and exports between actual and forecasted totals.

Table 3-12: Actual Versus Forecasted TEU Totals (2016)

Total TEUs	Import	Export
Port Houston Data	892,134	909,433
HSC ECIP Forecast	867,840	932,936
Forecast Accuracy	97%	103%

39 https://www.americanchemistry.com/Policy/Trade/Fueling-Export-Growth-US-Net-Export-Trade-Forecast-for-Key-Chemistries-to-2030.pdf

40 https://www.americanchemistry.com/Policy/Trade/Fueling-Export-Growth-US-Net-Export-Trade-Forecast-for-Key-Chemistries-to-2030.pdf

3.2.4.2 Growth Rates

Port Houston provided detailed 2012 country of origin (imports) and destination (exports) data for each container service calling the BPT and BCT. These data informed the proportion of total trade on each route by country. The forecast used the proportions of total trade on each route by country to develop a weighted rate of change for each route. **Table 3-13** summarizes the rate of change by service and year used in the containerized forecast. An average of the last three years' growth rates was used to extend the forecast to 2044.

Table 3-13: Containerized Trade Forecast - Rate of Change

Year	CAR-CA-NCSA	ECSA-NA	FE-NA-PAN	FE-NA-SUEZ	MED-NA	NEU-NA	CAR-CA-NCSA	ECSA-NA	FE-NA-PAN	FE-NA-SUEZ	MED-NA	NEU-NA
	EXPORTS						IMPORTS					
2016	4.69%	4.85%	9.62%	5.42%	5.53%	5.47%	3.64%	4.13%	6.47%	4.94%	3.32%	3.18%
2017	4.70%	5.04%	9.66%	5.31%	5.48%	5.58%	3.45%	3.98%	6.19%	4.50%	3.11%	3.01%
2018	4.72%	4.94%	9.64%	5.15%	5.38%	5.57%	3.46%	4.07%	6.38%	4.31%	3.08%	3.02%
2019	4.53%	4.83%	9.63%	4.99%	5.22%	5.42%	3.56%	4.18%	6.47%	4.39%	3.17%	3.14%
2020	4.33%	4.72%	9.47%	4.81%	4.99%	5.21%	3.55%	4.20%	6.71%	4.20%	3.14%	3.19%
2021	3.89%	4.35%	9.44%	4.39%	4.52%	4.82%	3.73%	4.48%	7.02%	4.34%	3.28%	3.38%
2022	3.79%	4.34%	9.26%	4.24%	4.39%	4.65%	4.01%	4.82%	7.18%	4.67%	3.56%	3.65%
2023	3.72%	4.29%	9.17%	4.21%	4.35%	4.55%	3.86%	4.77%	6.61%	4.61%	3.49%	3.49%
2024	3.53%	4.09%	9.07%	4.02%	4.16%	4.43%	3.74%	4.74%	6.24%	4.54%	3.44%	3.46%
2025	3.36%	3.93%	9.21%	3.84%	4.00%	4.27%	3.83%	4.93%	6.36%	4.67%	3.60%	3.62%
2026	3.35%	3.88%	9.12%	3.78%	3.93%	4.20%	3.71%	4.80%	6.12%	4.53%	3.47%	3.50%
2027	3.17%	3.76%	9.01%	3.60%	3.74%	4.03%	3.44%	4.52%	5.58%	4.23%	3.19%	3.28%
2028	3.18%	3.80%	8.87%	3.60%	3.73%	4.02%	3.39%	4.48%	5.45%	4.17%	3.12%	3.27%
2029	3.16%	3.83%	8.80%	3.58%	3.72%	3.97%	3.33%	4.41%	5.24%	4.10%	3.10%	3.23%
2030	3.07%	3.76%	8.69%	3.46%	3.59%	3.87%	3.14%	4.22%	4.88%	3.89%	2.89%	3.08%
2031	3.02%	3.73%	8.58%	3.39%	3.52%	3.79%	3.01%	4.08%	4.59%	3.74%	2.75%	2.98%
2032	2.96%	3.70%	8.48%	3.32%	3.44%	3.71%	2.88%	3.95%	4.30%	3.59%	2.62%	2.88%
2033	2.90%	3.68%	8.37%	3.25%	3.36%	3.63%	2.75%	3.81%	4.01%	3.44%	2.48%	2.77%
2034	2.85%	3.65%	8.27%	3.18%	3.29%	3.56%	2.62%	3.68%	3.72%	3.29%	2.35%	2.67%
2035	2.79%	3.62%	8.16%	3.10%	3.21%	3.48%	2.49%	3.54%	3.43%	3.14%	2.21%	2.57%

3.2.4.3 Forecast

Table 3-14 provides total tons by direction and route group for the HSC including BPT, BCT, and Jacintoport Container Terminal. The study forecasts that Port Houston container facilities reach maximum capacity in 2040.

Table 3-14: Containerized Cargo Forecast (metric tons)

Route – Tons	Baseline	2029	2034	2039	2044
Import Total	***6,703,000***	***12,179,000***	***14,459,000***	***16,871,000***	***17,406,000***
CAR-CA-NCSA	469,000	772,000	890,000	1,011,000	1,038,000
ECSA-NA	1,024,000	1,888,000	2,291,000	2,741,000	2,842,000
FE-NA-PAN	1,365,000	3,205,000	3,955,000	4,733,000	4,909,000
FE-NA-SUEZ	965,000	1,774,000	2,116,000	2,484,000	2,566,000
MED-NA	1,070,000	1,683,000	1,916,000	2,149,000	2,199,000
NEU-NA	1,810,000	2,857,000	3,292,000	3,752,000	3,852,000
Export Total	***8,110,000***	***16,479,000***	***20,649,000***	***25,941,000***	***27,191,000***
CAR-CA-NCSA	955,000	1,623,000	1,878,000	2,160,000	2,221,000
ECSA-NA	1,588,000	2,875,000	3,449,000	4,125,000	4,275,000
FE-NA-PAN	990,000	3,432,000	5,154,000	7,659,000	8,292,000
FE-NA-SUEZ	1,224,000	2,222,000	2,616,000	3,057,000	3,154,000
MED-NA	1,350,000	2,503,000	2,964,000	3,481,000	3,596,000
NEU-NA	2,003,000	3,823,000	4,587,000	5,459,000	5,653,000
Grand Total	**14,813,000**	**28,657,000**	**35,108,000**	**42,811,000**	**44,597,000**

Table 3-15 is an estimate of total TEUs based on average metric tons including empty TEUs. BCT is expected to reach capacity in 2039. Excess capacity will be transferred to BPT which will reach capacity in 2040.

Table 3-15: TEUs (Laden and Empty) by Route and Direction

Route – TEUs	Baseline	2029	2034	2039	2044
Import	***832,000***	***1,517,000***	***1,803,000***	***2,105,000***	***2,172,000***
CAR-CA-NCSA	79,000	129,000	149,000	170,000	174,000
ECSA-NA	129,000	237,000	288,000	344,000	357,000
FE-NA-PAN	179,000	419,000	517,000	619,000	642,000
FE-NA-SUEZ	108,000	198,000	236,000	278,000	287,000
MED-NA	104,000	164,000	186,000	209,000	214,000
NEU-NA	234,000	369,000	426,000	485,000	498,000
Export	***880,000***	***1,860,000***	***2,372,000***	***3,036,000***	***3,195,000***
CAR-CA-NCSA	92,000	157,000	182,000	209,000	215,000
ECSA-NA	142,000	257,000	308,000	368,000	381,000
FE-NA-PAN	149,000	516,000	775,000	1,151,000	1,246,000
FE-NA-SUEZ	115,000	209,000	246,000	288,000	297,000
MED-NA	143,000	265,000	313,000	368,000	380,000
NEU-NA	239,000	457,000	548,000	652,000	676,000
Total	***1,712,000***	***3,377,000***	***4,175,000***	***5,141,000***	***5,367,000***
CAR-CA-NCSA	171,000	287,000	331,000	379,000	389,000
ECSA-NA	270,000	494,000	595,000	712,000	738,000
FE-NA-PAN	327,000	935,000	1,292,000	1,770,000	1,888,000
FE-NA-SUEZ	223,000	407,000	483,000	565,000	583,000
MED-NA	247,000	428,000	500,000	577,000	594,000

NEU-NA	473,000	826,000	974,000	1,138,000	1,174,000

3.3 VESSEL FLEET FORECAST

3.3.1 World Fleet

In addition to a commodity forecast, a forecast of the future fleet is required to evaluate channel modifications. To develop projections of the future fleet calling at Port Houston, the study team made use of World Fleet forecasts of containerships and other vessels developed by Maritime Strategies Inc. (MSI) for Port Houston (2013), Port of Charleston (2015), and Port of Seattle (2016).

Table 3-16 shows the fleet subdivision for containerships and bulk cargo vessels used for this study. As the fleet anticipated to make use of Port Houston in both the Future Without Project (FWOP) and Future With Project (FWP) conditions are not expected to involve new and emerging vessels but rather vessels that currently make up a large portion of the existing world fleet, a new world fleet forecast was not undertaken.

Table 3-16: Fleet Subdivisions (Feet)

Vessel Type	Vessel Class	Beam		Draft		LOA	
		Min	Max	Min	Max	Min	Max
Containership	SPX	34.8	98.2	8.2	38.1	221.7	813.3
Containership	PX	98.4	106.3	30.8	44.8	572	970
Containership	PPX I	106.4	138	35.4	47.6	660.8	1044.7
Containership	PPX II	138	144	39.4	49.2	910.7	1205
Containership	PPX III	144	160.8	42.7	49.5	1036.7	1220
Containership	PPX IV	160.8	185	50.9	52.6	1220	1312.3
Tanker	10k-30k	78.9	86.5	30.9	33.0	498.3	520.3
Tanker	30k-55k	90.1	105.7	37.0	42.5	584.3	603.4
Tanker	55k-75k	105.8	105.9	41.7	47.0	725.0	749.2
Tanker	75k-100k	122.5	139.2	44.6	45.8	772.8	796.5
Tanker	100k-130k	144.5	144.5	49.1	49.1	817.4	817.4
Tanker	130k-157.5k	154.8	154.8	54.1	54.1	877.3	877.3
Tanker	157.5k-215k	158.7	158.7	55.9	55.9	899.8	899.8
Tanker	215k-282.5k	185.9	185.9	66.8	66.8	1,039.3	1,039.3
Tanker	282.5k-310k	195.4	195.4	70.6	70.6	1,088.2	1,088.2
Tanker	310k-320k	197.0	197.0	73.9	73.9	1,092.3	1,092.3
Bulk Carrier	7.5k-30k	71.2	81.7	27.2	32.2	467.4	540.5
Bulk Carrier	30k-45k	93.7	98.5	33.6	35.2	594.3	602.2
Bulk Carrier	45k-70k	105.4	105.9	38.7	42.2	627.3	638.6
Bulk Carrier	70k-110k	105.9	127.2	47.2	47.3	746.8	764.9
Bulk Carrier	110k-135k	141.1	141.1	47.2	47.2	832.3	832.3

Vessel Type	Vessel Class	Beam		Draft		LOA	
		Min	Max	Min	Max	Min	Max
Bulk Carrier	135k-162.5k	143.3	143.3	56.8	56.8	889.7	889.7
Bulk Carrier	162.5k-187.5k	148.1	148.1	59.7	59.7	957.1	957.1
Bulk Carrier	187.5k-225k	164.1	164.1	59.8	59.8	984.0	984.0
Bulk Carrier	225k-282.5k	187.8	187.8	60.8	60.8	1,077.7	1,077.7
Bulk Carrier	282.5k-315k	183.0	183.0	70.8	70.8	1,077.4	1,077.4
Chemical Tanker	4.5-13.5k	59.9	59.9	24.2	24.2	380.7	380.7
Chemical Tanker	13.5k-21.5k	74.7	74.7	29.5	29.5	472.9	472.9
Chemical Tanker	21.5k-29k	86.2	86.2	32.7	32.7	540.4	540.4
Chemical Tanker	29-33k	87.3	87.3	36.1	36.1	569.3	569.3
LNG Tanker	2.5k-13.5k	57.4	57.4	21.3	21.3	347.8	347.8
LNG Tanker	13.5k-33.5k	83.1	83.1	32.6	32.6	523.6	523.6
LNG Tanker	33.5k-49.2k	92.4	92.4	34.9	34.9	578.0	578.0
LNG Tanker	49.2k-64.2k	105.8	105.8	39.6	39.6	672.4	672.4
General Cargo	5.5k-12.5k	61.9	61.9	26.4	26.4	410.2	410.2
General Cargo	12.5k-15k	68.3	68.3	29.2	29.2	461.5	461.5
General Cargo	15.5k-18k	74.1	74.1	31.1	31.1	489.2	489.2
General Cargo	18k-22k	75.5	75.5	30.7	30.7	508.5	508.5
General Cargo	22k-27k	81.6	81.6	32.6	32.6	552.2	552.2
General Cargo	27k-30k	90.3	90.3	33.9	33.9	582.4	582.4
RoRo	3.65k-9.15k	73.0	73.0	21.7	21.7	449.8	449.8
RoRo	9.15k-15.9k	83.9	83.9	24.3	24.3	612.3	612.3
RoRo	15.9k-20.9k	105.9	105.9	32.7	32.7	655.8	655.8

MSI's forecasting technique begins with performing a detailed review of the current world fleet and how it is deployed on the trade routes of the world. Forecasting of the world fleet was made possible through MSI's proprietary Container Shipping Planning Service (CSPS) model, which applies historical and forecasted time series data from 1980–2030 for:

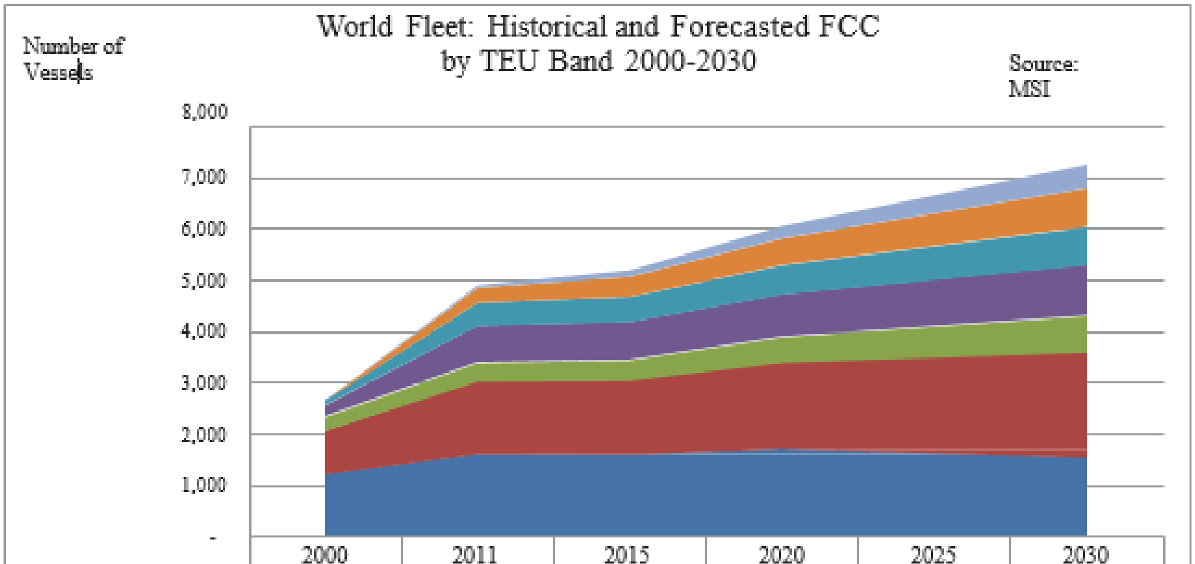
- Macroeconomic and trade variables including:
- Annual GDP growth rates by region
- Industrial production
- Population growth
- Inflation and interest rates
- Currency exchange
- Global container trade and movements in TEU lifts by region including:
- Primary lifts

- Transshipment lifts
- Loaded/Empty lifts
- Sector-specific fleet dynamics including:
- Fleet nominal capacity by vessel size and age
- Contracting, order book, deliveries, cancellations, slippage and scrapping
- Container fleet by size
- Sector-specific supply/demand balances
- Time charter rates and vessel operating costs
- Freight rates including:
  - Headhaul rates
  - Backhaul rates
  - New building, second-hand (by age) and scrap prices for standard sizes

Data sources for the CSPS model include:

- Macroeconomics: Oxford Economics, leading investment banks
- World Trade: United Nations Conference of Trade and Development, Drewry Shipping Consultants, Containerization International
- Fleet Supply: LR-Fairplay, Worldyards, Howe Robinson
- Charter Rates, Freight Rates and Vessel Prices: Drewry Shipping Consultants, Howe Robinson, Clarksons, and various contacts at shipping lines

When evaluating data on vessel composition, vessel age, and container markets, MSI then considered the "order book" to estimate new deliveries to the fleet into the future. Vessel scrapping is accounted for based on historical scrapping rates by vessel class and age. Containerships, particularly the largest ones, are relatively new, so widespread scrapping is not expected to take place until well in the future. Likewise, when economies are strong, vessel owners are more likely to hold onto their existing vessels (or build new ones) and less likely to scrap them. The forecasted world fleet provides a frame of reference to verify the validity of the Houston fleet forecast and is provided as background information. **Figure 3-3** provides an overview of the world containership fleet used in this study.



	2000	2011	2015	2020	2025	2030
12 k TEU +	-	47	124	232	348	458
7.6 k to 12 k TEU	-	291	388	515	632	742
5.2 k to 7.6 k TEU	104	456	498	577	654	747
3.9 k to 5.2 k TEU	203	707	735	826	905	991
2.9 k to 3.9 k TEU	272	364	393	497	600	708
1.3 k to 2.9 k TEU	850	1,420	1,446	1,684	1,869	2,051
0.1 k to 1.3k TEU	1,214	1,604	1,596	1,706	1,633	1,537

Figure 3-3: World Fleet: Historical and Forecasted FCC by TEU Band 2000-2030

3.3.2 Houston Ship Channel Container Fleet Forecast

The MSI forecast adapted for this study used the world forecast to determine the expected fleet composition at the HSC over the study period. For this study, two containership fleets were developed. The first replicates the MSI forecast completed for HSC 204(f). This fleet was used as the FWOP fleet. The second fleet introduced a PPX III containership vessel to represent the FWP. To determine the breakdown of this fleet, the study assumed a similar tonnage distribution across PPX II and PPX III vessels as was used for Charleston Harbor and Seattle Harbor Navigation Improvement Project. For all other vessel classes, the Port Houston MSI forecast (2013) was used to forecast future container traffic. The results of the fleet forecast are provided in **Table 3-17**.

Table 3-17: HSC Fleet Forecast by Service and Vessel Class

Service and Vessel Class	% Tonnage on Service							
	2029		2034		2039		2044	
	FWOP	FWP	FWOP	FWP	FWOP	FWP	FWOP	FWP
FE-NA-PAN SPX	0%	0%	0%	0%	0%	0%	0%	0%
FE-NA-PAN PX	38%	38%	27%	27%	16%	16%	10%	10%
FE-NA-PAN PPX1	30%	30%	28%	28%	29%	29%	24%	24%
FE-NA-PAN PPX2	33%	15%	45%	19%	55%	22%	66%	27%

Service and Vessel Class	% Tonnage on Service							
	2029		2034		2039		2044	
	FWOP	FWP	FWOP	FWP	FWOP	FWP	FWOP	FWP
FE-NA-PAN PPX3	0%	18%	0%	27%	0%	33%	0%	40%
FE-NA-SUEZ SPX	0%	0%	0%	0%	0%	0%	0%	0%
FE-NA-SUEZ PX	15%	15%	10%	10%	8%	8%	5%	5%
FE-NA-SUEZ PPX1	51%	51%	46%	46%	58%	58%	50%	50%
FE-NA-SUEZ PPX2	34%	15%	44%	18%	35%	14%	44%	18%
FE-NA-SUEZ PPX3	0%	19%	0%	26%	0%	21%	0%	27%
MED-NA SPX	6%	6%	5%	5%	4%	4%	3%	3%
MED-NA PX	35%	35%	26%	26%	18%	18%	12%	12%
MED-NA PPX1	31%	31%	30%	30%	30%	30%	26%	26%
MED-NA PPX2	28%	12%	39%	16%	47%	19%	59%	24%
MED-NA PPX3	0%	16%	0%	23%	0%	28%	0%	35%
NEU-NA SPX	1%	1%	1%	1%	0%	0%	0%	0%
NEU-NA PX	38%	38%	27%	27%	18%	18%	12%	12%
NEU-NA PPX1	29%	29%	28%	28%	28%	28%	23%	23%
NEU-NA PPX2	32%	14%	44%	18%	53%	21%	65%	26%
NEU-NA PPX3	0%	18%	0%	26%	0%	32%	0%	39%
ECSA-NA SPX	14%	14%	14%	14%	14%	14%	14%	14%
ECSA-NA PX	26%	26%	26%	26%	26%	26%	26%	26%
ECSA-NA PPX1	60%	60%	60%	60%	60%	60%	60%	60%
ECSA-NA PPX2	0%	0%	0%	0%	0%	0%	0%	0%
ECSA-NA PPX3	0%	0%	0%	0%	0%	0%	0%	0%
CAR-CA-NCSA SPX	74%	74%	74%	74%	74%	74%	74%	74%
CAR-CA-NCSA PX	26%	26%	26%	26%	26%	26%	26%	26%
CAR-CA-NCSA PPX1	0%	0%	0%	0%	0%	0%	0%	0%
CAR-CA-NCSA PPX2	0%	0%	0%	0%	0%	0%	0%	0%
CAR-CA-NCSA PPX3	0%	0%	0%	0%	0%	0%	0%	0%

3.3.2.1 Container Vessels Calling at HSC

One of the biggest challenges when undertaking a containership study is estimating the total volume of cargo stored on a vessel at a given time. Unlike bulk ports, which generally serve niche markets, container ports are dynamic. A useful way of thinking of the container trade is to consider the analogy of bus lines that make multiple stops on a particular route. Cargo is often loaded and unloaded simultaneously before calling at a string of other ports. As mentioned previously, the weight of cargo can vary greatly by trade route, whereas vessel operators can also carry large numbers of empty containers or sail with vacant slots. What further complicates matters is that as vessel operators share cargo, they may be carrying a wide mix of cargo boxes, each with entirely different weights.

A vessel loading factor analysis (LFA) helps to capture valid relationships and parameters for estimating the disposition of cargo and non-cargo components of vessel loading which in turn helps to better estimate the amount of cargo on a ship at a given time. The basic methodology and logic of the load factor analysis is based on long-established practices that have been historically applied to USACE-sponsored economic evaluations of navigation improvements. A better snapshot of the cargo aids in identifying requirements for vessel immersion and draft. Cargo components of an LFA include carried tonnages, containers that store the cargo, and empty containers. Some of the non-cargo components that are considered in an LFA include allowances for ballast, bunkerage, vacant slots, and any other load factor significant to reasonably estimate hull immersion and draft.

Once the commodity forecast and the initial Post-Panamax vessel call forecast by trade route were completed, a load factor and vessel cost analysis was undertaken. The LFA is described through the remainder of the benefit analysis and provides the rationale for deployment decisions associated with the potential economic efficiencies of channel modifications.

3.3.3 Bulk Vessels

The study assumes that segments 1 through 4 will see a fleet transition toward larger vessels. The transition of tanker vessels is the most consequential fleet transition besides that of containerships. The study assumes that HSC's tanker fleet distribution will increase in size to meet the world fleet order book's fleet distribution. **Table 3-18** provides a summary of projected tanker vessel capacity distribution in the world order book from Global Insight as of 2017. The HSC tanker fleet transitions to meet this fleet distribution over the study period.

Table 3-18: Tanker Vessel Capacity in the World Order Book (2017)

Class	DWT Range	% of World Order Book
HANDY	10k-30k	7%
MR	30k-55k	29%
PANAMAX	55k-75k	9%
AFRAMAX	75k-100k, 100k-130k	30%
SUEZMAX	130k-157.5k, 157.5k-215k	25%
	Grand Total	**100%**

For the transition to Aframax tankers expected in Segment 4, a similar methodology was used. The study limited the world tanker fleet distribution to Aframax tankers and transitioned the Segment 4 tanker fleet over the study period to meet the world fleet transition. **Table 3-19** provides a tonnage distribution summary for tankers in Segment 4 by study year.

Table 3-19: Tanker Tonnage Distribution for Segment 4

Tanker Class	2029	2034	2039	2044
30k-55k Tanker	68%	62%	55%	48%
55k-75k Tanker	24%	22%	20%	18%

75k-100k Tanker	4%	4%	4%	4%
100k-130k Tanker	4%	11%	17%	24%

The study assumes minimal fleet transition in the upper reaches (Segments 5 and 6) given that channel dimensions are not changing significantly in the proposed measures for these segments.

3.4 ALTERNATIVES FOR ECONOMIC EVALUATION

Alternative plans were developed to address congestion, vessel delays, and inefficient vessel loading issues throughout the channel. Alternatives are meant to be additive in that a combination of alternatives best meets the study's planning objectives; furthermore, a combination of plans maximizes net national economic development (NED) benefits. The following provides a summary of alternative plans evaluated by this study. The study first evaluated a minimum plan to satisfy system-wide (Galveston Bay and Buffalo Bayou) planning objectives (Alternative 1). The study then evaluates alternatives that specifically address Galveston Bay (Alternatives 2 and 3). Measures that target planning objectives in Buffalo Bayou were evaluated separately (Alternatives 4 and 5). Finally, planning objectives associated with a lack of mooring facilities are studied (Alternatives 6 and 7). Through evaluation of Alternatives 1 through 7, an array of the most beneficial measures that address planning objectives throughout the HSC was developed. These measures were compiled into the plan that provided the most economic benefit and best met the planning objectives of the study: Alternative 8. Alternative 8 is a comprehensive, system-wide plan that builds on Alternative 1 with the most beneficial features from Alternatives 1 through 7. The following provides a summary of measures associated with each alternative.

Alternative 1 (Minimum System-Wide Plan (No Bay Widening)). This plan involves measures that address planning objectives in both the bay and Buffalo Bayou. It is the minimum system-wide plan in that it attempts to accommodate the study's design vessels, but does not address the existing or future congestion in the channel. Components of Alternatives 2 through 7 will be added to this alternative to better address the system as a whole. Alternative 1 includes the following measures:

- Four bend easings on the main HSC channel in the Bay Reach with associated relocation of barge lanes (Segment 1)
- New turning basin/flare expansion on BSC near land cut entrance (Segment 2)
- Widen BSC from existing 300–400 feet to 455 feet (Segment 2)
- Shoaling attenuation structure around BSC Flare (Segment 2)
- Bay multipurpose mooring at BSC (Segment 2)
- Combination flare and turning basin on BCC near the entrance (Segment 3)
- Widen BCC from existing 300 feet to 455 feet (Segment 3)

- Channel deepening from the existing channel depth of 41.5 feet to a maximum depth of 46.5 feet as much as possible upstream of Boggy Bayou (Segment 4)
- Channel deepening from the existing channel depth of 37.5 feet to a maximum depth of 41.5 feet as much as possible upstream of Boggy Bayou (Segments 5 and 6)

Alternative 2 (Bay Plan). This alternative is a standalone plan that intends to specifically allow transit of the containership design vessel while maintaining two-way traffic in Galveston Bay. This alternative does not include any improvements to Buffalo Bayou. It is intended to be combined with additional improvements throughout the channel. Alternative 2 includes the following measures:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (Segment 1)
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530-foot width to between 650 to 900 feet (Segment 1)
- New turning basin with flare expansion on BSC (Segment 2)
- Widen BSC from existing 300 feet to 455 feet (Segment 2)
- Shoaling attenuation structure near the BSC Flare to reduce shoaling (Segment 2)
- Combination flare and turning basin on BCC (Segment 3)
- Widen BCC from existing 300 feet to 455 feet (Segment 3)

Alternative 3 (Suezmax Plan). Similar to Alternative 2, this plan focuses on maintaining two-way traffic in the bay; however, it specifically focuses on measures benefitting the Suezmax tanker. In addition to channel widening in the bay from Alternative 2, this alternative includes measures in the upper bay that accommodate more efficient tanker navigation. This plan can also be combined with additional channel improvements. Alternative 3 includes the following measures:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (Segment 1)
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530-foot width to between 650 to 900 feet (Segment 1)
- Two bend easings in the bayou portion of the HSC main channel above Morgan's Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (Segment 1)
- Minor widening of the channel in the bayou portion of the HSC main channel in the Hog Island Stretch and from San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet for approximately 1.3 miles (Segment 1)

- Widen BSC from existing 300–400 feet to 455 feet (Segment 2)
- Shoaling attenuation structure near the BSC Flare to reduce shoaling (Segment 2)

Alternative 4 (Aframax Plan). This alternative consists of improvements in Buffalo Bayou between Boggy Bayou and Sims Bayou (Segment 4) to accommodate transit of the Aframax tanker. The plan is intended as a standalone group of measures that can be added to other alternatives to address the system as a whole. Alternative 4 includes the following measures:

- Deepen the HSC main channel from Boggy Bayou to Sims Bayou beyond 41.5 feet as much as possible up to 46.5 feet deep (Segment 4)
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot width up to 530 feet (Segment 4)
- New turning basin in the Boggy Bayou to Greens Bayou segment near Pasadena docks (Segment 4)
- Expand Hunting Bayou Turning Basin (Segment 4)

Alternative 5 (Bulkers, Tankers, and Vehicle Carriers Plan). This alternative also focuses on measures in Buffalo Bayou. It focuses on bulker, tanker, and vehicle carrier traffic in Segments 4, 5, and 6 with the intention of improving loading efficiency through channel deepening. This plan can be added to other alternatives in other segments of the channel. Alternative 5 includes the following measures:

- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (Segment 4)
- Expand Hunting Bayou Turning Basin (Segment 4)
- Deepen the HSC main channel from Sims Bayou to I-610 bridge from the existing 37.5-foot depth up to 41.5 feet (Segment 5)
- Expand Brady Island Turning Basin (Segment 6)
- Deepen the HSC main channel from I-610 bridge to main turning basin from the existing 37.5-foot depth up to 41.5 feet (Segment 6)

Alternative 6 (Bay Mooring). Alternatives 6 and 7 evaluate the systemwide impact of adding a mooring facility to the HSC. Alternative 6 specifically evaluates the benefits of a mooring facility located in BSC (Segment 2). Alternative 6 includes the following measures:

- The addition of a new multipurpose mooring in the BSC to be located just outside the land cut (Segment 2)

Alternative 7 (Upper Channel Moorings). A mooring facility located in the upper bay near the entrance to Buffalo Bayou has significantly different impacts, costs, and benefits than in BSC. This necessitated an additional mooring facility alternative. Alternative 7 evaluates the following measures:

- Two new multipurpose moorings in the HSC upper channel; one mooring would be located near Alexander Island and the other mooring would be located near the San Jacinto State Park area (Segment 1)

Alternative 8 (The Everything Plan). This alternative intends to address planning objectives across the entire HSC navigation system. It builds on Alternative 1 with the most beneficial measures from Alternatives 2 through 7. Alternative 8 includes the following measures:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (Segment 1)
- Widening (in whole/part) the HSC main channel for meeting between Bolivar Roads and BCC from the existing 530-foot width to between 650 to 900 feet (Segment 1)
- Two bend easings in the bayou portion of the HSC main channel above Morgan's Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (Segment 1)
- Minor widening of the channel in the bayou portion of the HSC main channel in the Hog Island Stretch and from San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet approximately 1.3 miles (Segment 1);
- Two new multipurpose moorings in the HSC upper channel with one mooring located near Alexander Island and the other mooring located near the San Jacinto State Park area (Segment 1)
- New turning basin with flare expansion on BSC (Segment 2)
- Widen BSC from existing 300 feet to 455 feet (Segment 2)
- Shoaling attenuation structure near the BSC Flare (Segment 2)
- A new multipurpose mooring in the BSC just outside the land cut (Segment 2)
- Combination flare and turning basin on BCC (Segment 3)
- Widen BCC from existing 300 feet to 455 feet (Segment 3)
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (Segment 4)
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (Segment 4)

- New turning basin in the Boggy Bayou to Greens Bayou Segment near Pasadena docks (Segment 4)
- Expand Hunting Bayou Turning Basin (Segment 4)
- Deepen the HSC main channel from Sims Bayou to I-610 bridge from the existing 37.5-foot depth up to 41.5 feet (Segment 5)
- Expand Brady Island Turning Basin (Segment 6)
- Deepen the HSC main channel from I-610 bridge to main turning basin from the existing 37.5-foot depth up to 41.5 feet deep (Segment 6)

4 TRANSPORTATION COST SAVINGS BENEFITS ANALYSIS

The following section describes the economic analysis completed to determine the national economic development (NED) benefits of the proposed study measures. For the purposes of Deep Draft Navigation Economic Analysis per ER 1105-2-100, an NED benefit may include the following:

1) Reduced cost of transportation through use of vessels (modal shift) , through safer or more efficient operation of vessels and/or use of larger and more efficient vessels (channel enlargement), and through use of new or alternate vessel routes (new channels or port shift)

2) Increased net return to producers from access to new sources of lower cost materials, or access to new and more profitable markets (shift of origin or destination)

3) Increased production through new or greater production opportunity (commercial fishing and offshore minerals), or new economic activities involving new commodity movements (induced movements)

The benefits described above are meant to increase shipping efficiency, leading to a reduction in the total cost of commodity transit. The reduction in transportation costs becomes a national economic benefit when the savings are passed on to the consumer.

The purpose of this analysis is to describe the benefits associated with the channel modification improvements for the project alternatives under consideration for the HSC. NED benefits were estimated by calculating the reduction in transportation cost for each alternative using the HarborSym Modeling Suite of Tools (HMST) developed by IWR. The HMST reflects USACE guidance on transportation cost savings analysis. Model runs were completed for the deepening benefits for segments 4, 5 and 6, mooring alternatives, widening alternatives, and bend easing improvements for the container design vessel.

Within this section, the HMST is described in detail, including the widening, deepening, and other channel modification aspects, and its application in the study. The resulting benefits are described in Section 4.2 through Section 4.4.

4.1 METHODOLOGY

Channel improvements result in reduced transportation cost by allowing a more efficient future fleet mix and less congestion when traversing the port, resulting in at-sea and in-port cost savings. The HMST was designed to allow users to model these benefits. With a deepened channel, vessel fleet owners allocate their largest vessels to routes that have adequate traffic and reliable project depth. As the HSC is deepened, the reliability of the channel depth increases. The increased reliability is expected to encourage shippers to replace smaller less efficient vessels with the larger more efficient vessels on Port Houston route services.

There are three primary effects from channel deepening that lead to changes in the future fleet at the Port of the Houston. The first is an increase in a vessel's maximum practicable loading capacity. Channel restrictions limit a vessels capacity by limiting its draft. Deepening the channel reduces this constraint and the vessel's maximum practicable capacity increases towards its design capacity. This increase in vessel capacity results in fewer vessel trips being required to transport the forecasted cargo. The second effect of increased channel depth is the increased reliability of water depth, which encourages the deployment of larger vessels to Houston. The third effect is a consequence of the second. The increase in Post-Panamax vessels displaces the less economically efficient Panamax class vessels.

While lesser in magnitude when compared to channel deepening, additional transportation cost saving benefits result from the channel modifications aimed at reducing congestion within the harbor. The creation of meeting areas reduces wait times within the harbor. HarborSym allows for detailed modeling of vessel movements and transit rules on the waterway.

To begin, HarborSym was setup with the basic required variables. To estimate origin-destination (OD) cost saving benefits (or the reduction in transit costs associated with a drop in the total number of port calls caused by deeper loading or the use of a more efficient fleet mix), the Container Loading Tool (CLT), a module within the HMST, was used to generate a vessel call list based on the commodity forecast at the HSC for a given year, Houston's share of the world's vessel fleet, and available channel depth under the various alternatives. The resulting vessel traffic was simulated using HarborSym, producing average annual vessel OD transportation costs. The Tentatively Selected Plan (TSP) was identified by considering the highest net benefit based on the OD transportation cost saving benefits. The Bulk Loading Tool (BLT) was used to create traffic for non-containerized vessels and combining this traffic with the containerized vessel calls that was generated using the CLT for the OD transportation model to evaluate benefits of channel deepening bayou (Boggy Bayou the Main Turning Basin).

4.1.1 HarborSym Model Overview

IWR developed HarborSym as a planning level, general-purpose model to analyze the transportation costs of various waterway modifications within a harbor. HarborSym is a Monte Carlo simulation model of vessel movements at a port for use in economic analyses. While many harbor simulation models focus on landside operations, such as detailed terminal management, HarborSym instead concentrates on specific vessel movements and transit rules on the waterway, fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with the ocean voyage.

HarborSym represents a port as a tree-structured network of reaches, docks, anchorages, and turning areas. Vessel movements are simulated along the reaches, moving from the bar to one or more docks, and then exiting the port. Features of the model include intra-harbor vessel movements, tidal influence, the ability to model complex shipments, incorporation of turning areas and anchorages, and within-simulation visualization. The driving parameter for the HarborSym model is a vessel call at the port. A HarborSym analysis revolves around the factors that characterize or affect a vessel movement within the harbor.

4.1.2 Model Behavior

HarborSym is an event driven model. Vessel calls are processed individually and the interactions with other vessels are taken into account. For each iteration, the vessel calls for an iteration that falls within the simulation period are accumulated and placed in a queue based on arrival time. When a vessel arrives at the port, the route to all of the docks in the vessel call is determined. This route is comprised of discrete legs (contiguous sets of reaches, from the entry to the dock, from a dock to another dock, and from the final dock to the exit). The vessel attempts to move along the initial leg of the route. Potential conflicts with other vessels that have previously entered the system are evaluated according to the user-defined set of rules for each reach within the current leg, based on information maintained by the simulation as to the current and projected future state of each reach. If a rule activation occurs, such as no passing allowed in a given reach, the arriving vessel must either delay entry or proceed as far as possible to an available anchorage, waiting there until it can attempt to continue the journey. Vessels move from reach to reach, eventually arriving at the dock that is the terminus of the leg.

After the cargo exchange calculations are completed and the time the vessel spends at the dock has been determined, the vessel attempts to exit the dock, starting a new leg of the vessel call; rules for moving to the next destination (another dock or an exit of the harbor) are checked in a similar manner to the rule checking on arrival, before it is determined that the vessel can proceed on the next leg. As with the entry into the system, the vessel may need to delay departure and re-try at a later time to avoid rule violations and, similarly, the waiting time at the dock is recorded.

A vessel encountering rule conflicts that would prevent it from completely traversing a leg may be able to move partially along the leg, to an anchorage or mooring. If so, and if the vessel can use the anchorage (which may be impossible due to size constraints or the fact that the anchorage is filled by other vessels), then HarborSym will direct the vessel to proceed along the leg to the anchorage, where it will stay and attempt to depart periodically, until it can do so without causing rule conflicts in the remainder of the leg. The determination of the total time a vessel spends within the system is the summation of time waiting at entry, time transiting the reaches, time turning, time transferring cargo, and time waiting at docks or anchorages. HarborSym collects and reports statistics on individual vessel movements, including time in system, as well as overall summations for all movements in an iteration.

HarborSym was initially developed as a tool for analyzing channel widening projects, which were oriented toward determining time savings for vessels transiting within a harbor. It did not allow for assessing changes in vessel loading or in shipping patterns. The most recent release of HarborSym was designed to assist analysts in evaluating channel-deepening projects, in addition to the original model capabilities. The deepening features consider fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with ocean voyage.

Each vessel call has a known (calculated) associated cost, based on time spent in the harbor and ocean voyage and cost per hour. Also for each vessel call, the total quantity of commodity transferred to the port (both import and export) is known, in terms of commodity category, quantity, tonnage and value. The basic problem is to allocate the total cost of the call to the various commodity transfers that are made. Each vessel call may have multiple dock visits and multiple commodity transfers at each visit, but each commodity transfer record refers to a single commodity and specifies the import and export tonnage. Also, at the commodity level, the "tons per unit" for the commodity is known, so that each commodity transfer can be associated with an export and import tonnage. As noted above, the process is greatly simplified if all commodity transfers within a call are for categories that are measured in the same unit, but that need not be the case.

When a vessel leaves the system, the total tonnage, export tonnage, and import tonnage transferred by the call are available, as is the total cost of the call. The cost per ton can be calculated at the call level (divide total cost by respective total of tonnage). Once these values are available, it is possible to cycle through all of the commodity transfers for the vessel call. Each commodity transfer for a call is associated with a single vessel class and unit of measure. Multiplying the tons or value in the transfer by the appropriate per ton cost, the cost totals by class and unit for the iteration can be incremented. In this fashion, the total cost of each vessel call is allocated proportionately to the units of measure that are carried by the call, both on a tonnage and a value basis. Note that this approach does not require that each class or call carry only a commensurate unit of measure.

The model calculates import and export tons, import and export value, and import and export allocated cost. This information allows for the calculation of total tons and total cost, allowing for the derivation of the desired metrics at the class and total level. The model can thus deliver a high level of detail on individual vessel, class, and commodity level totals and costs.

Either all or a portion of the at-sea costs are associated with the subject port, depending on whether the vessel call is a partial or full load. The at-sea cost allocation procedure is implemented within the HarborSym Monte-Carlo processing and utilizes the estimate total trip cargo (ETTC) field from the vessel call information along with import tonnage and export tonnage. In all cases the ETTC is the user's best estimate of total trip cargo. Within the BLT and CLT, the ETTC field is estimated as cargo on board the vessel at arrival plus cargo on board the vessel at departure, in tons. ETTC can also be expressed as:

ETTC = 2*Cargo on Board at Arrival – Import tons + Export tons

There is a basic algorithm implemented to determine the fraction of at-sea costs to be allocated to the subject port. First, if ETTC for a vessel call is equal to zero or null, then none of the at-sea costs are associated with the port. The algorithm then checks if import or export tons are zero for a vessel call. If either are zero, then the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

At-Sea Cost Allocation Fraction = (Import tons + Export tons)/ETTC

Finally, when both import and export tons are greater than zero, the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

At-Sea Cost Allocation Fraction = 0.5 * (Import tons/Tonnage on board at arrival)
+ 0.5 * (Export tons/Tonnage on board at departure)

Where:

Tonnage on board at arrival = (ETTC + Imports – Exports)/2
Tonnage on board at departure = Tonnage on board at arrival – Imports + Exports

4.1.3 HarborSym Data Inputs

The data required to run HarborSym are separated into six categories, as described below. Key data for the HSC study are provided.

Simulation Parameters. Parameters include start date, the duration of the iteration, the number of iterations, the level of detail of the result output, and the wait time before rechecking rule

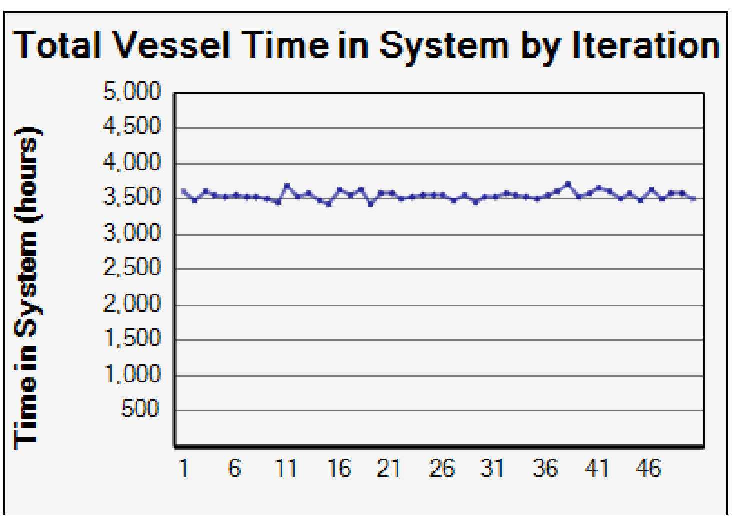


Figure 4-1: HarborSym Iterations for Containership OD Modeling (Hours)

violations when a vessel experiences a delay. The base year for the model was 2029. A model run was performed for the following years: 2029, 2034, 2039, and 2044. The OD model runs for containership benefits in 2029, for example, showed through 50 iterations a standard deviation of 61 hours (**Figure 4-1).**

Figure 4-2 illustrates there is very low variation in vessel time in the system for the OD model runs. As an example, the existing condition OD model run in 2029 for channel deepening in Segment 4 had an average total vessel time in the system after 10 iterations was 49,902 hours with a standard deviation of 43 hours.

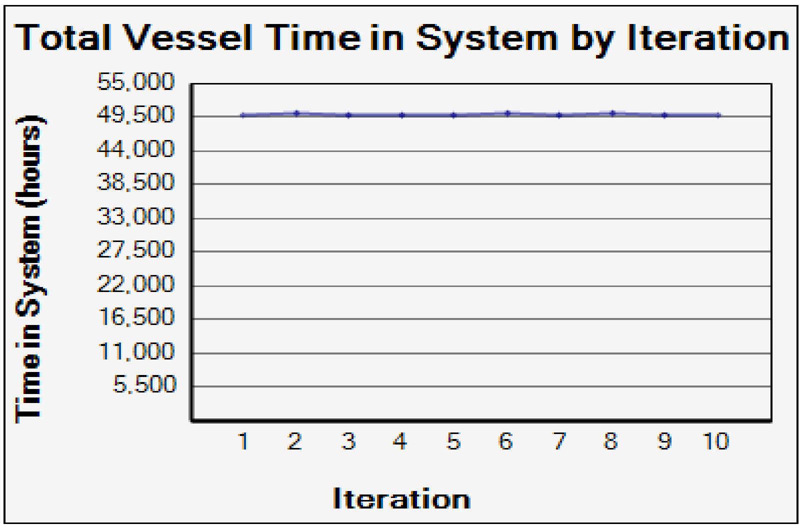


Figure 4-2: HarborSym Iterations for Segment 4 OD Modeling (Hours)

Figure 4-3 also shows very little variation in the origin-destination benefits of channel deepening in Segments 5 and 6. The average total vessel time in system after 10 iterations was 20,573 hours with a standard deviation of 34 hours.

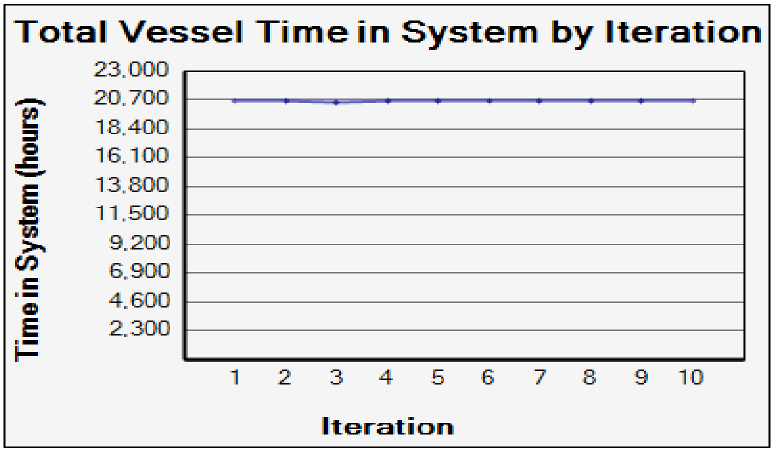


Figure 4-3: HarborSym Iterations for Segment 5-6 OD Modeling (Hours)

Physical and Descriptive Harbor Characteristics. These data inputs include the specific network of HSC such as the node location and type, reach length, width, and depth, in addition to tide and current stations. This also includes information about the docks in the harbor such as length and the maximum number of vessels the dock can accommodate at any given time.

General Information. General information used as inputs to the model include: specific vessel and commodity classes, route groups, specifications of turning area usage at each dock, and specifications of anchorage use within the harbor. Distances between the route groups were developed by evaluating the trade routes calling on HSC. Those routes were separated into trade lanes based on their world region and itinerary. The route group distance included in the analysis for each trade lane is calculated from the average distance for each trade route that was identified for the specific trade lane, as shown in **Table 4-1**. This data was taken from container services calling Port Houston as of May 2016. Distances were calculated using the VESON Nautical Distance Tool (https://veslink.com/distances/default.aspx). Values are in nautical miles.

Table 4-1: Route Group Information

Route Type	Region	Total Sea Distance		
		Min	Most Likely	Max
Bulk Cargo	Canada	4,586	6,243	11,688
	Caribbean, Central America, and Mexico	1,562	3,449	13,220
	East Asia	17,894	19,394	22,274
	East Coast South America	6,778	9,686	12,976
	Mediterranean	7,572	10,503	13,572
	Middle East	11,674	16,733	22,666
	Northern Europe	1,752	10,221	18,630
	South Africa	14,276	16,510	19,482
	Southeast Asia	12,414	21,615	23,850
	West Coast Africa	9,134	12,105	13,672
	West Coast South America	3,308	7,438	13,088

Route Type	Region	Total Sea Distance		
		Min	Most Likely	Max
Containerized Cargo	Far East - North America (via Panama Canal)	21,526	22,828	23,366
	Far East - North America (via Suez Canal)	22,494	22,509	22,832
	Mediterranean - North America	12,711	12,841	13,139
	Northern Europe - North America	10,963	11,500	12,311
	East Coast South America - North America	12,000	13,430	14,909
	Caribbean - Central America - North Coast South America	1,182	5,053	7,194

Vessel Speeds. Table 4-2 presents the average vessel speed by reach group for all vessels. These speeds in reach are an average of all vessel classes based on pilot input and AIS data.

Table 4-2: Vessel Speed by Reach (knots)

Reach Group	Min	Max
Bolivar Roads to Redfish Island	8	15
Redfish Island to Bayport Ship Channel	8	15
Bayport Ship Channel Reaches	3	5
Bayport Ship Channel to Morgan's Point	5	8
Barbours Cut	3	3
Morgan's Point to Buffalo Bayou	6	8
Buffalo Bayou to Boggy Bayou	3	6
Boggy Bayou to Sims Bayou	3	6
Sims Bayou to I-610 Bridge	3	6
I610 Bridge to Turning Basin	3	6

Vessel Operations. Hourly operating costs while in-port and at-sea were determined for all vessels. These are based on the most recent vessel operating costs developed by the Institute for Water Resources (IWR). These operating costs are proprietary to the USACE and can be provided upon request. The IWR data also includes inputs for at-sea speed by vessel class. These values are entered as a triangular distribution and presented in **Table 4-3**.

Table 4-3: Vessel Operations

Vessel Type	Class	At-Sea Speed		
		Min	Most Likely	Max
Containership	SPX	16	18	19
	PX	19	20	20
	PPX I	21	22	22
	PPX II	20	21	21
	PPX III	20	21	21

Vessel Type	Class	At-Sea Speed		
		Min	Most Likely	Max
	PPX IV	19	21	24
Tanker	10k-30k DWT	12	13	15
	30k-55k DWT	12	13	15
	55k-75k DWT	12	13	15
	75k-100k DWT	12	13	15
	100k-130k DWT	12	14	15
	130k-157.5k DWT	12	14	15
	157.5k-215k DWT	12	14	15
	215k-282.5k DWT	13	14	15
	282.5k-310k DWT	13	14	15
	310k-320k DWT	13	14	15
Bulker	7.5k-30k DWT	11	12	13
	30k-45k DWT	11	13	14
	45k-70k DWT	12	13	14
	70k-110k DWT	12	13	14
	110k-135k DWT	12	13	14
	135k-162.5k DWT	11	13	14
	162.5k-187.5k DWT	12	13	14
	187.5k-225k DWT	12	13	14
	225k-282.5k DWT	12	13	15
	282.5k-315k DWT	12	13	14
LPG Tanker	2.5k-13.5k	12	13	15
	13.5k-33.5k DWT	13	14	15
	33.5k-49.2k DWT	13	15	16
	49.2k-64.2k DWT	14	15	17
General Cargo	5.5k-12.5k DWT	11	12	14
	12.5k-15k DWT	12	13	14
	15.5k-18k DWT	12	13	14
	18k-22k DWT	12	14	15
	22k-27k DWT	13	14	16
	27k-30k DWT	12	13	15
RORO	3.65k-9.15k DWT	14	16	17
	9.15k-15.9k DWT	16	17	19
	15.9k-20.9k DWT	16	18	20
Chemical Tanker	4.5-13.5k DWT	11	12	13
	13.5k-21.5k DWT	11	12	14
	21.5k-29k DWT	12	13	15
	29-33k DWT	12	13	15

Reach Transit Rules. Vessel transit rules for each reach reflect restrictions on meeting, daylight restrictions, vessel size limitations, under-keel clearance requirements, and other pilot working rules in particular segments of HSC are used to simulate actual conditions in the reaches. Alleviating pilot rules associated with meeting restriction and daylight transit rules was evaluated by this study. **Table 4-4** summarizes the rules and anticipated changes given channel modifications in the Bay Reaches. Additional transit rules were applied to the model throughout the system; however, they were not expected to change in the future with-project condition.

Table 4-4: Potential Changes to Pilot Rules with Widening Measures

Current Working Rules and Practices (530-foot Channel)	Anticipated Change to Working Rules and Practices in the Widened Section (650-foot to 820-foot Channel)
Two widebodies meeting in the HSC between buoy 18 and beacons 75/76 shall be restricted to a combined beam of 310 ft and shall be limited to a combined draft of 85 ft	No combined beam restriction and no combined draft restriction in the widened portion of the channel
Any widebody tanker proceeding with cargo will be daylight restricted above buoy 18	The widened channel extends the transit window for widebody tankers with cargo.
Any widebody vessel over 150 ft in beam and/or over 900 ft in LOA will be daylight restricted above buoy 18 at all times	No beam or LOA daylight restriction for the widened portion of the channel.
Two widebodies meeting in the HSC between beacons 75/76 and Boggy Bayou shall be restricted to a combined beam of 272 ft. and shall be limited to a combined draft of 77 ft.	No combined beam restriction and no combined draft restriction for only the widened portion of the Channel.
Containerships with dimensions equal to or greater than 1150 LOA × 141 beam will not be met by any vessel in the HSC	Containerships with dimensions equal to or greater than 1150 LOA x 141 beam will meet vessels in the widened portion of the channel.
Loaded Suezmax tankers will not meet any vessel with a beam above 106	Loaded Suezmax tankers will meet vessels in the widened portion of the channel.
Loaded Aframax tankers (approximately 135 × 850) will not meet a larger, loaded vessel	Loaded Aframax tankers will meet larger vessels in the widened portion of the channel.
Containerships and large tankers (Aframax and larger) transit 1–2 knots slower in a 530-foot channel.	The larger tankers and containerships could transit the widened portion of the bay 1–2 knots faster.

Vessels Calls. The vessel call lists are made up of forecasted vessel calls for a given year as generated by the CLT (see **Section 4.1.4**) and BLT (see **Section 4.1.5**). Each vessel call list contains the following information: arrival date, arrival time, vessel name, entry point, exit point, arrival draft, import/export, dock name, dock order, commodity, units, origin/destination, vessel type, Lloyds Registry, net registered tons, gross registered tons, dead weight tons, capacity, length overall, beam, draft, flag, tons per inch immersion factor, ETTC, and the route group for which it belongs.

4.1.4 Containerized Vessel Call List

The forecasted commodities for HSC were allocated to the future fleet using the CLT. The CLT module produces a containership-only future vessel call list based on user inputs describing commodity forecasts at docks and the available fleet. The module is designed to process in two unique steps to generate a shipment list for use in HarborSym. First, a synthetic fleet of vessels is generated that can service the port. This fleet includes the maximum possible vessel calls based on the user provided availability information. Second, the commodity forecast demand is allocated to individual vessels from the generated fleet, creating a vessel call and fulfilling an available call from the synthetic fleet.

In order to successfully utilize this tool on a planning study, users provide extensive data describing containership loading patterns and services frequenting the study port. The user provides a vessel fleet forecast by vessel class, season, and service, and a commodity forecast by dock, season, and region. The following sections discuss the CLT loading behavior algorithm and the CLT data inputs for the HSC study.

4.1.4.1 CLT Loading Algorithm

The CLT generates a vessel call list by first generating a synthetic vessel fleet based on user inputs. Each vessel in the fleet is randomly assigned physical characteristics based on parameters provided by the user.

To begin, tentative arrival draft is determined for each generated vessel based on user-provided cumulative distribution functions (CDFs). A random draw is made from that CDF and the arrival draft is initially set to that value. The maximum allowable arrival draft is then determined as the minimum of:

1. Prior port limiting depth
2. Design draft
3. Limiting depth at the dock + underkeel clearance + sinkage adjustment + tidal availability + sea level change

The tentative arrival draft is then compared to the maximum allowable arrival draft, and set to the lesser value, that is, either the statistically estimated value or the constrained value.

Next, the CLT conducts an LFA given the physical characteristics of each generated vessel. LFA explores the relationships between a ships physical attributes, considerations for operations and attributes of the trade route cargo to evaluate the operating efficiencies of vessel classes at alternative sailing drafts. Several intermediate calculations are required. The following variables are used by the LFA algorithm but are calculated from the inputs.

- Vessel operating cost per 1000 miles is calculated as 1000 miles divided by the applied speed times the hourly at sea cost = 1000 miles / (Applied Speed X Hourly Cost)
- The allocation of vessel space to vacant slots, empty and loaded containers is calculated by adding the cargo weight per box plus the box weight plus an allowance for the empty
- Total weight per loaded container =
- Average Lading Weight per Loaded TEU by Route (tonnes)
- + Average Container (Box only) Weight per TEU (tonnes)
- + (Average Container (Box only) Weight per TEU (tonnes)*(Percent Empty TEUs))
- Shares of vessel capacity are then calculated as:
- Cargo Share = Average Lading Weight per Loaded TEU by Route (tonnes)
- Total weight per loaded container in tonnes
- Laden Container Share = Average Container (Box only) Weight per TEU (tonnes)
- Total weight per loaded container in tonnes
- Empty Container Share = ((Average Container (Box only) Weight per TEU (tonnes))*(Percent Empty TEUs)) Total weight per loaded container in tonnes)
- Volume capacity limits are calculated as follows:
- Number of vacant slots = Nominal TEU Rating * Percent vacant slots
- Max Occupied Slots = Nominal TEU Rating - Number of vacant slots
- Max Laden TEUs = Occupied Slots/(1+Percent Empties)
- Max Empty TEUs = Occupied Slots - Laden TEUs
- Maximum Volume Restricted Tonnage is then calculated as:
- Max weight for cargo (tonnes) = Max Laden TEUs * Average Lading Weight per Loaded TEU by Route (tonnes)
- Max weight for laden boxes (tonnes) = Max Laden TEUs * Average Container (Box only) Weight per TEU (tonnes)
- Max weight for empties(tonnes) = Max Empty TEUs * Average Container (Box only) Weight per TEU (tonnes)
- Total volume restricted tonnage (cubed out tonnage)(tonnes) = Max weight for cargo + Max weight for laden boxes + Max weight for empties

The LFA proceeds as follows:

- The initial draft is varied from the vessels maximum (loaded) to minimum (empty). At each sailing draft the total tonnage that can be carried is calculated using the Tons Per Inch Immersion (TPI) rating for the vessel.
- DWT Available for Vessel Draft = DWT Rating (tonnes) – [(Aggregate Maximum Summer Load Line Draft – Sailing Draft)*12 inches*TPI]
- This capacity is then allocated, first to ballast and operations to yield capacity available for cargo.
- Approximate Variable Ballast = DWT Available for Vessel Draft * Percent Assumption for Variable Ballast
- Allowance for Operations in tonnes = DWT Rating (tonnes) * Percent Allowance for Operations
- Available for Cargo = (DWT Available for Vessel Draft)- (Approximate Variable Ballast) - (Allowance for Operations)
- The capacity available for cargo is restricted if the vessel has “cubed” or “volumed” out:
- Available for Cargo adjusted for volume restriction if any (tonnes) = the lesser of Available for Cargo and Total volume restricted tonnage (cubed out tonnage)
- The tonnage available for cargo is then allocated to cargo, laden and empty containers based on the shares of vessel capacity:
- Distribution of Space Available for Cargo (tonnes) = Available for Cargo adjusted for volume restriction if any in tonnes * Cargo Share in percent
- Distribution of Space Available for Laden TEUs (tones) = Available for Cargo adjusted for volume restriction if any in tonnes * Laden Container Share in percent
- Distribution of Space Available for Empty TEUs (tonnes) = Available for Cargo adjusted for volume restriction if any * Empty Container Share
- The number of TEUs is then estimated for each share use:
- Number of Laden TEUs = Distribution of Space Available for Cargo/Average Lading Weight per Loaded TEU by Route (tonnes)
- Number Empty TEUs = Distribution of Space Available for Empty TEUs /Average Container (Box only) Weight per TEU (tonnes)
- Occupied TEU Slots on Vessel = Number of Laden TEUs + Number Empty TEUs
- Vacant Slots = Nominal TEU Rating − Occupied TEU Slots

- The CLT then calculates the ETTC (estimate of total trip cargo) for each vessel call as the cargo on board the vessel at arrival plus the cargo on board the vessel at departure, in tons.

The CLT works to load each vessel available to carry the commodity on the given route until the forecast is satisfied or the available fleet is exhausted.

4.1.4.2 CLT Data Inputs for Houston Ship Channel

There are a number of data required by the CLT. The commodity forecast can be found in Section 3.2 and the vessel fleet can be found in Section 3.3. Vessel sailing draft distributions are critical for determining the benefits of both the meeting area and tide delay analyses due to channel depth and under keel requirements, as well as determining how much cargo a vessel can carry and thus how many trips are required to satisfy a commodity forecast.

Figure 4-4 through **Figure 4-8** provide the arrival draft CDFs for containerized vessels by channel depth. The CDFs were developed by evaluating the arrival drafts of the vessels by container class calling on the harbor from 2011 to 2015 using Houston Pilot arrival draft data. Each call was separated into a container vessel class depending on the vessel characteristics of each call. A probability curve for the arrival draft of the vessels for future project conditions was developed using this information. The arrival draft curves were developed with the assistance of the IWR. The assumption was made that for each additional foot of channel depth available to carriers the average Post-Panamax container vessel would use approximately 0.6 to 0.8 feet of that depth. Therefore, for the analysis, it was assumed that each Post-Panamax container vessel would sail with an additional 0.7 feet for each one-foot increment of channel depth evaluated. The restriction placed on this assumption is that once a vessel class reaches its design draft on the curve the class no longer shifts regardless of the channel depth. This assumption explains **Figure 4-4,** which is the SPX arrival draft by channel depth. Regardless of channel depth, the SPX vessel arrival draft curve does not shift. It was also assumed only vessels constrained by the existing channel depth would take advantage of additional depth.

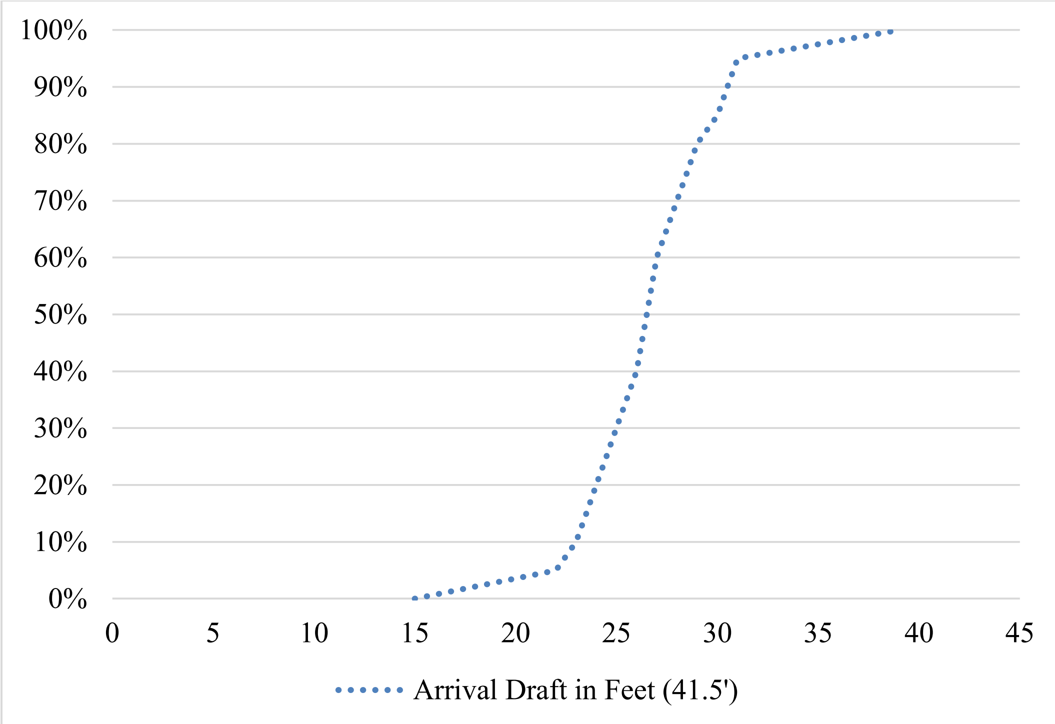


Figure 4-4: SPX Arrival Draft by Channel Depth

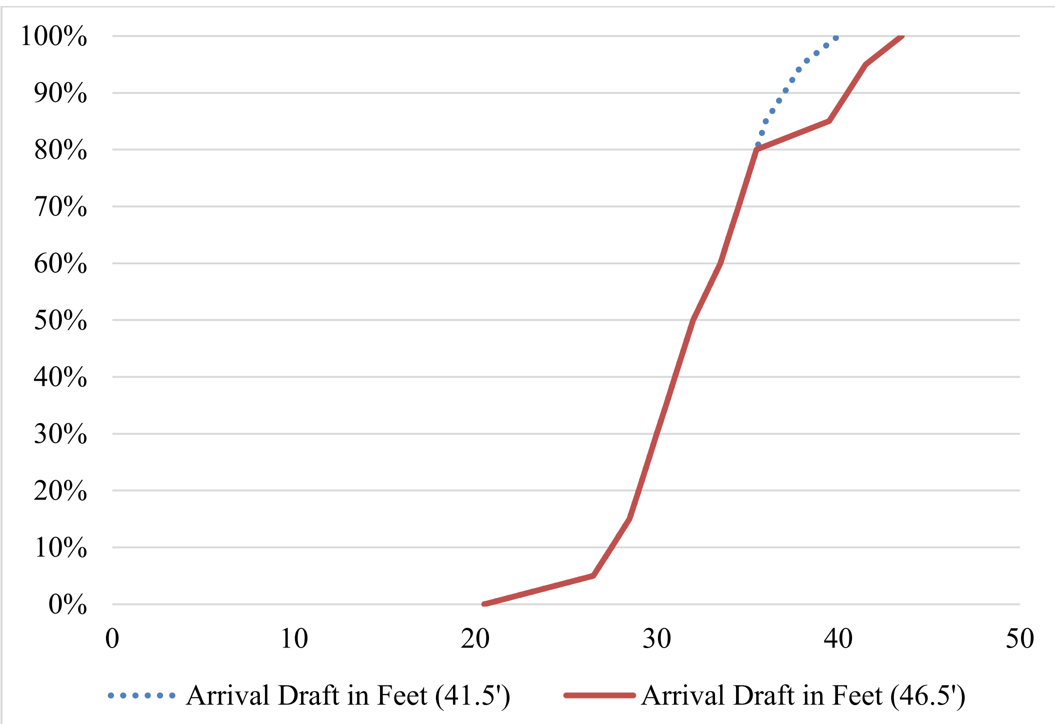


Figure 4-5: PX Arrival Draft by Channel Depth

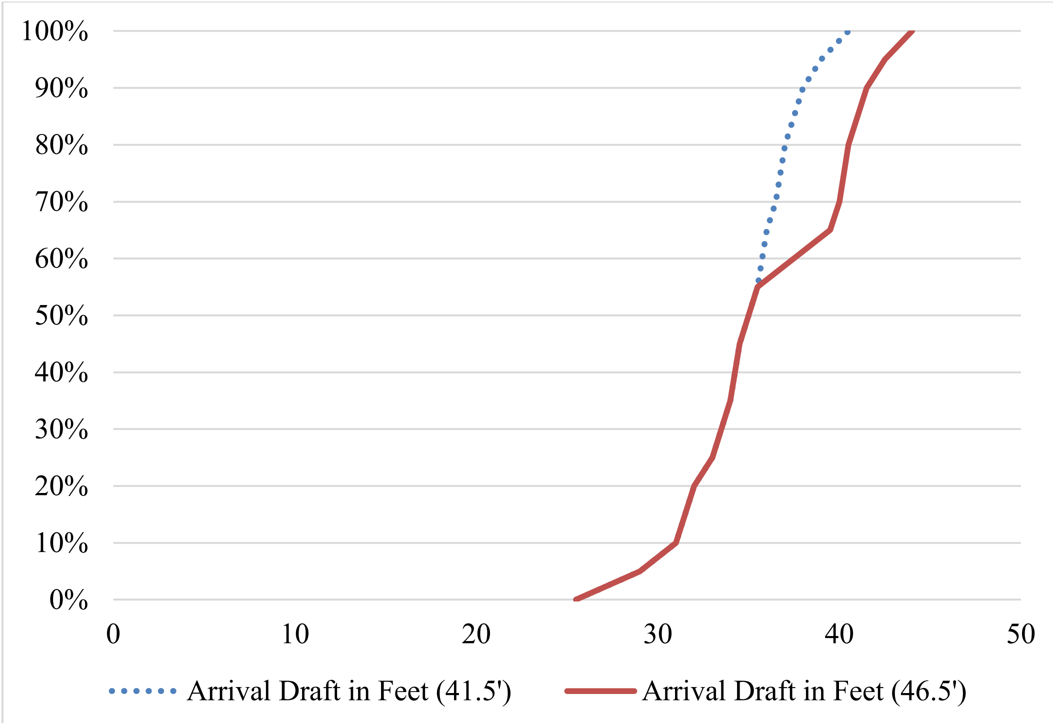


Figure 4-6: PPX I Arrival Draft by Channel Depth

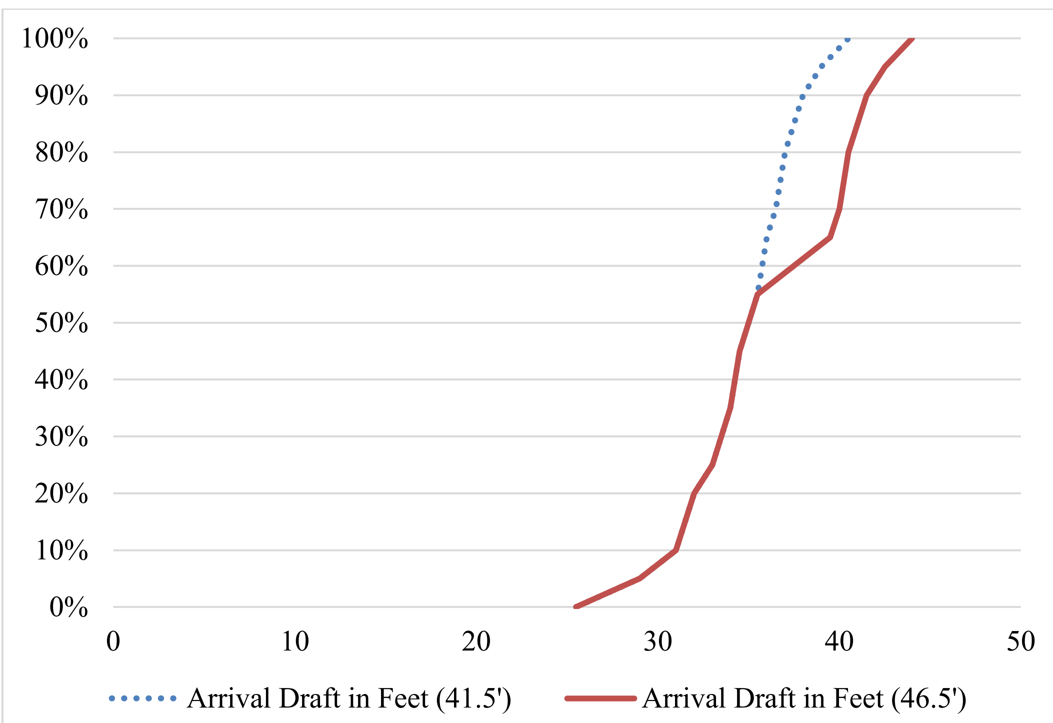


Figure 4-7: PPX II Arrival Draft by Channel Depth

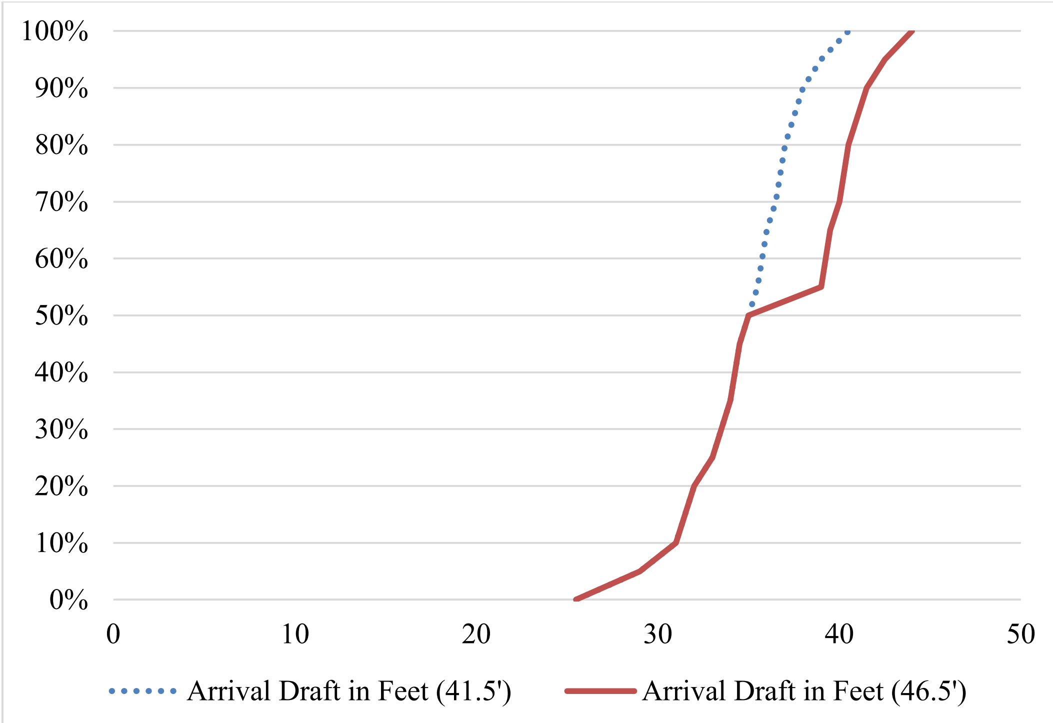


Figure 4-8: PPX III Arrival Draft by Channel Depth

Table 4-5 provides the vessel class assumptions used in the LFA, such as average lading weight per TEU in metric tons (see Section 2.5.3), container (tare) weight, empty TEU allotment, vacant slot allotment, variable ballast, import/export fraction (cargo share), etc. These inputs were developed using historical data provided by the Port and with the assistance of IWR (Lading Weight per Loaded TEU, Empty TEU and Vacant Slot allotment, Operations Allowance (Ops.), and Variable Ballast by trade lane). The import/export fractions were calculated by evaluating the tonnage (both imports and exports) handled at HSC for each individual call and the estimated total tonnage on each vessel (PIERS data), taking into account the vessel characteristics (LOA, beam, design draft, design hull, etc.) and sailing draft when calling on the harbor, by vessel class (Houston Pilots data).

Table 4-5: Vessel Class Modeling Assumptions

Service	Vessel Class	Avg. Lading Weight Per TEU	Avg. Tare Weight Per TEU	Empty TEU	Vacant Slot	Ops. (% DWT)	Ballast (% DWT)	Import Fraction	Export Fraction
FE-NA-PAN	SPX	8.72	2	24%	7.7%	6.7%	11%	40%	31%
	PX	8.72	2	24%	7.7%	6.7%	11%	40%	31%
	PPXI	8.72	2	24%	7.7%	6.7%	11%	40%	31%
	PPXII	8.72	2	24%	7.7%	6.7%	11%	40%	31%
	PPXIII	8.72	2	24%	7.7%	6.7%	11%	40%	31%
	SPX	9.79	2	9%	4.7%	6.7%	11%	65%	85%

Service	Vessel Class	Avg. Lading Weight Per TEU	Avg. Tare Weight Per TEU	Empty TEU	Vacant Slot	Ops. (% DWT)	Ballast (% DWT)	Import Fraction	Export Fraction
FE-NA-SUEZ	PX	9.79	2	9%	4.7%	6.7%	11%	65%	85%
	PPXI	9.79	2	9%	4.7%	6.7%	11%	65%	85%
	PPXII	9.79	2	9%	4.7%	6.7%	11%	65%	85%
	PPXIII	9.79	2	9%	4.7%	6.7%	11%	65%	85%
MED-NA	SPX	9.24	2	14%	4.7%	6.7%	11%	22%	23%
	PX	9.24	2	14%	4.7%	6.7%	11%	22%	23%
	PPXI	9.24	2	14%	4.7%	6.7%	11%	29%	40%
	PPXII	9.24	2	14%	4.7%	6.7%	11%	29%	40%
	PPXIII	9.24	2	14%	4.7%	6.7%	11%	29%	40%
NEU-NA	SPX	9.27	2	10%	4.7%	6.7%	11%	28%	28%
	PX	9.27	2	10%	4.7%	6.7%	11%	28%	28%
	PPXI	9.27	2	10%	4.7%	6.7%	11%	27%	27%
	PPXII	9.27	2	10%	4.7%	6.7%	11%	34%	33%
	PPXIII	9.27	2	10%	4.7%	6.7%	11%	34%	33%
ECSA-NA	SPX	12.01	2	24%	6.2%	6.7%	11%	95%	100%
	PX	12.01	2	24%	6.2%	6.7%	11%	20%	39%
	PPXI	12.01	2	24%	6.2%	6.7%	11%	20%	18%
	PPXII	12.01	2	24%	6.2%	6.7%	11%	20%	18%
	PPXIII	12.01	2	24%	6.2%	6.7%	11%	20%	18%
CAR-CA-NCSA	SPX	10.89	2	21%	7.7%	6.7%	11%	17%	26%
	PX	10.89	2	21%	7.7%	6.7%	11%	8%	26%
	PPXI	10.89	2	21%	7.7%	6.7%	11%	8%	26%

Table 4-6 provides details on the vessel subclasses, which is used by the CLT to create vessels to satisfy the commodity forecast. The user provides the linkage between the HarborSym vessel class and the IWR-defined vessel subclass. The percentage share of each subclass was defined by historical data provided by the port.

Table 4-6: Containerized Vessel Subclass Modeling Assumptions

Vessel Class	LOA	Beam	Max SLLD	Capacity (DWT)	TEU Rating	TPI Factor	Sink-age	Percentage of Class
SPX	466	72	26.23	11,726	907	59.2	0.7	10
SPX	499	79	28.93	14,924	1,090	68.8	0.8	10
SPX	534	84	30.35	18,438	1,388	78.5	0.8	10
SPX	570	84	31.28	20,643	1,447	87.1	0.8	10
SPX	576	87	32.49	22,184	1,529	87.2	0.9	10
SPX	585	89	33.46	24,283	1,618	93.6	0.9	5
SPX	596	91	34.57	24,812	1,778	96.3	0.9	15
SPX	603	91	35.56	25,370	1,895	97.1	0.9	10

Vessel Class	LOA	Beam	Max SLLD	Capacity (DWT)	TEU Rating	TPI Factor	Sink-age	Percentage of Class
SPX	657	97	36.21	31,139	2,268	113.8	1	10
SPX	675	98	37.58	33,887	2,470	117.7	1	10
PX	776	103	38.46	42,183	3,084	146	1	10
PX	765	104	39.41	43,311	3,188	142.8	1	10
PX	794	105	40.34	44,991	3,389	150.2	1.1	10
PX	845	105	41.22	50,070	3,841	162.7	1.1	10
PX	906	105	42.53	56,792	4,125	176.7	1.1	20
PX	887	105	43.41	54,885	3,993	170.4	1.2	20
PX	959	105	44.39	64,956	4,729	192.7	1.2	20
PPXI	1013	123	39.37	74,070	5,918	240.9	1	10
PPXI	928	130	41.44	75,623	5,534	214.7	1.1	10
PPXI	972	131	42.81	77,149	4,858	219	1.1	10
PPXI	899	131	44.36	78,284	4,912	208	1.2	10
PPXI	934	131	46.01	78,618	5,793	215.1	1.2	10
PPXI	949	131	46.02	79,891	6,050	221.6	1.2	10
PPXI	953	131	46.05	80,651	6,186	222.3	1.2	5
PPXI	964	131	46.07	80,504	6,295	225.4	1.2	5
PPXI	974	131	46.09	81,237	6,387	228.7	1.2	5
PPXI	981	131	46.1	110,448	6,441	230.7	1.2	5
PPXI	984	131	46.13	75,898	6,505	230.9	1.2	5
PPXI	988	131	46.17	86,060	6,549	233.1	1.2	5
PPXI	991	131	46.23	102,179	6,600	233.7	1.2	5
PPXI	991	131	46.34	102,871	6,662	233.5	1.2	3
PPXI	969	131	47.6	103,817	6,329	229.4	1.3	2
PPXII	1101	135	42.65	104,549	9,148	290.3	1.1	10
PPXII	984	135	44.29	104,104	6,332	244.6	1.2	10
PPXII	1017	135	46.13	103,865	7,200	260.3	1.2	10
PPXII	1089	135	47.61	104,657	8,212	284.9	1.3	10
PPXII	1099	135	47.63	105,458	8,528	289.2	1.3	5
PPXII	1106	135	47.64	106,737	8,670	291.5	1.3	5
PPXII	1108	135	47.65	108,348	8,787	292	1.3	5
PPXII	1112	135	47.67	92,498	8,874	292.6	1.3	5
PPXII	1114	135	47.66	92,875	8,916	293.5	1.3	5
PPXII	1117	135	47.66	93,905	9,018	295.3	1.3	5
PPXII	1122	135	47.67	95,169	9,145	297.7	1.3	10
PPXII	1127	135	47.66	96,687	9,294	300.3	1.3	10
PPXII	1138	135	47.6	98,893	9,513	303.4	1.3	10
PPXIII	1200	140	49	118,908	10,100	315	1.3	45
PPXIII	1100	158	49	115,700	10,888	315	1.3	45
PPXIII	1200	158	51.18	162,867	13,798	423	1.4	10

The below vessel call list shown in **Table 4-7** represent benefits from a shift from the FWOP vessel (PPX II) to a larger, more efficient PPX III vessel. The reduction in OD costs are associated with the reduction in number of PPX II calls caused by use of the PPX III.

Table 4-7: Containerized Vessel Calls

Year	Vessel Class	FWOP	Bayport Improvement	Barbours Improvement	Bayport & Barbours Improvement (Measures for Design Vessel Transit)
2029	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2034	SPX	353	353	353	353
	PX	674	674	674	674
	PPX I	374	374	374	374
	PPX II	260	175	188	103
	PPX III	-	76	63	139
2039	SPX	433	433	433	433
	PX	718	718	718	718
	PPX I	493	493	493	493
	PPX II	364	238	263	137
	PPX III	-	111	90	201
2044	SPX	440	440	440	440
	PX	508	508	508	508
	PPX I	535	535	535	535
	PPX II	598	358	473	234
	PPX III	-	213	110	323

4.1.4.3 Houston Share of World Fleet

The previous tables provided the number of vessel calls by route group and vessel class for Port Houston from 2029, 2034, 2039, and 2044. The estimated number of vessels required to transport the forecast cargo is shown in the following tables. The number of vessels is approximated and was derived by assuming an average string of vessels is made up of eight vessels calling weekly. The equivalent vessel numbers are a result of dividing the number of vessel calls in the previous tables by 52 weeks and multiplying by 6.14 vessels per service. While some services have fewer than eight vessels and some have more, depending on the frequency of service and the trade route distance, six vessels is a general average. The percent of world fleet values is derived by simply dividing the equivalent number of vessels in a given year by the number of vessels in the respective classes by the historical and projected world fleet.

The purpose of this analysis and presentation is to serve as a cross check on the reasonableness of the projected number of vessel calls by comparing them to the historical and future world fleet. As shown in **Table 4-8**, the historical share of the world fleet of SPX vessels calling HSC has fallen since 2011 showing a modest transition to larger vessels. **Table 4-9** presents the estimated future percent of the world fleet calling HSC. As shown, it is estimated Houston's share of Post-Panamax vessel will grow through the study period given market shifts and the impact of the Panama Canal Expansion. HSC's share of the total world fleet remains consistent throughout the project alternatives.

Table 4-8: Historical Share of World Containership Fleet

HSC % World Fleet	2011		2012		2013		2014	
	Vessels	% World Fleet	Vessels	% World Fleet	Vessels	% World Fleet	Vessels	% World Fleet
SPX	395	2%	329	2%	278	1%	291	1%
PX	568	4%	560	4%	534	4%	538	4%
PPX I	87	2%	123	3%	150	3%	183	4%
PPX II	6	0%	3	0%	2	0%	2	0%
Total	**1,056**	**2%**	**1,015**	**2%**	**964**	**2%**	**1,014**	**2%**

Table 4-9: Estimated Future Percent of World Fleet Calling HSC

Alternative	2029		2034	
	Vessels	% World Fleet	Vessels	% World Fleet
Without Project				
SPX	42	2%	42	2%
PX	72	5%	80	6%
PPX I	36	3%	44	3%
PPX II	18	5%	31	9%
PPX III	0	0%	0	0%
Total	126	2%	154	2%
Bayport Improvement				
SPX	42	2%	42	2%
PX	72	5%	80	6%
PPX I	36	3%	44	3%
PPX II	12	4%	21	6%
PPX III	5	1%	9	1%
Total	125	2%	153	2%
Barbours Improvement				
SPX	42	2%	42	2%
PX	72	5%	80	6%
PPX I	36	3%	44	3%
PPX II	13	4%	22	6%
PPX III	4	1%	7	1%
Total	125	2%	153	2%

Alternative	2029		2034	
	Vessels	% World Fleet	Vessels	% World Fleet
Barbours Cut and Bayport Improvement				
SPX	42	2%	42	2%
PX	72	5%	80	6%
PPX I	36	3%	44	3%
PPX II	7	2%	12	4%
PPX III	9	1%	16	2%
Total	**125**	**2%**	**153**	**2%**

The conclusion of the cross check confirms that the projected vessel calls for the HSC do not result in an excessive amount of the total world fleet in the without or with project conditions, and supports the reasonableness of the results.

4.1.5 Non-Containerized Vessel Call List

The non-containerized vessel call list for future years was developed using the BLT, a tool within the HMST. Users must provide data to specify the framework for generating the synthetic vessel call list. The BLT relies on much of the information and data from HarborSym, but has data additional specific requirements. Within the BLT, the input requirements include:

- Commodity forecasts (annual import/export) at each dock
- Description of the available fleet by vessel class, including:
    - Statistical data describing the cumulative distribution function for deadweight tons of vessels within the class
    - Regression information for deriving length overall (LOA), beam and design draft from capacity
    - Regression information for calculating TPI based on beam, design draft, capacity and LOA
    - The number of potential calls that can be made annually by each vessel class
- Logical constraints describing:
    - Commodities that can be carried by each vessel class
    - Vessel classes that can be serviced at each dock
    - Parameters, defined at the vessel class/commodity level for determination of how individual calls and commodity transfers are generated, such as commodity loading factors, allocation priorities, and commodity flow direction (import or export calls)

Procedures exist, using the Extreme Optimization package and some Access routines, to populate much of the required forecast information based on an examination of an existing vessel call list created from historical data. Statistical measures, commodity transfer amounts, and logical constraints can all be derived from an examination of a set of historical calls that have been stored in a HarborSym database. The system populator function facilitates data entry by providing a basis for the forecasts, which the user can edit as necessary.

4.1.5.1 BLT Loading Algorithm

With the user provided input requirements, the BLT creates and loads a synthetic fleet according to the following steps:

1. Generation of a fleet of specific vessels based upon a known number of vessel calls by class and a statistical description of the characteristics of the vessel class. This process begins by generating one specific vessel for each call in the class. The capacity of the vessel is set by a random draw from the cumulative density function that is stored for the class. Based on the regression coefficients that are stored for the class, each of which is of the form:
   - Log (parameter) = a + b*log (Capacity)
   - LOA, Beam and Design Draft are determined for the vessel using a linear regression of the form:
     - TPI = a + b*Beam + c*Design Draft + d*Capacity + e*LOA
   - The TPI is calculated based on the previously generated physical characteristics and coefficients stored, at the class level, for this regression model. This process is repeated until a unique vessel is created for each available call in the forecast. If no TPI is generated, the default TPI specified by the user for the vessel class is assigned.
2. Attempt to assign a portion of the commodity forecast at a dock to a vessel. Each commodity forecast at a dock is processed in turn. If a vessel is available that can serve the commodity at the dock, it is loaded for either export only, import only, or both export and import. Potential vessels that can carry the forecast are assigned in a user-specified (at the class level) allocation order, so that the most economical vessel classes will always be used first. Under the current assumptions, a vessel call handles a single commodity at a single dock, i.e., each call consists of a single dock visit and a single commodity transfer (which may contain both an export quantity and an import quantity). The specification of the actual call assignment and commodity loading is dependent upon the maximum that a vessel can draft and still reach and leave the dock.
   - The amount of the commodity forecast that is actually carried on the vessel is used to decrement the remaining quantity to be allocated for that particular commodity forecast. After a single vessel call is assigned to a particular forecast, the total number of remaining available vessels for the class is decremented and the next commodity forecast in turn is processed. That is, each forecast attempts to have a portion of its

demand satisfied by a single vessel call and then the next forecast is processed. This is to prevent all of the most efficient vessels from being assigned to a single commodity forecast.

- This process proceeds, in a loop, continually attempting to assign commodity to a vessel from the remaining available fleet. Whenever a successful assignment is made, this generates a vessel call, dock visit, and the associated commodity transfer. This effort continues until no more assignments to a vessel call can be made, either because all commodity forecasts have been satisfied or there is no available vessel that can service the remaining quantities (because there is no vessel of the required class that can handle the particular commodity/dock combination of the forecast or because no vessel can be loaded to satisfy the dock controlling depth constraint).

3. At the end of the process, when no more assignments are possible, arrival times are assigned for each vessel. The algorithm used to assign arrival times assumes a uniform inter-arrival time for all calls within a class. After the allocation process is complete, the number of calls made by each class of vessel is known. This is used to calculate the inter-arrival time of vessels for that class. The arrival of the first vessel in the class is set randomly at a time between the start of the year and the calculated inter-arrival time, but all subsequent vessel arrivals for the class will have the identical inter-arrival time.
4. The generated vessel calls are written to a HarborSym vessel call database and the user is presented with output information on which commodity forecasts were satisfied, any remaining unsatisfied forecasts and detailed information on each vessel loading and the vessels that were used to satisfy each commodity forecast.

The intended approach is for the user to work iteratively within the BLT, making runs, examining the forecast satisfaction that is achieved and varying the fleet character and composition for subsequent runs, so that the final result is a balanced, reasonable projection of vessel calls to satisfy the input forecast demand. The BLT provides extensive output to assist the user in this regard.

Once a vessel is determined to be available for loading for a particular forecast, the BLT must determine the type of loading, the quantity loaded, and the arrival draft of the vessel. The user can control certain aspects of the process through data specification, in particular the type of call (import, export or both) and the percent of capacity that is loaded for import and export, as described below.

Any given vessel call can attempt to satisfy an import demand (arrive with cargo for the port, leave empty), an export demand (arrive empty, leave with cargo loaded at the port) or simultaneously an import and export demand (that is, arriving with cargo to unload at the port [import], and then departing with cargo bound for another port [export]), based on the user defined directional movement assigned to the vessel class. Four possibilities are defined for this behavior, with specification at the Vessel Class/Commodity Category level:

- Export Only
- Import Only
- Random
- Both Export and Import

Certain combinations of class and commodity categories might be exclusively import only or export only. A "Random" assignment designates that calls from the class/commodity combination can be either import or export at a dock, but not both simultaneously. If a "Random" type is assigned, then the ratio of calls that will be randomly generated as import is specified.

The quantity of a vessel's capacity that is to be loaded for satisfaction of the import and export demands is described, again at the Vessel Class/Commodity Category level, by a triangular distribution that specifies a loading factor. A minimum, most likely, and maximum, in percent of total available capacity, is defined for both export and import.

When a vessel is available for satisfying a demand, first the type of satisfaction (import only, export only, random or both) is determined, as noted above. If "random" is associated with the current class/commodity, then a random draw is made from a uniform distribution and compared with the user-specified import ratio, to determine if the call is import only or export only. For example, if the user has entered a value of 70 percent for imports, indicating that 30 percent of the calls are exports, then a random draw is made from a uniform (0.1) distribution. If the random number is less than or equal to 0.7, then the call is assigned as an import, otherwise it is assigned as export.

Once the type of call is determined, the BLT must next ascertain how much capacity can be loaded on the vessel while satisfying the draft constraints. The process is similar for both export and import. First, a draw is made from the respective triangular distribution to get a percentage loading factor. This is then applied to the vessel DWT, adjusted to reduce the available tonnage based on allowance for operations, to get a tentative quantity to be loaded. The import/export capacity to be loaded is adjusted only if the available loading capacity is less than the initial calculation.

The tonnage associated with allowance for operations is based on IWR-developed data given fractional allowance for operations as a function of vessel tonnage (DWT), see **Figure 4-9**. The additional draft implied by the tentative quantity to be loaded is calculated based on the vessel TPI. A value of empty vessel draft for each vessel has previously been calculated, based on an assumption that the vessel DWT is associated with the vessel design draft. The empty vessel draft from which loading can start is then calculated as: Empty Vessel Draft = Design Draft – (DWT/TPI)/12.0.

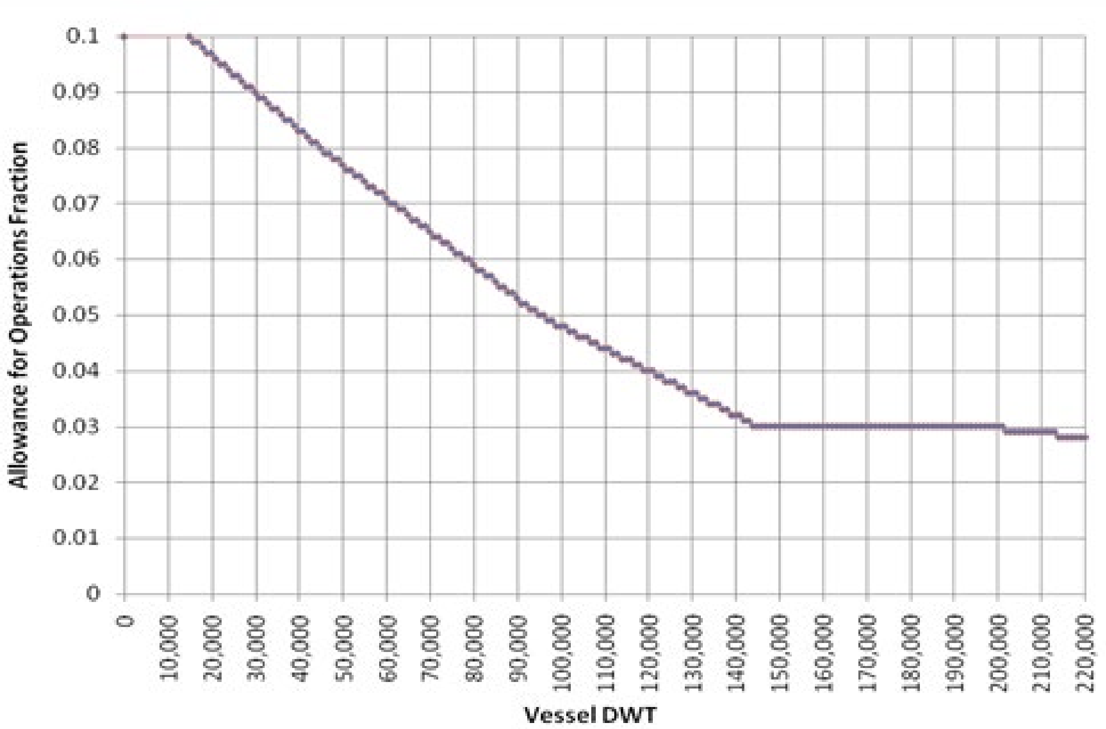


Figure 4-9: Allowance for Operations Given Vessel DWT

The total draft associated with the tentative loading is then calculated as the sum of four drafts:

> Total Draft (tentative loading) = Empty Vessel Draft + Additional Draft Associated with Tentative Loading + Additional Draft associated with Allowance for Operations + Underkeel Clearance

In order to test the ability of the vessel to arrive at or leave the dock, to this total draft associated with tentative loading must be added the required UKC (a function of the vessel class). This gives the "test draft" that is checked against the limiting depth to the dock. Note that this is not the same as the eventually calculated arrival draft of the vessel at the bar, which is written to the vessel call data base. If this test draft is greater than the limiting depth to the dock (as defined by user input), the quantity loaded must be reduced, so that the calculated draft is less than the limiting depth to the dock. This calculation is executed to determine if the tentative loading can be reduced sufficiently to meet the dock limiting depth. If so, then the vessel is loaded with the amount of commodity to reach the target draft. If it is not possible to assign a commodity quantity that, when loaded on the vessel, does not exceed the dock limiting depth, then the vessel cannot service the allocation.

Once the commodity allocation has been completed, the vessel loading is known and the arrival draft (at the bar) must be determined. A class level "minimum sailing draft" has been specified by the user at the vessel class level. This minimum sailing draft, or empty vessel draft, reflects the ballasted draft at which a light vessel will sail. If a vessel is handling an export only, then it is assumed to arrive light, at the empty vessel sailing draft. If a vessel is handling an import to the port, then it arrives at the draft associated with the import loading (which may have been reduced to the limiting depth at the dock). It is important to note that UKC is not included in the arrival draft that is stored in the vessel call database because it does not factor into the actual sailing draft, but, as noted above it is used in checking the constraint associated with the limiting depth to the dock. In practice, UKC is used in the BLT to handle the depth constraint, but is not incorporated in the actual sailing draft. UKC is then added back in as an additional constraint that is applied in HarborSym itself based on sailing rules. In this manner, the arrival draft is consistently calculated based on the sum of empty vessel draft, draft associated with loading, and draft associated with allowance for operations.

The BLT module writes all the needed fields to the vessel call database. Of note is how the ETTC field is handled. Within the BLT, ETTC is populated by simply adding together import tons and export tons, which assumes that all at-sea costs for a vessel call generated by the BLT are allocated to the subject port.

4.1.5.2 BLT Data Inputs

The bulk fleet was developed using historical calls from 2011-2014 (Houston Pilots Logs). **Table 4-10** summarizes total bulk only calls by vessel type and vessel class for the FWOP and FWP (based on Alternative 8). The study uses the total reductions in the vessel calls to calculate benefits to measures that increase loading efficiency (such as deepening or channel expansion).

Table 4-10: Vessel Call Assumptions for Bulk Fleet

Vessel Type	Vessel Class	2029		2034		2039	
		FWOP	FWP	FWOP	FWP	FWOP	FWP
Tanker	10k-30k	9	9	10	10	-	-
Tanker	30k-55k	1,516	1,123	1,516	962	1,409	922
Tanker	55k-75k	360	360	413	413	447	447
Tanker	75k-100k	81	81	77	77	78	78
Tanker	100k-130k	571	571	579	579	572	572
Tanker	130k-157.5k	45	85	41	100	41	105
Tanker	157.5k-215k	53	80	49	93	65	100
Tanker	215k-282.5k	-	-	-	-	-	-
Tanker	282.5k-310k	-	-	-	-	-	-
Tanker	310k-320k	-	-	-	-	-	-
Bulker	7.5k-30k	129	129	121	121	141	141
Bulker	30k-45k	452	452	552	552	601	601
Bulker	45k-70k	715	715	779	779	845	845
Bulker	70k-110k	106	106	113	113	114	114
Bulker	110k-135k	7	7	7	7	7	7
LPG Tanker	2.5k-13.5k	219	219	122	122	190	190
LPG Tanker	13.5k-33.5k	198	198	210	210	225	225

Vessel Type	Vessel Class	2029		2034		2039	
		FWOP	FWP	FWOP	FWP	FWOP	FWP
LPG Tanker	33.5k-49.2k	21	21	16	16	17	17
LPG Tanker	49.2k-64.2k	285	285	302	302	289	289
General Cargo	5.5k-12.5k	806	806	941	941	1,203	1,203
General Cargo	12.5k-15k	248	248	316	316	328	328
General Cargo	15.5k-18k	168	168	184	184	208	208
General Cargo	18k-22k	202	202	225	225	238	238
General Cargo	22k-27k	177	177	186	186	187	187
General Cargo	27k-30k	199	199	213	213	235	235
RoRo Carrier	9.15k-15.9k	51	51	59	59	61	61
RoRo Carrier	15.9k-20.9k	93	93	110	110	130	130
Chemical Tanker	4.5k-13.5k	263	263	355	355	402	402
Chemical Tanker	13.5k-21.5k	526	526	562	562	574	574
Chemical Tanker	21.5-29k	143	143	140	140	141	141
Chemical Tanker	29k-33k	208	208	206	206	211	211
Total		**7,851**	**7,525**	**8,404**	**7,953**	**8,959**	**8,571**

4.1.6 Study Measures and Economic Evaluation Strategy

Section 3.4 provides an overview of the alternatives formulated for this study. The study proposed 13 standalone measures to address the planning objectives of this study composed of 38 separate structural measures. **Table 4-11** lists all measures that underwent economic evaluation for this study, including a brief description and identification of the alternative plans in which they are included.

Table 4-11: HSC ECIP Measures Grouping

Alternative	Measures Grouping	Description	Measures
1, 2, 8	Measures for Design Vessel Transit	Bend Easing, Shoaling Attenuation, Channel Widening, and Turning Basin improvement to allow containership design vessel to transit.	BE1_138+369_530
			BE1_128+731_530
			BE1_078+844_530
			BE1_028+605_530
			BE2_BSCFlare
			SA2_BSCFlare
			CW2_BSC_455
			CW3_BCC_455
			BETB3_BCCFlare_1800NS
1, 4, 5, 8	Bayou Deepening	Deepening in Segments 4, 5, and 6	CD4_Whole
			CD5_Whole + CD6_Whole
4, 8	Aframax Widening	Widening in Segment 4 to allow transit of Aframax tankers	CW4_BB-GB_530
2, 3, 8			CW1_BR-Redfish_900
			CW1_Redfish-BSC_900

Alternative	Measures Grouping	Description	Measures
	Bay Widening_900	Bay Widening to 900 feet to establish meeting areas between Bolivar Roads and Barbours Cut	CW1_BSC-BCC_900
			CW1_BR-Redfish_900 CW1_Redfish-BSC_900
			CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900
2, 3, 8	Bay Widening_820	Bay Widening to 820 feet to establish meeting areas between Bolivar Roads and Barbours Cut	CW1_BR-Redfish_820
			CW1_Redfish-BSC_820
			CW1_BSC-BCC_820
			CW1_BR-Redfish_820 CW1_Redfish-BSC_820
			CW1_BR-Redfish_820 CW1_Redfish-BSC_820 CW1_BSC-BCC_820
2, 3, 8	Bay Widening_650	Bay Widening to 650 feet to establish meeting areas between Bolivar Roads and Barbours Cut	CW1_BR-Redfish_650
			CW1_Redfish-BSC_650
			CW1_BSC-BCC_650
			CW1_BR-Redfish_650 CW1_Redfish-BSC_650
			CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650
3, 8	SJM-BB Widening	Widening channel from San Jacinto Monument to Boggy Bayou to 530 feet	CW1_SJM-BB_530
3, 8	Upper Bay BE_Suezmax	Bend Easing in the upper bay for Suezmax tankers	CW1_HOG_600
			BE1_153+06
			BE1_246+54
1, 2, 6, 8	Bay Mooring	Bay Mooring Facility	MM2_BSC_1800
1, 8	BSC TB	Bayport Ship Channel Turning Basin Improvement	TB2_BSCRORO_1800
7, 8	Bayou Mooring	Mooring Facility in the Bayou Reaches	MM1_AI(d)
			MM1_520+00*
4, 5, 8	Bayou TB	Turning Basin Improvements to allow turning of design vessels	TB4_775+00
			TB4_Hunting
5, 8	Brady Island TB	Turning Basin Improvement to accommodate design vessels and prevent channel congestion	TB6_Brady_900

The above measures can be grouped into two benefit streams: (1) origin-destination (OD) benefits and (2) transportation cost savings benefits. (1) OD benefits are the result of improved vessel loading capacity due to channel deepening or widening, which allows larger and/or more heavily loaded vessels to transit the channel. This has the potential to reduce the total number of calls required to transport the forecasted throughput tonnage at Houston Ship Channel. These benefits are primarily accrued from a reduction of at-sea costs. (2) Transportation cost savings benefits for this study refers to benefits accrued from vessels transiting the channel more efficiently. In this study, this is the result of measures such as improvements of meeting areas, mooring facilities, and turning basins. These benefits accrue entirely from a reduction of in-port costs.

The following benefit analysis details OD benefits for HSC ECIP study measures (Section 4.2); and transportation cost savings benefits (Section 4.3). Section 4.4 groups the measures evaluated for this study into the formulated alternatives for the final benefit-cost analysis.

4.2 ORIGIN DESTINATION TRANSPORTATION COST SAVINGS

Transportation cost benefits were estimated using the HarborSym Economic Reporter, a tool that summarizes and annualizes HarborSym results from multiple simulations. This tool collects the transportation costs from various model run output files and generates the transportation cost reduction for all project years, and then produces an Average Annual Equivalent (AAEQ).

Transportation costs were estimated for a 50-year period of analysis for the years 2029 through 2078. Transportation costs were estimated using HarborSym for the years 2029, 2034, 2039, and 2044. The present value was estimated by interpolating between the modeled years and discounting at the current FY 2018 Federal Discount rate of 2. 75 percent. Estimates were determined for each alternative project depth. At-Sea transportation cost saving benefits account for approximately 95 percent of benefits in these measures given that the reduction in transportation costs associated with the hundreds to thousands of miles traveled at-sea is much more significant than in-port transportation costs.

The analysis includes summaries of total transportation costs, transportation cost savings, and AAEQ transportation cost and cost savings. The overall reduction in total number of container calls (**Table 4-7)** and bulk vessel calls (**Table 4-10**) is the driving force behind origin-destination benefits.

4.2.1 Measures for Design Vessel Transit

Channel modifications such as bend easings, channel widening at BSC and BCC, flare modifications, and turning basin improvements would allow the containership design vessels to transit in Alternatives 1, 2, and 8. With the additional channel capacity, the study assumes a percentage of vessels will transition to the larger, more economical design vessels. As discussed in Section 3.3.2, fleet forecasts from MSI and world fleet data obtained from Global Insight informed the forecasted fleet transition. **Table 4-7** provides a summary of the fleet transition for 2029, 2034, 2039, and 2044 given modifications that allow design vessel transit to BSC and BCT. The Measures for Design Vessel Transit measure group also allows a Suezmax tanker (130k-215k

DWT Tanker) to transit Bayport Ship Channel (fleet transition included in **Table 4-10**). **Table 4-12** provides the annual transportation costs in total and for the at-sea and in-port portions for measures for design vessel transit to BSC, BCT, and both BSC and BCT (Measures for Design Vessel Transit). **Table 4-13** provides a summary of cost saving benefits for improvements to BSC and BCT. **Table 4-14** summarizes AAEQ cost statistics.

Table 4-12: Measures for Design Vessel Origin-Destination Annual Transportation Cost (Million $)

Annual O-D At-Sea and In-Port Transportation Cost Allocated to Port (Million $)				
Year	**FWOP**	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$289.7	$281.7	$283.2	$275.2
2030	$334.8	$325.9	$326.9	$318.0
2031	$379.8	$370.1	$370.6	$360.9
2032	$424.9	$414.2	$414.4	$403.7
2033	$470.0	$458.4	$458.1	$446.5
2034	$515.0	$502.5	$501.9	$489.4
2035	$551.7	$536.6	$537.3	$522.2
2036	$588.3	$570.6	$572.8	$555.1
2037	$625.1	$604.8	$608.4	$588.1
2038	$661.7	$638.8	$643.8	$620.9
2039	$698.4	$672.9	$679.3	$653.8
2040	$773.3	$743.7	$753.5	$723.9
2041	$848.2	$814.7	$827.5	$794.0
2042	$923.0	$885.5	$901.6	$864.1
2043	$998.0	$956.4	$975.7	$934.1
2044-2078	$1,072.8	$1,027.2	$1,049.8	$1,004.2
Annual O-D In-Port Transportation Cost (Million $)				
Year	**FWOP**	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$10.3	$10.4	$10.2	$10.3
2030	$11.8	$11.8	$11.8	$11.8
2031	$13.3	$13.4	$13.3	$13.4
2032	$14.8	$14.9	$14.8	$14.9
2033	$16.3	$16.4	$16.3	$16.4
2034	$17.8	$17.9	$17.9	$18.0
2035	$19.2	$19.3	$19.3	$19.4
2036	$20.5	$20.6	$20.6	$20.7
2037	$21.9	$21.9	$22.0	$22.0
2038	$23.2	$23.2	$23.4	$23.4
2039	$24.6	$24.6	$24.7	$24.7

2040	$27.6	$27.6	$27.7	$27.7
2041	$30.5	$30.6	$30.7	$30.8
2042	$33.5	$33.6	$33.6	$33.7
2043	$36.6	$36.6	$36.7	$36.7
2044-2078	$39.6	$39.7	$39.6	$39.7
Annual O-D At-Sea Transportation Cost Allocated to Port (Million $)				
Year	**FWOP**	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$279.5	$271.5	$272.9	$264.9
2030	$323.0	$314.0	$315.2	$306.2
2031	$366.5	$356.6	$357.3	$347.4
2032	$410.1	$399.3	$399.6	$388.8
2033	$453.6	$441.9	$441.7	$430.0
2034	$497.2	$484.6	$484.0	$471.4
2035	$532.5	$517.3	$518.1	$502.9
2036	$567.8	$550.1	$552.2	$534.5
2037	$603.2	$582.8	$586.4	$566.0
2038	$638.5	$615.6	$620.5	$597.6
2039	$673.8	$648.3	$654.6	$629.1
2040	$745.7	$716.1	$725.8	$696.2
2041	$817.6	$784.0	$796.9	$763.3
2042	$889.5	$851.9	$868.0	$830.4
2043	$961.4	$919.7	$939.1	$897.4
2044-2078	$1,033.3	$987.6	$1,010.2	$964.5

Table 4-13: Measures for Design Vessel Origin-Destination Annual Transportation Cost Saving Benefits by Channel Depth (Million $)

Annual O-D At-Sea and In-Port Transportation Cost Saving Benefits (Million $)			
Year	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$8.0	$6.5	$14.5
2030	$8.9	$7.9	$16.8
2031	$9.8	$9.2	$19.0
2032	$10.7	$10.5	$21.2
2033	$11.6	$11.9	$23.5
2034	$12.5	$13.1	$25.6
2035	$15.1	$14.4	$29.5
2036	$17.7	$15.5	$33.2
2037	$20.3	$16.7	$37.0
2038	$22.9	$17.9	$40.8

2039	$25.5	$19.1	$44.6
2040	$29.5	$19.8	$49.3
2041	$33.5	$20.7	$54.2
2042	$37.6	$21.4	$59.0
2043	$41.6	$22.3	$63.9
2044-2078	$45.7	$23.0	$68.7
Annual O-D In-Port Transportation Cost Saving Benefits (Million $)			
Year	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$(0.1)	$0.1	$0.0
2030	$(0.1)	$-	$(0.1)
2031	$(0.1)	$-	$(0.1)
2032	$(0.1)	$-	$(0.1)
2033	$(0.1)	$-	$(0.1)
2034	$(0.1)	$(0.1)	$(0.2)
2035	$(0.1)	$(0.1)	$(0.2)
2036	$(0.1)	$(0.1)	$(0.2)
2037	$(0.1)	$(0.1)	$(0.2)
2038	$(0.1)	$(0.2)	$(0.3)
2039	$(0.1)	$(0.1)	$(0.1)
2040	$(0.1)	$(0.1)	$(0.2)
2041	$(0.1)	$(0.2)	$(0.3)
2042	$(0.1)	$(0.1)	$(0.2)
2043	$(0.1)	$(0.1)	$(0.2)
2044-2078	$(0.1)	$-	$(0.1)
Annual O-D At-Sea Transportation Cost Saving Benefits (Million $)			
Year	**BSC**	**BCT**	**Measures for Design Vessel Transit**
2029	$8.1	$6.6	$14.7
2030	$9.0	$7.8	$16.8
2031	$9.9	$9.2	$19.1
2032	$10.8	$10.5	$21.3
2033	$11.7	$11.9	$23.6
2034	$12.6	$13.2	$25.8
2035	$15.2	$14.4	$29.6
2036	$17.8	$15.6	$33.4
2037	$20.3	$16.8	$37.1
2038	$22.9	$18.0	$40.9
2039	$25.5	$19.2	$44.7

2040	$29.6	$19.9	$49.5
2041	$33.6	$20.7	$54.3
2042	$37.6	$21.5	$59.1
2043	$41.7	$22.3	$64.0
2044-2078	$45.7	$23.1	$68.8

Table 4-14: Origin-Destination AAEQ Transportation Cost and Cost Saving (Million $)

Alternative	OD AAEQ Transportation Cost (Million $)	OD AAEQ Transportation Cost Savings (Million $)
FWOP	$851.7	
BSC	$818.0	$33.72
BCT	$832.5	$19.20
Measures for Design Vessel Transit	$798.8	$52.92

4.2.2 Bayou Deepening & Aframax Widening

The following describes channel deepening benefits for Segments 4, 5, and 6. Segment 4 includes analysis of Aframax widening, which would allow the transit of the Aframax Design vessel to berths in Segment 4. Segment 5 and Segment 6 are grouped as Segment 5 accrues very low benefits from deepening; however, it is required for deepening in Segment 6.

4.2.2.1 Segment 4 Deepening and Aframax Widening (CD4_Whole & CW4_BB-GB_530)

Table 4-15 presents transportation costs for channel deepening in Segment 4 from Boggy Bayou to the Washburn Tunnel (CD4_Whole) as well as channel widening from Boggy Bayou to Greens Bayou to allow the Aframax design tanker transit (CW4_BB-GB_530). The last column (CD 46.5 & AFRA) represents the combination of channel deepening in Segment 4 (CD4_Whole) and Aframax widening (CW4_BB-GB_530). **Table 4-16** presents annual transportation cost saving benefits for each depth. A summary of AAEQ transportation cost and cost savings benefits is available in **Table 4-17**.

Table 4-15: Segment 4 Origin-Destinatin Annual Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Million $)				
Year	**FWOP**	**CD4_43.5**	**CD4_46.5**	**CW4_BB-GB_530**
2029	$1,154.7	$1,141.5	$1,127.8	$1,120.7
2030	$1,172.3	$1,159.1	$1,145.2	$1,137.5
2031	$1,190.0	$1,176.7	$1,162.6	$1,154.4
2032	$1,207.6	$1,194.4	$1,180.0	$1,171.3
2033	$1,225.3	$1,212.0	$1,197.4	$1,188.1
2034	$1,242.9	$1,229.6	$1,214.8	$1,205.0
2035	$1,253.2	$1,239.9	$1,224.4	$1,214.0
2036	$1,263.4	$1,250.2	$1,233.9	$1,223.1
2037	$1,273.7	$1,260.5	$1,243.5	$1,232.2

2038	$1,284.0	$1,270.7	$1,253.0	$1,241.2
2039	$1,294.2	$1,281.0	$1,262.6	$1,250.3
2040	$1,294.2	$1,281.0	$1,262.6	$1,250.3
2041	$1,294.2	$1,281.0	$1,262.6	$1,250.3
2042	$1,294.2	$1,281.0	$1,262.6	$1,250.3
2043	$1,294.2	$1,281.0	$1,262.6	$1,250.3
2044-2078	$1,294.2	$1,281.0	$1,262.6	$1,250.3
In-Port Transportation Costs (Million $)				
Year	**FWOP**	**CD4_43.5**	**CD4_46.5**	**CW4_BB-GB_530**
2029	$43.9	$43.6	$43.4	$43.3
2030	$44.3	$44.0	$43.8	$43.7
2031	$44.7	$44.3	$44.2	$44.1
2032	$45.0	$44.7	$44.5	$44.4
2033	$45.4	$45.1	$44.9	$44.8
2034	$45.7	$45.4	$45.3	$45.2
2035	$45.9	$45.6	$45.4	$45.3
2036	$46.0	$45.7	$45.5	$45.4
2037	$46.2	$45.9	$45.7	$45.6
2038	$46.3	$46.0	$45.8	$45.7
2039	$46.5	$46.2	$46.0	$45.8
2040	$46.5	$46.2	$46.0	$45.8
2041	$46.5	$46.2	$46.0	$45.8
2042	$46.5	$46.2	$46.0	$45.8
2043	$46.5	$46.2	$46.0	$45.8
2044-2078	$46.5	$46.2	$46.0	$45.8
At-Sea Transportation Cost Allocated to Port (Million $)				
Year	**FWOP**	**CD4_43.5**	**CD4_46.5**	**CW4_BB-GB_530**
2029	$1,110.7	$1,097.9	$1,084.4	$1,077.3
2030	$1,128.0	$1,115.1	$1,101.4	$1,093.8
2031	$1,145.3	$1,132.4	$1,118.4	$1,110.3
2032	$1,162.6	$1,149.7	$1,135.5	$1,126.8
2033	$1,179.9	$1,166.9	$1,152.5	$1,143.3
2034	$1,197.2	$1,184.2	$1,169.5	$1,159.8
2035	$1,207.3	$1,194.3	$1,179.0	$1,168.7
2036	$1,217.4	$1,204.5	$1,188.4	$1,177.7
2037	$1,227.5	$1,214.6	$1,197.8	$1,186.6
2038	$1,237.6	$1,224.7	$1,207.2	$1,195.5
2039	$1,247.8	$1,234.9	$1,216.6	$1,204.4
2040	$1,247.8	$1,234.9	$1,216.6	$1,204.4
2041	$1,247.8	$1,234.9	$1,216.6	$1,204.4
2042	$1,247.8	$1,234.9	$1,216.6	$1,204.4

2043	$1,247.8	$1,234.9	$1,216.6	$1,204.4
2044-2078	$1,247.8	$1,234.9	$1,216.6	$1,204.4

Table 4-16: Segment 4 Origin-Destination Annual Transportation Cost Saving Benefits (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Million $)			
Year	**CD4_43.5**	**CD4_46.5**	**CW4_BB-GB_530**
2029	$13.2	$26.9	$34.0
2030	$13.2	$27.1	$34.8
2031	$13.3	$27.4	$35.6
2032	$13.2	$27.6	$36.3
2033	$13.3	$27.9	$37.2
2034	$13.3	$28.1	$37.9
2035	$13.3	$28.8	$39.2
2036	$13.2	$29.5	$40.3
2037	$13.2	$30.2	$41.5
2038	$13.3	$31.0	$42.8
2039	$13.2	$31.6	$43.9
2040	$13.2	$31.6	$43.9
2041	$13.2	$31.6	$43.9
2042	$13.2	$31.6	$43.9
2043	$13.2	$31.6	$43.9
2044-2078	$13.2	$31.6	$43.9
In-Port Transportation Costs (Million $)			
Year	**CD4_43.5**	**CD4_46.5**	**CW4_BB-GB_530**
2029	$0.3	$0.5	$0.6
2030	$0.3	$0.5	$0.6
2031	$0.4	$0.5	$0.6
2032	$0.3	$0.5	$0.6
2033	$0.3	$0.5	$0.6
2034	$0.3	$0.4	$0.5
2035	$0.3	$0.5	$0.6
2036	$0.3	$0.5	$0.6
2037	$0.3	$0.5	$0.6
2038	$0.3	$0.5	$0.6
2039	$0.3	$0.5	$0.7
2040	$0.3	$0.5	$0.7
2041	$0.3	$0.5	$0.7
2042	$0.3	$0.5	$0.7
2043	$0.3	$0.5	$0.7
2044-2078	$0.3	$0.5	$0.7
At-Sea Transportation Cost Allocated to Port (Million $)			

Year	CD4_43.5	CD4_46.5	CW4_BB-GB_530
2029	$12.8	$26.3	$33.4
2030	$12.9	$26.6	$34.2
2031	$12.9	$26.9	$35.0
2032	$12.9	$27.1	$35.8
2033	$13.0	$27.4	$36.6
2034	$13.0	$27.7	$37.4
2035	$13.0	$28.3	$38.6
2036	$12.9	$29.0	$39.7
2037	$12.9	$29.7	$40.9
2038	$12.9	$30.4	$42.1
2039	$12.9	$31.2	$43.4
2040	$12.9	$31.2	$43.4
2041	$12.9	$31.2	$43.4
2042	$12.9	$31.2	$43.4
2043	$12.9	$31.2	$43.4
2044-2078	$12.9	$31.2	$43.4

Table 4-17: Segment 4 Origin-Destination AAEQ Transportation Cost and Cost Saving Benefits by Project Depth

Project Depth	OD AAEQ Transportation Cost (Million $)	OD AAEQ Transportation Cost Saving (Million $)
FWOP	$1,271.6	-
43.5	$1,258.4	$13.2
46.5	$1,241.0	$30.6
CD4_46.5 & CW4_BB-GB	$1,229.6	$42.0

4.2.3 Segment 5 and Segment 6 Deepening (CD5_Whole & CD6_Whole)

Table 4-18 presents transportation costs for channel deepening in Segment 5 and Segment 6 (Sims Bayou to Main Turning Basin) from 37.5 MLLW to 41.5 MLLW (CD5_Whole and CD6_Whole). **Table 4-19** presents the transportation cost saving benefits for deepening measures in Segment 5 and Segment 6. **Table 4-20** summarizes the AAEQ Benefits for each depth.

Table 4-18: Segment 5-6 Origin-Destination Annual Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)			
Year	**FWOP**	**CD5-6_39.5**	**CD5-6_41.5**
2029	$789.2	$782.0	$780.1
2030	$810.9	$802.5	$799.7
2031	$832.6	$823.0	$819.3
2032	$854.3	$843.5	$838.9
2033	$876.0	$864.1	$858.6

2034	$897.7	$884.6	$878.2
2035	$918.2	$905.8	$899.8
2036	$938.6	$927.0	$921.4
2037	$959.1	$948.2	$942.9
2038	$979.5	$969.4	$964.5
2039	$999.9	$990.6	$986.1
2040	$999.9	$990.6	$986.1
2041	$999.9	$990.6	$986.1
2042	$999.9	$990.6	$986.1
2043	$999.9	$990.6	$986.1
2044-2078	$999.9	$990.6	$986.1
In-Port Transportation Costs ($)			
Year	**FWOP**	**CD5-6_39.5**	**CD5-6_41.5**
2029	$18.4	$18.3	$18.2
2030	$19.0	$18.8	$18.7
2031	$19.5	$19.3	$19.2
2032	$20.0	$19.8	$19.7
2033	$20.5	$20.3	$20.2
2034	$21.1	$20.8	$20.6
2035	$21.5	$21.2	$21.1
2036	$22.0	$21.7	$21.6
2037	$22.5	$22.2	$22.1
2038	$22.9	$22.7	$22.6
2039	$23.4	$23.2	$23.1
2040	$23.4	$23.2	$23.1
2041	$23.4	$23.2	$23.1
2042	$23.4	$23.2	$23.1
2043	$23.4	$23.2	$23.1
2044-2078	$23.4	$23.2	$23.1
At-Sea Transportation Cost Allocated to Port ($)			
Year	**FWOP**	**CD5-6_39.5**	**CD5-6_41.5**
2029	$770.8	$763.7	$761.9
2030	$792.0	$783.7	$781.0
2031	$813.1	$803.8	$800.1
2032	$834.3	$823.8	$819.3
2033	$855.5	$843.8	$838.4
2034	$876.7	$863.8	$857.5
2035	$896.6	$884.6	$878.6
2036	$916.6	$905.3	$899.7
2037	$936.6	$926.0	$920.8
2038	$956.6	$946.7	$941.9

2039	$976.6	$967.4	$963.0
2040	$976.6	$967.4	$963.0
2041	$976.6	$967.4	$963.0
2042	$976.6	$967.4	$963.0
2043	$976.6	$967.4	$963.0
2044-2078	$976.6	$967.4	$963.0

Table 4-19: Segment 5-6 Origin-Destination annual Transportation Cost Saving Benefits by Channel Depth (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)		
Year	**CD5-6_39.5**	**CD5-6_41.5**
2029	$7.2	$9.1
2030	$8.4	$11.2
2031	$9.6	$13.3
2032	$10.8	$15.4
2033	$11.9	$17.4
2034	$13.1	$19.5
2035	$12.4	$18.4
2036	$11.6	$17.2
2037	$10.9	$16.2
2038	$10.1	$15.0
2039	$9.3	$13.8
2040	$9.3	$13.8
2041	$9.3	$13.8
2042	$9.3	$13.8
2043	$9.3	$13.8
2044-2078	$9.3	$13.8
In-Port Transportation Costs ($)		
Year	**CD5-6_39.5**	**CD5-6_41.5**
2029	$0.1	$0.2
2030	$0.2	$0.3
2031	$0.2	$0.3
2032	$0.2	$0.3
2033	$0.2	$0.3
2034	$0.3	$0.5
2035	$0.3	$0.4
2036	$0.3	$0.4
2037	$0.3	$0.4
2038	$0.2	$0.3
2039	$0.2	$0.3
2040	$0.2	$0.3
2041	$0.2	$0.3

2042	$0.2	$0.3
2043	$0.2	$0.3
2044-2078	$0.2	$0.3
At-Sea Transportation Cost Allocated to Port ($)		
Year	**CD5-6_39.5**	**CD5-6_41.5**
2029	$7.1	$8.9
2030	$8.3	$11.0
2031	$9.3	$13.0
2032	$10.5	$15.0
2033	$11.7	$17.1
2034	$12.9	$19.2
2035	$12.0	$18.0
2036	$11.3	$16.9
2037	$10.6	$15.8
2038	$9.9	$14.7
2039	$9.2	$13.6
2040	$9.2	$13.6
2041	$9.2	$13.6
2042	$9.2	$13.6
2043	$9.2	$13.6
2044-2078	$9.2	$13.6

Table 4-20: Segment 5-6 Origin-Destination AAEQ Transportation Cost and Cost Saving by Project Depth (Million $)

Project Depth	OD AAEQ Transportation Cost (Million $)	OD AAEQ Transportation Cost Saving (Million $)
FWOP	$961.8	-
CD5-6_39.5	$952.1	$9.8
CD5-6_41.5	$947.6	$14.2

4.3 TRANSPORTATION COST SAVINGS BENEFIT ANALYSIS

The transportation cost savings benefit analysis is entirely based on in-port reduction in transportation costs as a result of channel improvements. The benefit cost analysis presented in this section is for the project depths determined to be the most likely selected plans based on the OD benefits and rough order cost analysis (46.5 MLLW for Segment 1 through Segment 4 and 41.5 MLLW for Segment 5 and Segment 6). All benefits use the FY 2018 Federal Discount rate (2.75 percent).

4.3.1 Bay Widening (CW1_BR-Redfish, CW1_Redfish-BSC, and CW1_BSC-BCC)

The following outlines benefits of meeting areas proposed in the bay (CW1_BR-Redfish_650-900, CW1_Redfish-BSC_650-900, and CW1_BSC-BCC_650-900). These benefits are outlined in **Table 4-4**. Primarily, benefits accrue from the reduction in daylight restrictions for wide-body vessels and in the increased ability for these vessels to meet in the channel. **Table 4-21** summarizes transportation costs for each measure group. **Table 4-22** summarizes transportation cost savings for each measure group. **Table 4-23** provides AAEQ Costs and AAEQ Cost Savings.

Table 4-21: Bay Meeting Area Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Million $)						
Year	**FWOP**	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029	$271.8	$266.0	$266.4	$269.5	$260.1	$257.3
2030	$277.2	$270.9	$271.3	$274.8	$264.6	$261.1
2031	$282.5	$275.8	$276.2	$280.0	$269.1	$264.8
2032	$287.9	$280.8	$281.1	$285.3	$273.6	$268.6
2033	$293.2	$285.7	$286.0	$290.5	$278.1	$272.3
2034	$298.5	$290.6	$290.9	$295.7	$282.6	$276.1
2035	$303.6	$295.2	$295.9	$300.7	$286.7	$280.0
2036	$308.6	$299.9	$300.9	$305.6	$290.9	$283.9
2037	$313.6	$304.5	$305.8	$310.6	$295.1	$287.8
2038	$318.7	$309.1	$310.8	$315.5	$299.3	$291.8
2039	$323.7	$313.8	$315.7	$320.5	$303.5	$295.7
2040	$325.1	$315.0	$316.6	$321.9	$304.4	$296.6
2041	$326.5	$316.1	$317.4	$323.2	$305.2	$297.4
2042	$327.9	$317.3	$318.2	$324.6	$306.1	$298.3
2043	$329.3	$318.5	$319.0	$325.9	$307.0	$299.2
2044-2078	$330.7	$319.7	$319.8	$327.3	$307.9	$300.0
In-Port Transportation Costs (Million $)						
Year	**FWOP**	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029	$271.8	$266.0	$266.4	$269.5	$260.1	$257.3
2030	$277.2	$270.9	$271.3	$274.8	$264.6	$261.1
2031	$282.5	$275.8	$276.2	$280.0	$269.1	$264.8
2032	$287.9	$280.8	$281.1	$285.3	$273.6	$268.6
2033	$293.2	$285.7	$286.0	$290.5	$278.1	$272.3
2034	$298.5	$290.6	$290.9	$295.7	$282.6	$276.1
2035	$303.6	$295.2	$295.9	$300.7	$286.7	$280.0
2036	$308.6	$299.9	$300.9	$305.6	$290.9	$283.9
2037	$313.6	$304.5	$305.8	$310.6	$295.1	$287.8
2038	$318.7	$309.1	$310.8	$315.5	$299.3	$291.8

2039	$323.7	$313.8	$315.7	$320.5	$303.5	$295.7
2040	$325.1	$315.0	$316.6	$321.9	$304.4	$296.6
2041	$326.5	$316.1	$317.4	$323.2	$305.2	$297.4
2042	$327.9	$317.3	$318.2	$324.6	$306.1	$298.3
2043	$329.3	$318.5	$319.0	$325.9	$307.0	$299.2
2044-2078	$330.7	$319.7	$319.8	$327.3	$307.9	$300.0
At-Sea Transportation Cost Allocated to Port (Million $)						
Year	**FWOP**	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029-2078	$0	$0	$0	$0	$0	$0

Table 4-22: Bay Meeting Annual Transportation Cost Saving Benefits (Million $)

Total At-Sea and In-Port Transportation Cost Savings (Million $)					
Year	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029	$5.8	$5.4	$2.3	$11.7	$14.5
2030	$6.3	$5.9	$2.4	$12.6	$16.1
2031	$6.7	$6.3	$2.5	$13.4	$17.7
2032	$7.1	$6.7	$2.6	$14.3	$19.3
2033	$7.5	$7.2	$2.7	$15.1	$20.9
2034	$7.9	$7.6	$2.8	$16.0	$22.5
2035	$8.3	$7.7	$2.9	$16.8	$23.6
2036	$8.7	$7.8	$3.0	$17.7	$24.7
2037	$9.1	$7.8	$3.0	$18.5	$25.8
2038	$9.5	$7.9	$3.1	$19.4	$26.9
2039	$9.9	$8.0	$3.2	$20.2	$28.0
2040	$10.1	$8.5	$3.3	$20.8	$28.5
2041	$10.4	$9.1	$3.3	$21.3	$29.1
2042	$10.6	$9.7	$3.3	$21.8	$29.6
2043	$10.8	$10.3	$3.4	$22.3	$30.2
2044-2078	$11.0	$10.9	$3.4	$22.8	$30.7
In-Port Transportation Cost Savings (Million $)					
Year	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029	$5.8	$5.4	$2.3	$11.7	$14.5
2030	$6.3	$5.9	$2.4	$12.6	$16.1
2031	$6.7	$6.3	$2.5	$13.4	$17.7
2032	$7.1	$6.7	$2.6	$14.3	$19.3
2033	$7.5	$7.2	$2.7	$15.1	$20.9
2034	$7.9	$7.6	$2.8	$16.0	$22.5
2035	$8.3	$7.7	$2.9	$16.8	$23.6
2036	$8.7	$7.8	$3.0	$17.7	$24.7
2037	$9.1	$7.8	$3.0	$18.5	$25.8

2038	$9.5	$7.9	$3.1	$19.4	$26.9
2039	$9.9	$8.0	$3.2	$20.2	$28.0
2040	$10.1	$8.5	$3.3	$20.8	$28.5
2041	$10.4	$9.1	$3.3	$21.3	$29.1
2042	$10.6	$9.7	$3.3	$21.8	$29.6
2043	$10.8	$10.3	$3.4	$22.3	$30.2
2044-2078	$11.0	$10.9	$3.4	$22.8	$30.7
At-Sea Transportation Cost Savings Allocated to Port (Million $)					
Year	**BR-Redfish**	**Redfish-BSC**	**BSC-BCC**	**BR-BSC**	**BR-BCC**
2029-2078	$0	$0	$0	$0	$0

Table 4-23: Bay Meeting Area AAEQ Transportation Cost and Cost Saving Benefits (Million $)

Alternative	AAEQ Transportation Cost	AAEQ Transportation Cost Reduction Benefit
FWOP	$318.3	$-
CW1_BR-RF	$308.5	$9.8
CW1_RF-BSC	$308.9	$9.4
CW1_BSC-BCC	$315.1	$3.2
CW1_BR-RF CW1_RF-BSC	$298.1	$20.2
CW1_BR-RF CW1_RF-BSC CW1_BSC-BCC	$291.0	$27.3

Widening measures were incrementally evaluated. Ship Simulation will be completed to determine the width needed for the changes outlined in **Table 4-4**. Until ship simulation is complete, the study assumes vessels realize the same benefits for each channel widening increment (650 feet, 820 feet, and 900 feet).

Evaluation completed in this study involved justifying widening measures separately and combined. The study assumes that a combination of CW1_BR-Redfish and CW1_Redfish-BSC allows nighttime transit to terminals in BSC. The study assumes that a combination CW1_BR-Redfish, CW1_Redfish-BSC, and CW1_BSC-BCC allows nighttime transits to terminals located in BSC and BCC. **Table 4-24** provides a summary of benefits by measure given a full bay widening (CW1_BR-Redfish, CW1_Redfish-BSC, and CW1_BSC-BCC).

Table 4-24: Transportation Cost Savings Benefits for Incremental Widening (Million $)

Alternative	Total AAEQ Benefits
CW1_BR-Redfish	$9.8
CW1_Redfish-BSC	$10.4
CW1_BSC-BCC	$7.1

4.3.2 San Jacinto to Boggy Bayou Meeting Area (CW1_SJM-BB_530)

The following outlines benefits of meeting areas proposed from San Jacinto Monument to Boggy Bayou (CW1_SJM-BB_560). Widening in this section alleviates one-way traffic rules in an attempt to ease congestion in this reach. **Table 4-25** summarizes transportation costs of the FWOP and FWP, **Table 4-26** summarizes transportation cost savings of channel widening, and **Table 4-27** provides a summary of AAEQ Costs and AAEQ Cost Saving Benefits.

Table 4-25: SJM-BB Meeting Area Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Million $)		
Year	**FWOP**	**CW1_SJM-BB_530**
2029	$102.6	$102.4
2030	$103.6	$103.4
2031	$104.5	$104.3
2032	$105.4	$105.2
2033	$106.4	$106.1
2034	$107.3	$107.1
2035	$107.3	$107.1
2036	$107.4	$107.1
2037	$107.4	$107.2
2038	$107.4	$107.2
2039	$107.5	$107.2
2040	$107.5	$107.2
2041	$107.5	$107.2
2042	$107.5	$107.2
2043	$107.5	$107.2
2044-2078	$107.5	$107.2
In-Port Transportation Costs (Million $)		
Year	**FWOP**	**CW1_SJM-BB_530**
2029	$102.6	$102.4
2030	$103.6	$103.4
2031	$104.5	$104.3
2032	$105.4	$105.2
2033	$106.4	$106.1
2034	$107.3	$107.1
2035	$107.3	$107.1
2036	$107.4	$107.1
2037	$107.4	$107.2
2038	$107.4	$107.2
2039	$107.5	$107.2
2040	$107.5	$107.2

2041	$107.5	$107.2
2042	$107.5	$107.2
2043	$107.5	$107.2
2044-2078	$107.5	$107.2
At-Sea Transportation Cost Allocated to Port (Million $)		
Year	**FWOP**	**CW1_SJM-BB_530**
2029-2078	$0	$0

Table 4-26: SJM-BB Transpotation Cost Saving Benefits (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port (Million $)	
Year	**FWP**
2029	$0.2
2030	$0.2
2031	$0.2
2032	$0.2
2033	$0.3
2034	$0.2
2035	$0.2
2036	$0.3
2037	$0.2
2038	$0.2
2039	$0.3
2040	$0.3
2041	$0.3
2042	$0.3
2043	$0.3
2044-2078	$0.3
In-Port Transportation Costs (Million $)	
Year	**FWP**
2029	$0.2
2030	$0.2
2031	$0.2
2032	$0.2
2033	$0.3
2034	$0.2
2035	$0.2
2036	$0.3
2037	$0.2
2038	$0.2
2039	$0.3
2040	$0.3

2041	$0.3
2042	$0.3
2043	$0.3
2044-2078	$0.3
At-Sea Transportation Cost Allocated to Port (Million $)	
Year	**FWP**
2029-2078	$0

Table 4-27: SJM-BB Meeting Area AAEQ Transportation Cost and Cost Saving Benefits (Million $)

Alternative	AAEQ Transportation Cost (Million $)	AAEQ Transportation Cost Reduction Benefit (Million $)
FWOP	$106.9	0
CW1_SJM-BB_530	$106.7	$0.2

4.3.3 Mooring Facilities

The following outlines benefits of mooring facilities proposed from in the Bay (MM2_BSC_1800) and the Bayou (MM1_AI(d) and MM1_520+00). These mooring facilities reduce the total number of transits to Bolivar Road and Gulf Anchorages for small tankers and chemical tanker vessels, reducing total transportation costs for these vessels and relieving congestion throughout the HSC. **Table 4-28** summarizes transportation costs, **Table 4-29** summarizes transportation cost savings for each measure group, and **Table 4-30** provides AAEQ Costs and AAEQ Cost Savings.

Table 4-28: Mooring Facility Annual Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)				
Year	**FWOP**	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029	$8.2	$5.0	$4.1	$3.7
2030	$8.2	$5.1	$4.1	$3.7
2031	$8.3	$5.1	$4.2	$3.8
2032	$8.4	$5.2	$4.2	$3.8
2033	$8.5	$5.2	$4.3	$3.9
2034	$8.5	$5.3	$4.3	$3.9
2035	$8.6	$5.3	$4.3	$4.0
2036	$8.7	$5.4	$4.4	$4.0
2037	$8.8	$5.4	$4.4	$4.0
2038	$8.8	$5.4	$4.4	$4.0
2039	$8.9	$5.5	$4.4	$4.0
2040	$8.9	$5.5	$4.4	$4.0
2041	$8.9	$5.5	$4.4	$4.0
2042	$8.9	$5.5	$4.4	$4.0
2043	$8.9	$5.5	$4.4	$4.0

2044-2078	$8.9	$5.5	$4.4	$4.0
In-Port Transportation Costs ($)				
Year	**FWOP**	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029	$8.2	$5.0	$4.1	$3.5
2030	$8.2	$5.1	$4.1	$3.6
2031	$8.3	$5.1	$4.2	$3.7
2032	$8.4	$5.2	$4.2	$3.8
2033	$8.5	$5.2	$4.3	$3.9
2034	$8.5	$5.3	$4.3	$3.9
2035	$8.6	$5.3	$4.3	$4.0
2036	$8.7	$5.4	$4.4	$4.0
2037	$8.8	$5.4	$4.4	$4.0
2038	$8.8	$5.4	$4.4	$4.0
2039	$8.9	$5.5	$4.4	$4.0
2040	$8.9	$5.5	$4.4	$4.0
2041	$8.9	$5.5	$4.4	$4.0
2042	$8.9	$5.5	$4.4	$4.0
2043	$8.9	$5.5	$4.4	$4.0
2044-2078	$8.9	$5.5	$4.4	$4.0
At-Sea Transportation Cost Allocated to Port ($)				
Year	**FWOP**	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029-2078	$0.0	$0.0	$0.0	$0.1

Table 4-29: Mooring Facility Annual Transportation Cost Saving Benefits (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)			
Year	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029	$3.2	$4.1	$4.5
2030	$3.1	$4.1	$4.5
2031	$3.2	$4.1	$4.5
2032	$3.2	$4.2	$4.6
2033	$3.3	$4.2	$4.6
2034	$3.2	$4.2	$4.6
2035	$3.3	$4.3	$4.6
2036	$3.3	$4.3	$4.7
2037	$3.4	$4.4	$4.8
2038	$3.4	$4.4	$4.8
2039	$3.4	$4.5	$4.9
2040	$3.4	$4.5	$4.9
2041	$3.4	$4.5	$4.9
2042	$3.4	$4.5	$4.9
2043	$3.4	$4.5	$4.9

2044	$3.4	$4.5	$4.9
In-Port Transportation Costs ($)			
Year	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029	$3.2	$4.1	$4.7
2030	$3.1	$4.1	$4.6
2031	$3.2	$4.1	$4.6
2032	$3.2	$4.2	$4.6
2033	$3.3	$4.2	$4.6
2034	$3.2	$4.2	$4.6
2035	$3.3	$4.3	$4.6
2036	$3.3	$4.3	$4.7
2037	$3.4	$4.4	$4.8
2038	$3.4	$4.4	$4.8
2039	$3.4	$4.5	$4.9
2040	$3.4	$4.5	$4.9
2041	$3.4	$4.5	$4.9
2042	$3.4	$4.5	$4.9
2043	$3.4	$4.5	$4.9
2044-2078	$3.4	$4.5	$4.9
At-Sea Transportation Cost Allocated to Port ($)			
Year	**MM2_BSC_1800**	**MM1_AI(d)**	**MM1_520+00**
2029	$0.0	$0.0	-$0.1
2030	$0.0	$0.0	-$0.1
2031	$0.0	$0.0	-$0.1
2032	$0.0	$0.0	-$0.1
2033	$0.0	$0.0	$0.0
2034	$0.0	$0.0	$0.0
2035	$0.0	$0.0	$0.0
2036	$0.0	$0.0	$0.0
2037	$0.0	$0.0	$0.0
2038	$0.0	$0.0	$0.0
2039-2078	$0.0	$0.0	$0.0

Table 4-30: Mooring Facility AAEQ Transportation Cost and Cost Saving Benefits

Alternative	AAEQ Transportation Cost (Million $)	AAEQ Transportation Cost Reduction Benefit (Million $)
FWOP	$8.8	$-
MM2_BSC_1800	$5.4	$3.4
MM1_AI(d)	$4.4	$4.4
MM1_520+00	$4.0	$4.8

4.3.4 BSC Turning Basin

The following outlines benefits of an additional turning basin as Bayport Ship Channel (TB2_BSCRORO). It is assumed that the additional turning basin at BSC will relieve congestion at the existing turning basin and prevent vessel delays for containerships transiting the channel with the design containership is at berth. **Table 4-31** summarizes transportation costs, **Table 4-32** summarizes transportation cost savings for each measure group, and **Table 4-33** provides AAEQ Costs and AAEQ Cost Savings.

Table 4-31: BSC Turning Basin Annual Transportation Cost (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)		
Year	**FWOP**	**FWP**
2029	$22.8	$21.9
2030	$23.7	$22.8
2031	$24.7	$23.7
2032	$25.6	$24.7
2033	$26.6	$25.6
2034	$27.5	$26.5
2035	$29.1	$28.0
2036	$30.6	$29.4
2037	$32.1	$30.9
2038	$33.6	$32.3
2039	$35.1	$33.8
2040	$35.7	$34.3
2041	$36.2	$34.9
2042	$36.8	$35.4
2043	$37.4	$36.0
2044-2078	$37.9	$36.5
In-Port Transportation Costs ($)		
Year	**FWOP**	**FWP**
2029	$22.6	$21.7
2030	$23.5	$22.7
2031	$24.5	$23.6
2032	$25.4	$24.5
2033	$26.4	$25.4
2034	$27.3	$26.3
2035	$28.9	$27.8
2036	$30.4	$29.2
2037	$31.9	$30.7
2038	$33.4	$32.1
2039	$34.9	$33.5

2040	$35.4	$34.1
2041	$36.0	$34.6
2042	$36.6	$35.2
2043	$37.1	$35.7
2044-2078	$37.7	$36.3
At-Sea Transportation Cost Allocated to Port ($)		
Year	**FWOP**	**FWP**
2029-2078	$0.2	$0.2

Table 4-32: BSC Turning Basin Annual Transportation Cost Savings (Million $)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($)	
Year	**FWP**
2029	$0.9
2030	$0.9
2031	$1.0
2032	$0.9
2033	$1.0
2034	$1.0
2035	$1.1
2036	$1.2
2037	$1.2
2038	$1.3
2039	$1.3
2040	$1.4
2041	$1.3
2042	$1.4
2043	$1.4
2044-2078	$1.4
In-Port Transportation Costs ($)	
Year	**FWP**
2029	$0.9
2030	$0.8
2031	$0.9
2032	$0.9
2033	$1.0
2034	$1.0
2035	$1.1
2036	$1.2
2037	$1.2
2038	$1.3
2039	$1.4

2040	$1.3
2041	$1.4
2042	$1.4
2043	$1.4
2044-2078	$1.4
At-Sea Transportation Cost Allocated to Port ($)	
Year	**FWP**
2029-2078	$0.0

Table 4-33: BSC Turning Basin AAEQ Transportation Cost and Cost Saving Benefits by Project Depth

Alternative	AAEQ Transportation Cost (Million $)	AAEQ Transportation Cost Reduction Benefit (Million $)
FWOP	$34.3	$-
TB2_BSC_RORO	$33.0	$1.3

4.3.5 Other Measures Benefit Evaluation

The following measures were included in the analysis and did not yield significant economic benefit; however, ship simulation will be required to determine if they are required for the accrual of benefits of any of the measures previously described.

- CW1_HOG_600
- BE1_153+06
- BE1_246+54
- TB4_775+00
- TB4_Hunting
- TB6_Brady_900

4.4 BENEFITS BY ALTERNATIVE

The preceding analysis provides the complete benefit evaluation for all measure groups considered to meet planning objectives at HSC. These measure groups were combined into eight study alternatives. The Complete Benefit-Cost analysis for each alternative is provided in **Table 4-34** (Alternative 1)**,**

Table 4-35 summarizes the benefit-cost analysis completed for Alternative 2 (the "Bay Plan"). Initial screening of alternative revealed that 900-foot bay widening would not be economically justified. The analysis assumes that any bay widening feature will require between 650 and 820 feet of width. The analysis uses Alternative 8 widening benefits for Alternative 2. Actual benefits would differ between the alternatives and additional analysis would be required if the PDT carries Alternative 2 forward. All bay widening is economically justified at 650-feet and included in the total benefit-cost summary; however, full bay widening at 850 feet would not be economically justified and is not included in a total benefit-cost summary.

Table 4-35 (Alternative 2)**, Table 4-36** (Alternative 3)**, Table 4-37** (Alternative 4)**, Table 4-38** (Alternative 5)**, Table 4-39** (Alternative 6), **Table 4-40** (Alternative 7)**,** and
Table 4-41 summarizes the benefit-cost analysis completed for Alternative 8 ("The Everything Plan"). Similar to Alternative 2 and Alternative 3, 900-foot bay widening is not economically justified. The table includes benefit-cost summaries for both 820-foot widening and 650-foot widening. Only 650-foot widening is economically justified through the bay; however, 820-foot widening is carried forward for additional analysis through ship simulation and economic analysis. **Table 4-41** (Alternative 8). Green highlighted measures are justified and carried forward. Grey highlighted measures are unjustified and are not carried forward. Yellow highlighted measures are unjustified, but require ship simulation prior to removing. All analysis uses October 2017 Price Levels and the FY18 Federal Discount Rate of 2.75 percent.

Table 4-34 summarizes the benefit-cost analysis completed for Alternative 1 (the "Minimum System-Wide Plan). The Bayport Ship Channel Turning Basin (BSC TB) is not economically justified but carried forward for further consideration via ship simulation.

Table 4-34 – Alternative 1 – Minimum System-Wide Plan (No Bay Widening) ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Measures for Design Vessel Transit	BE1_138+369_530	$21,100	$54,000	**$32,900**	**2.6**
	BE1_128+731_530				
	BE1_078+844_530				
	BE1_028+605_530				
	BE2_BSCFlare				
	SA2_BSCFlare				
	CW2_BSC_455				
	CW3_BCC_455				
	BETB3_BCCFlare_1800NS				
BSC TB	TB2_BSCRORO_1800	$2,900	$1,300	**$ (1,600)**	**0.4**
Bayou Deepening	CD4_Whole	$1,800	$30,600	**$28,800**	**17.0**
	CD5_Whole + CD6_Whole	$800	$14,200	**$13,400**	**17.8**
Total[1,2,3]		**$27,100**	**$100,100**	**$73,000**	**3.7**

[1] *Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-35 summarizes the benefit-cost analysis completed for Alternative 2 (the "Bay Plan"). Initial screening of alternative revealed that 900-foot bay widening would not be economically justified. The analysis assumes that any bay widening feature will require between 650 and 820 feet of width. The analysis uses Alternative 8 widening benefits for Alternative 2. Actual benefits would differ between the alternatives and additional analysis would be required if the PDT carries Alternative 2 forward. All bay widening is economically justified at 650-feet and included in the total benefit-cost summary; however, full bay widening at 850 feet would not be economically justified and is not included in a total benefit-cost summary.

Table 4-35 – Alternative 2 – Bay Plan ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900	$11,800	$9,800	**$(2,000)**	**0.8**
	CW1_Redfish-BSC_900	$28,600	$9,400	**$(19,200)**	**0.3**
	CW1_BSC-BCC_900	$17,800	$3,200	**$(14,600)**	**0.2**
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	$40,400	$20,200	**$(20,200)**	**0.5**
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	$58,100	$27,300	**$(30,800)**	**0.5**
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820	$7,900	$9,800	**$1,900**	**1.2**
	CW1_Redfish-BSC_820	$21,600	$9,400	**$(12,200)**	**0.4**
	CW1_BSC-BCC_820	$13,900	$3,200	**$(10,700)**	**0.2**
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	$29,500	$20,200	**$(9,300)**	**0.7**
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820 CW1_BSC-BCC_820	$43,400	$27,300	**$(16,100)**	**0.6**
Bay widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650	$2,000	$9,800	**$7,800**	**4.9**
	CW1_Redfish-BSC_650	$8,000	$9,400	**$1,400**	**1.2**
	CW1_BSC-BCC_650	$6,000	$3,200	**$(2,800)**	**0.5**
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	$10,000	$20,200	**$10,200**	**2.0**
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	$16,000	$27,300	**$11,300**	**1.7**
Design Vessel Measures	BE1_138+369_530 BE1_128+731_530 BE1_078+844_530 BE1_028+605_530 BE2_BSCFlare SA2_BSCFlare CW2_BSC_455 CW3_BCC_455 BETB3_BCCFlare_1800NS	$21,100	$54,000	**$32,900**	**2.6**
BSC TB	TB2_BSCRORO_1800	$2,900	$1,300	**$(1,600)**	**0.4**

Total (650)[1,2,3]	$ 40,000	$82,600	$42,600	2.0

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-36 summarizes the benefit-cost analysis completed for Alternative 3 (the "Suezmax Plan"). Similar to Alternative 2, the analysis uses Alternative 8 widening benefits for Alternative 3. Actual benefits would differ between the alternatives and additional analysis would be required if the PDT carries Alternative 3 forward. Widening in the Bay, Upper Bay, San-Jacinto to Boggy Bayou, and Bayport Ship Channel remain in the total pending safety validation through ship simulation.

Table 4-36 – Alternative 3 – Suezmax Plan ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900*	$11,800	$9,800	**$(2,000)**	**0.8**
	CW1_Redfish-BSC_900	$28,600	$9,400	**$(19,200)**	**0.3**
	CW1_BSC-BCC_900	$17,800	$3,200	**$(14,600)**	**0.2**
	CW1_BR-Redfish_900* CW1_Redfish-BSC_900	$40,400	$20,200	**$(20,200)**	**0.5**
	CW1_BR-Redfish_900* CW1_Redfish-BSC_900 CW1_BSC-BCC_900	$58,200	$27,300	**$(30,900)**	**0.5**
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820*	$7,900	$9,800	**$1,900**	**1.2**
	CW1_Redfish-BSC_820	$21,600	$9,400	**$(12,200)**	**0.4**
	CW1_BSC-BCC_820	$13,900	$3,200	**$(10,700)**	**0.2**
	CW1_BR-Redfish_820* CW1_Redfish-BSC_820	$29,500	$20,200	**$(9,300)**	**0.7**
	CW1_BR-Redfish_820* CW1_Redfish-BSC_820 CW1_BSC-BCC_820	$43,400	$27,300	**$(16,100)**	**0.6**
Bay widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650*	$2,000	$9,800	**$7,800**	**4.9**
	CW1_Redfish-BSC_650	$8,000	$9,400	**$1,400**	**1.2**
	CW1_BSC-BCC_650	$6,000	$3,200	**$(2,800)**	**0.5**
	CW1_BR-Redfish_650* CW1_Redfish-BSC_650	$10,000	$20,200	**$10,200**	**2.0**
	CW1_BR-Redfish_650* CW1_Redfish-BSC_650 CW1_BSC-BCC_650	$16,000	$27,300	**$11,300**	**1.7**
Bay Bend Easing	BE1_138+369_530 BE1_128+731_530 BE1_078+844_530 BE1_028+605_530	$3,300	$0	**$(3,300)**	**N/A**
Upper Bay Bend Easing	CW1_HOG_600 BE1_153+06	$1,900	$0	**(1,900)**	**N/A**

	BE1_246+54				
SJM-BB	CW1_SJM-BB_530	$1,500	$200,000	**$(1,300)**	**0.1**
BSC Widening	CW2_BSC_455	$8,100	$1,100	**$(7,000)**	**0.1**
Total[1,2,3]		**$30,800**	**$28,600**	**$(2,200)**	**0.9**

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-37 summarizes the benefit-cost analysis completed for Alternative 4 (the "Aframax Plan"). Analysis includes Segment 4 turning basin measures and channel widening for validation through ship simulation.

Table 4-37 – Alternative 4 – Aframax Plan ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Aframax Measures	CD4_Whole	$1,800	$30,600	**$28,800**	**17.0**
	CW4_BB-GB_530	$2,700	$11,400	**$8,700**	**4.2**
	TB4_775+00	$1,900	$-	**$(1,900)**	**0.0**
	TB4_Hunting	$300	$-	**$(300)**	**0.0**
	CW1_SJM-BB_530	$1,500	$200	**$(1,300)**	**0.1**
Total[1,2,3]		**$8,700**	**$42,200**	**$33,500**	**4.9**

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-38 summarizes the benefit-cost analysis completed for Alternative 5. Hunting and Brady Island Turning Basins are included for validation through ship simulation.

Table 4-38 – Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
To Accommodate Bulker, Tanker, and Behicle Carrier Design Vessel	CD4_Whole	$1,800	$30,600	**$28,800**	**17.0**
	TB4_Hunting	$300	$-	**$(300)**	
	CD5_Whole + CD6_Whole	$800	$14,200	**$13,400**	**17.8**
	TB6_Brady_900	$1,000	$-	**$(1,000)**	
Total[1,2,3]		**$4,400**	**$44,800**	**$40,400**	**10.2**

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-39 summarizes the benefit-cost analysis completed for Alternative 6. Alternative 6 is not economically justified.

Table 4-39 – Alternative 6 – Bay Mooring ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Mooring	MM2_BSC_1800	$5,100	$3,400	**$(1,700)**	**0.7**

Table 4-40 summarizes the benefit-cost analysis completed for Alternative 7. Only the mooring facility located near 520+00 is economically justified and included in the total.

Table 4-40 – Alternative 7 – Upper Channel Moorings ($000)

Alt.	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Mooring	MM1_AI(d)	$6,700	$4,400	**$(2,300)**	**0.7**
	MM1_520+00	$3,300	$4,800	**$1,500**	**1.5**
Total[1,2,3]		**$3,300**	**$4,800**	**$1,500**	**1.5**

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

Table 4-41 summarizes the benefit-cost analysis completed for Alternative 8 ("The Everything Plan"). Similar to Alternative 2 and Alternative 3, 900-foot bay widening is not economically justified. The table includes benefit-cost summaries for both 820-foot widening and 650-foot widening. Only 650-foot widening is economically justified through the bay; however, 820-foot widening is carried forward for additional analysis through ship simulation and economic analysis.

Table 4-41 – Alternative 8 – The Everything Plan ($000)

Alternative	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Measures for Design Vessel Transit	BE1_138+369_530 BE1_128+731_530 BE1_078+844_530 BE1_028+605_530 BE2_BSCFlare SA2_BSCFlare CW2_BSC_455 CW3_BCC_455 BETB3_BCCFlare_1800NS	$21,100	$54,000	**$32,900**	**2.6**
BSC TB	TB2_BSCRORO_1800	$2,900	$1,300	**$(1,600)**	**0.4**
Bay Mooring	MM2_BSC_1800	$5,100	$3,400	**$(1,700)**	**0.7**
Bayou Deepening	CD4_Whole	$1,800	$30,600	**$28,800**	**17.0**
	CD5_Whole + CD6_Whole	$800	$14,200	**$13,400**	**17.8**
Bay Widening_900	CW1_BR-Redfish_900	$11,800	$9,800	**$(2,000)**	**0.8**
	CW1_Redfish-BSC_900	$28,600	$9,400	**$(19,200)**	**0.3**
	CW1_BSC-BCC_900	$17,800	$3,200	**$(14,600)**	**0.2**
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	$40,400	$20,200	**$(20,200)**	**0.5**

Alternative	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	$58,200	$27,300	**$(30,900)**	**0.5**
Bay Widening_820	CW1_BR-Redfish_820	$7,900	$9,800	**$1,900**	**1.2**
	CW1_Redfish-BSC_820	$21,600	$9,400	**$(12,200)**	**0.4**
	CW1_BSC-BCC_820	$13,900	$3,200	**$(10,700)**	**0.2**
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	$29,500	$20,200	**$(9,300)**	**0.7**
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820 CW1_BSC-BCC_820	$43,400	$27,300	**$(16,100)**	**0.6**
Bay Widening_650	CW1_BR-Redfish_650	$2,000	$9,800	**$7,800**	**4.9**
	CW1_Redfish-BSC_650	$8,000	$9,400	**$1,400**	**1.2**
	CW1_BSC-BCC_650	$6,000	$3,200	**$(2,800)**	**0.5**
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	$10,000	$20,200	**$10,200**	**2.0**
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	$16,000	$27,300	**$11,300**	**1.7**
SJM-BB Widening	CW1_SJM-BB_530	$1,500	$200	**$(1,300)**	**0.2**
Upper Bay BE_Suezmax	CW1_HOG_600 BE1_153+06 BE1_246+54	$1,900	$-	**$-**	**0.0**
Aframax Widening	CW4_BB-GB_530	$2,700	$11,400	**$8,700**	**4.2**
Bayou TB	TB4_775+00	$1,900	$-	**$(1,900)**	**0.0**
	TB4_Hunting	$300	$-	**$(300)**	**0.0**
Brady Island TB	TB6_Brady_900	$1,000	$-	**$(1,000)**	**0.0**
Bayou Mooring	MM1_AI(d)	$6,700	$4,400	**$(2,300)**	**0.7**
	MM1_520+00*	$3,300	$4,800	**$1,500**	**1.5**
Total (650')[1,2,3]		**$55,700**	**$143,800**	**$88,100**	**2.6**
Total (820') [1,2,3]		**$83,100**	**$143,800**	**$60,700**	**1.7**

[1]*Includes measures that are economically justified (green) and requiring validation via ship simulation (*yellow).*
[2] *Includes costs associated with pipeline relocations and real estate*
[3] *Excludes measures lacking economic justification (*gray).*

4.5 TSP RECOMMENDATION

Based on economic evaluation, environmental acceptability, and engineering feasibility, the Project Delivery Team recommends Alternative 8 as the recommended plan. **Table 4-42** summarizes all costs and benefits associated with each alternative using October 2017 price level and the FY18 discount rate (2.75 percent). Bay widening requires ship simulation prior to final screening. Until simulation confirms an acceptable width and length for the change in pilot rules listed in **Table 4-4**, the study assumes that the channel width required to realize the benefits discussed in **Section 4.4** is between 650 feet and 820 feet. Costs, net benefits, and benefit-cost ratios are presented for both widths.

Table 4-42: All Alternative Cost and Benefit Analysis ($000)

Alternative	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
1	$848,906	$27,100	$100,100	**$73,000**	3.7
2	$1,304,268	$40,000	$82,600	**$42,600**	2.1
3	$1,018,093	$30,800	$28,600	**$(2,200)**	0.9
4	$312,136	$8,700	$42,200	**$33,500**	4.9
5	$126,677	$4,400	$44,800	**$40,400**	10.2
6	$164,125	$5,100	$3,400	**$(1,700)**	0.7
7	$116,240	$3,300	$4,800	**$1,500**	1.5
8 (650’)	$1,849,741	$55,700	$143,800	**$88,100**	**2.6**
8 (820’)	$2,727,206	$83,100	$143,800	**$60,700**	**1.7**

4.6 DEPTH OPTIMIZATION

The PDT conducted channel depth optimization for deepening measures in Segment 4 and Segments 5 through 6. This analysis confirms that the measures listed in **Table 4-41** maximize net excess benefits. **Table 4-43** summarizes the results of the analysis using October 2017 price levels and the FY18 Federal discount rate (2.75 percent).

Table 4-43: Channel Depth Optimization

Location	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Segment 4	CD4_43.5	$429	$14,500	$14,071	33.8
	CD4_46.5	$1,800	$30,600	$28,800	17.0
Segments 5-6	CD5_38.5 & CD6_38.5	$399	$9,750	$9,351	24.4
	CD5_41.5 & CD6_41.5	$800	$14,200	$13,400	17.8

4.7 DETAILED BENEFIT-COST ANALYIS OF TSP

Table 4-44 provides total project costs and interest during construction of the TSP with 650-foot widening and with 820-foot widening. Interest during construction accounts for the opportunity cost of expended funds before the benefits of the project are available and is included among the economic costs that comprise the project costs. The amount of the pre-base year cost equivalent adjustments depends on the interest rate; the construction schedule, which determines the point in time at which costs occur; and the magnitude of the costs to be adjusted. The Preconstruction Engineering and Design (PED) durations are included in the IDC as well as the construction durations. Interest during construction (IDC) was calculated assuming that the schedule may vary depending on the time required to obtain congressional authorization and funding. Other areas of the project uncertainties include the dredging industry execution of bid and contract requirements, availability of contractors' dredging equipment to comply with environmental windows, and delays due to unexpected weather conditions. Based on these uncertainties the construction duration for the project is variable. For IDC estimating purposes the District used 60 months for each project alternative. The IDC was computed with the 2017 fiscal year interest rate of 2.75 percent.

Table 4-44: HSC ECIP Equivalent Annual Costs and Benefits

2017 Price Level, 50 Year Period of Analysis, 2.75 Percent Discount Rate		
(TSP - Difference in Reference to Width of Bay Widening (650 feet and 820 feet range)		
	TSP (650' widening)	TSP (820' widening)
Investment Costs		
Total Project Construction Costs	$950,000,000	$1,452,000,000
Interest During Construction	$66,600,000	$103,100,000
Total Investment Cost	**$1,016,600,000**	**$1,554,000,000**
Average Annual Costs		
Construction Average Annual Costs	$37,700,000	$57,600,000
OMRR&R	$18,000,000	$25,500,000
Total Average Annual Costs	**$55,700,000**	**$83,100,000**
Average Annual Benefits	$143,800,000	$143,800,000
Net Annual Benefits	$88,100,000	$60,700,000
Benefit-Cost Ratio	**2.6**	**1.7**

5 SENSITIVITY ANALYSIS

The Principle & Guidelines and subsequent ER1105-2-100 recognize the inherent variability to water resources planning. Navigation projects in particular are fraught with uncertainty about future conditions given ever-changing market conditions. Therefore, this economic evaluation conducted a sensitivity analysis in which the most consequential assumptions pertaining to commodity and vessel traffic were adjusted to test the robustness of the final benefit evaluation. The HarborSym model used in the basic evaluation included variations or ranges for many of the variables involved in the vessel costs, loading, distances, etc. However, it used only one basis commodity forecast, a key area of potential uncertainty. This sensitivity analysis presents the results of a large range of potentially different forecast of future commodity traffic at Houston Ship Channel.

5.1 CONTAINERIZED DATA

Section 3.2.4.1 details the methodology used to develop the containerized forecast for HSC ECIP, Section 4.2.1 summarizes origin-destination benefits of measures for design vessel transit, and Section 4.4 provides the benefit-cost ratio for all alternatives including containership origin-destination benefits. This sensitivity analysis developed three alternate scenarios for commodity and vessel fleet growth: “High Growth”, “Low Growth”, and “No Growth” from the Base Year (2029). The “High Growth” Scenario (Table 5-1) assumes the port's container terminals reach capacity by 2039. Between 2029 and 2039, total throughput tonnage grows at a compound annual growth rate of 4.5 percent (equal to the containerized tonnage growth rate between 2010 and 2014). Low Growth Scenario (Table 5-2) assumes that containerized throughput tonnage will grow at approximately half the baseline growth rate over the study period. Using this assumption, Port Houston Container Terminals reach capacity in 2049. No Growth Scenario (Table 5-3) assumes no growth in throughput tonnage at Houston Ship Channel from the base year.

Table 5-1: Containerized Data High Growth Scenario

Route – Tons	Baseline	2029	2034	2039	2044
Import Total	*6,703,000*	*12,179,000*	*16,871,000*	*17,406,000*	*17,406,000*
CAR-CA-NCSA	469,000	772,000	1,011,000	1,038,000	1,038,000
ECSA-NA	1,024,000	1,888,000	2,741,000	2,842,000	2,842,000
FE-NA-PAN	1,365,000	3,205,000	4,733,000	4,909,000	4,909,000
FE-NA-SUEZ	965,000	1,774,000	2,484,000	2,566,000	2,566,000
MED-NA	1,070,000	1,683,000	2,149,000	2,199,000	2,199,000
NEU-NA	1,810,000	2,857,000	3,752,000	3,852,000	3,852,000
Export Total	*8,110,000*	*16,479,000*	*25,941,000*	*27,191,000*	*27,191,000*
CAR-CA-NCSA	955,000	1,623,000	2,160,000	2,221,000	2,221,000
ECSA-NA	1,588,000	2,875,000	4,125,000	4,275,000	4,275,000
FE-NA-PAN	990,000	3,432,000	7,659,000	8,292,000	8,292,000
FE-NA-SUEZ	1,224,000	2,222,000	3,057,000	3,154,000	3,154,000
MED-NA	1,350,000	2,503,000	3,481,000	3,596,000	3,596,000
NEU-NA	2,003,000	3,823,000	5,459,000	5,653,000	5,653,000

Route – Tons	Baseline	2029	2034	2039	2044
Grand Total	**14,813,000**	**28,657,000**	**42,811,000**	**44,597,000**	**44,597,000**

Table 5-2: Containerized Data Low Growth Scenario

Route – Tons	Baseline	2029	2039	2049	2054
Import Total	*6,703,000*	*12,179,000*	*14,459,000*	*17,406,000*	*17,406,000*
CAR-CA-NCSA	469,000	772,000	890,000	1,038,000	1,038,000
ECSA-NA	1,024,000	1,888,000	2,291,000	2,842,000	2,842,000
FE-NA-PAN	1,365,000	3,205,000	3,955,000	4,909,000	4,909,000
FE-NA-SUEZ	965,000	1,774,000	2,116,000	2,566,000	2,566,000
MED-NA	1,070,000	1,683,000	1,916,000	2,199,000	2,199,000
NEU-NA	1,810,000	2,857,000	3,292,000	3,852,000	3,852,000
Export Total	*8,110,000*	*16,479,000*	*20,649,000*	*27,191,000*	*27,191,000*
CAR-CA-NCSA	955,000	1,623,000	1,878,000	2,221,000	2,221,000
ECSA-NA	1,588,000	2,875,000	3,449,000	4,275,000	4,275,000
FE-NA-PAN	990,000	3,432,000	5,154,000	8,292,000	8,292,000
FE-NA-SUEZ	1,224,000	2,222,000	2,616,000	3,154,000	3,154,000
MED-NA	1,350,000	2,503,000	2,964,000	3,596,000	3,596,000
NEU-NA	2,003,000	3,823,000	4,587,000	5,653,000	5,653,000
Grand Total	**14,813,000**	**28,657,000**	**35,108,000**	**44,597,000**	**44,597,000**

Table 5-3: Containerized Data No Growth Scenario

Route – Tons	Baseline	2029	2034	2039	2044
Import Total	*6,703,000*	*12,179,000*	*12,179,000*	*12,179,000*	*12,179,000*
CAR-CA-NCSA	469,000	772,000	772,000	772,000	772,000
ECSA-NA	1,024,000	1,888,000	1,888,000	1,888,000	1,888,000
FE-NA-PAN	1,365,000	3,205,000	3,205,000	3,205,000	3,205,000
FE-NA-SUEZ	965,000	1,774,000	1,774,000	1,774,000	1,774,000
MED-NA	1,070,000	1,683,000	1,683,000	1,683,000	1,683,000
NEU-NA	1,810,000	2,857,000	2,857,000	2,857,000	2,857,000
Export Total	*8,110,000*	*16,479,000*	*16,479,000*	*16,479,000*	*16,479,000*
CAR-CA-NCSA	955,000	1,623,000	1,623,000	1,623,000	1,623,000
ECSA-NA	1,588,000	2,875,000	2,875,000	2,875,000	2,875,000
FE-NA-PAN	990,000	3,432,000	3,432,000	3,432,000	3,432,000
FE-NA-SUEZ	1,224,000	2,222,000	2,222,000	2,222,000	2,222,000
MED-NA	1,350,000	2,503,000	2,503,000	2,503,000	2,503,000
NEU-NA	2,003,000	3,823,000	3,823,000	3,823,000	3,823,000
Grand Total	**14,813,000**	**28,657,000**	**28,657,000**	**28,657,000**	**28,657,000**

The sensitivity analysis also tested potential impacts of changes in containership fleet transition compared to the baseline forecast. The High Growth Scenario (Table 5-4) assumed that fleet transition took place at twice the rate forecasted by the baseline forecast. The Low Growth

Scenario (Table 5-5) assumed the fleet transition took place at approximately half the rate forecasted by the baseline condition. The No Growth Scenario (Table 5-6) assumed no change in containership fleet.

Table 5-4: Containerized Calls High Growth Scenario

Year	Vessel Class	FWOP	Bayport Improvement	Barbours Improvement	Bayport & Barbours Improvement (Measures for Design Vessel Transit)
2029	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2034	SPX	433	433	433	433
	PX	718	718	718	718
	PPX I	493	493	493	493
	PPX II	364	238	263	137
	PPX III	-	111	90	201
2039	SPX	440	440	440	440
	PX	508	508	508	508
	PPX I	535	535	535	535
	PPX II	598	358	473	234
	PPX III	-	213	110	323
2044	SPX	440	440	440	440
	PX	508	508	508	508
	PPX I	535	535	535	535
	PPX II	598	358	473	234
	PPX III	-	213	110	323

Table 5-5: Containerized Calls Low Growth Scenario

Year	Vessel Class	FWOP	Bayport Improvement	Barbours Improvement	Bayport & Barbours Improvement (Measures for Design Vessel Transit)
2029	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2039	SPX	353	353	353	353
	PX	674	674	674	674
	PPX I	374	374	374	374
	PPX II	260	175	188	103

Year	Vessel Class	FWOP	Bayport Improvement	Barbours Improvement	Bayport & Barbours Improvement (Measures for Design Vessel Transit)
	PPX III	-	76	63	139
2049	SPX	433	433	433	433
	PX	718	718	718	718
	PPX I	493	493	493	493
	PPX II	364	238	263	137
	PPX III	-	111	90	201
2054	SPX	440	440	440	440
	PX	508	508	508	508
	PPX I	535	535	535	535
	PPX II	598	358	473	234
	PPX III	-	213	110	323

Table 5-6: Containerized Calls No Growth Scenario

Year	Vessel Class	FWOP	Bayport Improvement	Barbours Improvement	Bayport & Barbours Improvement (Measures for Design Vessel Transit)
2029	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2034	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2039	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77
2044	SPX	357	357	357	357
	PX	611	611	611	611
	PPX I	301	301	301	301
	PPX II	151	104	111	63
	PPX III	-	42	35	77

Figure 5-1 and Figure 5-2 below show the import and export containerized commodity tonnage forecast scenarios, respectively.

Figure 5-1: Containerized Import Forecast Scenarios

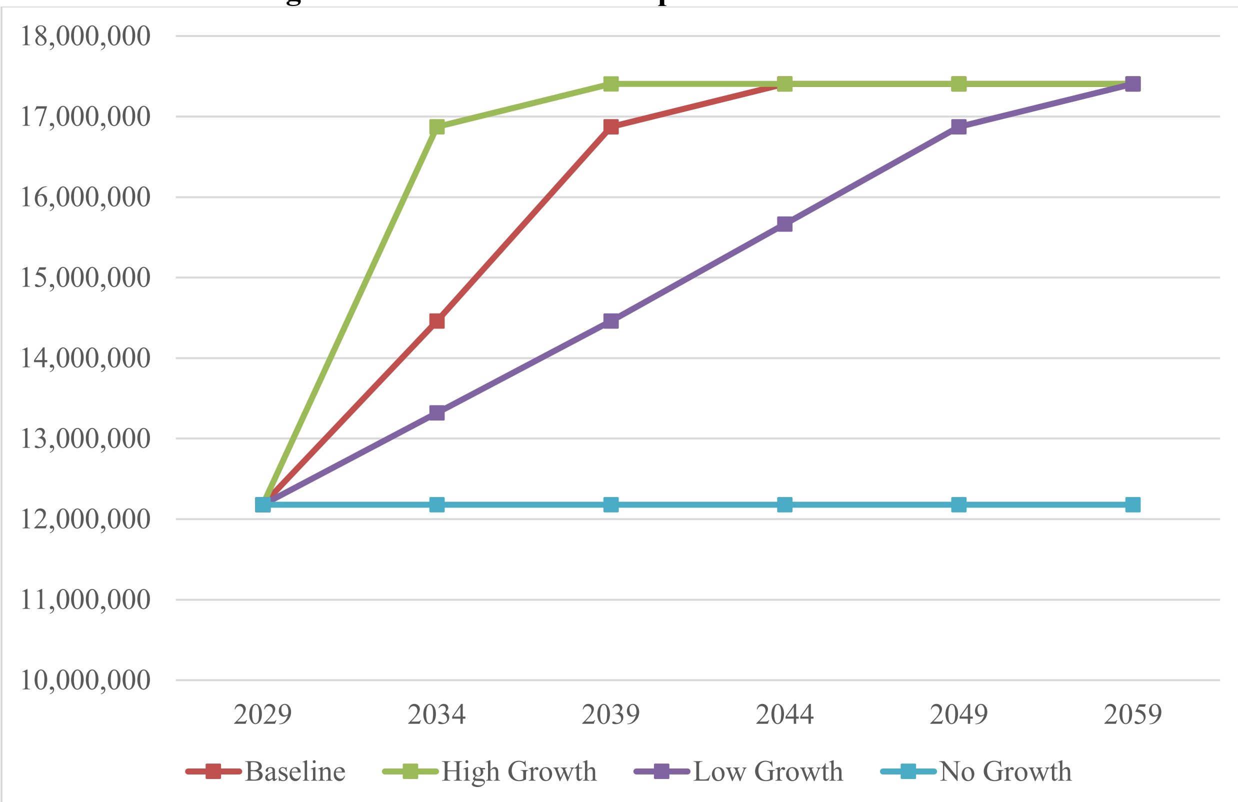
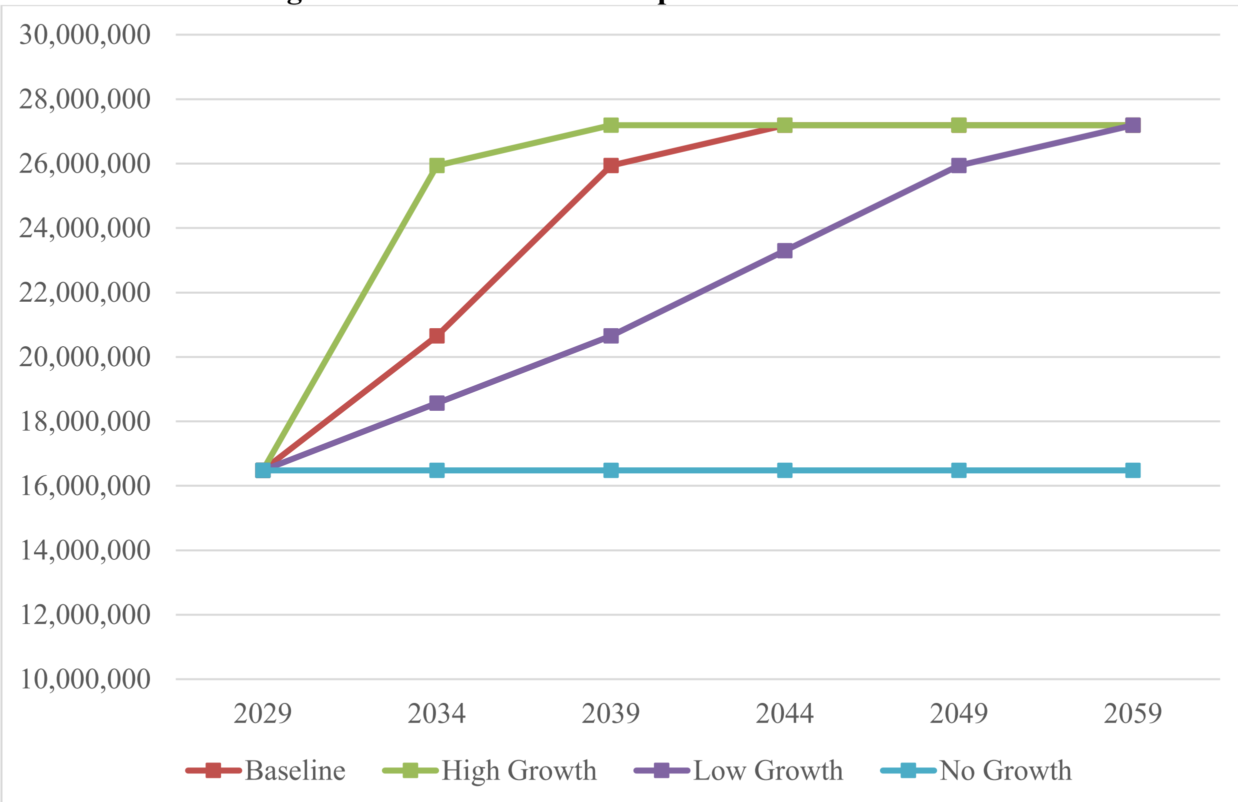


Figure 5-2: Containerized Export Forecast Scenarios



5.1.1 Containerized Benefits Sensitivity Analysis Results

Table 5-7 summarizes the benefit cost analysis of the sensitivity analysis. The baseline forecast used in the main analysis is included for comparison. The results of this analysis show that economic justification stands for all scenarios with the exception of the No Growth Scenario. This points to the importance of both the fleet shift and commodity growth in the baseline condition's out years. While important to note that the No Growth Scenario would lead to an unjustified project, this is also the least likely scenario.

Table 5-7: Summary of Containerized Benefits Sensitivity Analysis

Scenario	Total AAEQ Costs	Total AAEQ Benefits*	Total Net Benefits	Benefit/Cost Ratio
High Growth	$21,100,000	$59,200,000	$38,100,000	2.8
Baseline	$21,100,000	$52,900,000	$31,800,000	2.5
Low Growth	$21,100,000	$41,700,000	$20,600,000	2.0
No Growth	$21,100,000	$14,500,000	($6,600,000)	0.7

*Excludes benefits associated with transit of Suezmax Tankers into Bayport Ship Channel

5.2 BULK DATA

Section 3.2.1 details the methodology used to develop the bulk commodity forecast for HSC ECIP, Section 4.2.2 through Section 4.2.3 summarizes origin-destination benefits of bulk commodity traffic, and Section 4.4 provides the benefit-cost ratio for all alternatives including bulk origin-destination benefits. This sensitivity analysis developed three alternate scenarios for commodity and vessel fleet growth: “High Growth”, “Low Growth”, and “No Growth” from the Base Year (2029). The “High Growth” Scenario (Table 5-8) assumes Houston Ship Channel reaches capacity by 2034. Between 2029 and 2034, total throughput tonnage grows at a compound annual growth rate of 1.3 percent (equal to the bulk tonnage growth rate between 2013 and 2015). Low Growth Scenario (Table 5-9) assumes that bulk throughput tonnage will grow at approximately half the baseline growth rate over the study period. The No Growth Scenario (Table 5-10) assumes no growth in throughput tonnage at Houston Ship Channel from the base year.

Table 5-8: Bulk Data High Growth Scenario

Direction	Commodity Name	2029	2034
Imports	Chemicals and Related Products	4,652,000	5,794,000
	Coal	-	-
	Crude Materials	3,252,000	3,832,000
	Food and Farm Products	819,000	1,089,000
	Manufactured Equipment, Machinery	1,565,000	2,101,000
	Other	578,000	578,000
	Petroleum and Petroleum Products	49,547,000	50,896,000
	Primary Manufactured Goods	11,361,000	14,537,000
	Total	**71,774,000**	**78,827,000**
Exports	Chemicals and Related Products	11,950,000	13,795,000
	Coal	1,595,000	1,871,000
	Crude Materials	1,074,000	1,307,000
	Food and Farm Products	6,862,000	8,316,000
	Manufactured Equipment, Machinery	1,879,000	2,618,000
	Other	607,000	607,000
	Petroleum and Petroleum Products	83,614,000	84,030,000
	Primary Manufactured Goods	684,000	889,000
	Total	**108,263,000**	**113,432,000**

Table 5-9: Bulk Data Low Growth Scenario

Direction	Commodity Name	2029	2039	2049
Imports	Chemicals and Related Products	4,652,000	5,217,000	5,794,000
	Coal	-	-	-
	Crude Materials	3,252,000	3,524,000	3,832,000
	Food and Farm Products	819,000	943,000	1,089,000
	Manufactured Equipment, Machinery	1,565,000	1,844,000	2,101,000
	Other	578,000	578,000	578,000

Direction	Commodity Name	2029	2039	2049
	Petroleum and Petroleum Products	49,547,000	50,687,000	50,896,000
	Primary Manufactured Goods	11,361,000	13,034,000	14,537,000
	Total	**71,774,000**	**75,828,000**	**78,827,000**
Exports	Chemicals and Related Products	11,950,000	12,687,000	13,795,000
	Coal	1,595,000	1,741,000	1,871,000
	Crude Materials	1,074,000	1,184,000	1,307,000
	Food and Farm Products	6,862,000	7,528,000	8,316,000
	Manufactured Equipment, Machinery	1,879,000	2,272,000	2,618,000
	Other	607,000	607,000	607,000
	Petroleum and Petroleum Products	83,614,000	84,819,000	84,030,000
	Primary Manufactured Goods	684,000	794,000	889,000
	Total	**108,263,000**	**111,633,000**	**113,432,000**

Table 5-10: Bulk Data No Growth Scenario

Direction	Commodity Name	2029
Imports	Chemicals and Related Products	4,652,000
	Coal	-
	Crude Materials	3,252,000
	Food and Farm Products	819,000
	Manufactured Equipment, Machinery	1,565,000
	Other	578,000
	Petroleum and Petroleum Products	49,547,000
	Primary Manufactured Goods	11,361,000
	Total	**71,774,000**
Exports	Chemicals and Related Products	11,950,000
	Coal	1,595,000
	Crude Materials	1,074,000
	Food and Farm Products	6,862,000
	Manufactured Equipment, Machinery	1,879,000
	Other	607,000
	Petroleum and Petroleum Products	83,614,000
	Primary Manufactured Goods	684,000
	Total	**108,263,000**

The sensitivity analysis also tested potential impacts of changes in bulk fleet transition compared to the baseline forecast. The High Growth Scenario (Table 5-11) assumed that fleet transition took place at twice the rate forecasted by the baseline forecast. The Low Growth Scenario (Table 5-12) assumed the fleet transition took place at approximately half the rate forecasted by the baseline condition. The No Growth Scenario (Table 5-13) assumed no change in bulk fleet.

Table 5-11: Bulk Vessel Calls High Growth Scenario

Vessel Type	Vessel Class	2029		2034	
		FWOP	FWP	FWOP	FWP
Tanker	10k-30k Tanker	9	9	-	-
Tanker	30k-55k Tanker	1,516	1,123	1,409	922
Tanker	55k-75k Tanker	360	360	447	447
Tanker	75k-100k Tanker	81	81	78	78
Tanker	100k-130k Tanker	571	571	572	572
Tanker	130k-157.5k Tanker	45	85	41	105
Tanker	157.5k-215k Tanker	53	80	65	100
Tanker	215k-282.5k Tanker	-	-	-	-
Tanker	282.5k-310k Tanker	-	-	-	-
Tanker	310k-320k Tanker	-	-	-	-
Bulker	7.5k-30k Bulker	129	129	141	141
Bulker	30k-45k Bulker	452	452	601	601
Bulker	45k-70k Bulker	715	715	845	845
Bulker	70k-110k Bulker	106	106	114	114
Bulker	110k-135k Bulker	7	7	7	7
LNG Tanker	2.5k-13.5k LNG	219	219	190	190
LNG Tanker	13.5k-33.5k LNG	198	198	225	225
LNG Tanker	33.5k-49.2k LNG	21	21	17	17
LNG Tanker	49.2k-64.2k LNG	285	285	289	289
General Cargo	5.5k-12.5k General Cargo	806	806	1,203	1,203
General Cargo	12.5k-15k General Cargo	248	248	328	328
General Cargo	15.5k-18k General Cargo	168	168	208	208
General Cargo	18k-22k General Cargo	202	202	238	238
General Cargo	22k-27k General Cargo	177	177	187	187
General Cargo	27k-30k General Cargo	199	199	235	235
RoRo Carrier	9.15k-15.9k RoRo	51	51	61	61
RoRo Carrier	15.9k-20.9k RoRo	93	93	130	130
Chemical Tanker	4.5k-13.5k Chem Tanker	263	263	402	402
Chemical Tanker	13.5k-21.5k Chem Tanker	526	526	574	574
Chemical Tanker	21.5-29k Chem Tanker	143	143	141	141
Chemical Tanker	29k-33k Chem Tanker	208	208	211	211
Total		**7,851**	**7,525**	**8,959**	**8,571**

Table 5-12: Bulk Vessel Calls Low Growth Scenario

Vessel Type	Vessel Class	2029		2039		2049	
		FWOP	FWP	FWOP	FWP	FWOP	FWP
Tanker	10k-30k Tanker	9	9	10	10	-	-
Tanker	30k-55k Tanker	1,516	1,123	1,516	962	1,409	922
Tanker	55k-75k Tanker	360	360	413	413	447	447
Tanker	75k-100k Tanker	81	81	77	77	78	78
Tanker	100k-130k Tanker	571	571	579	579	572	572

Vessel Type	Vessel Class	2029		2039		2049	
		FWOP	FWP	FWOP	FWP	FWOP	FWP
Tanker	130k-157.5k Tanker	45	85	41	100	41	105
Tanker	157.5k-215k Tanker	53	80	49	93	65	100
Tanker	215k-282.5k Tanker	-	-	-	-	-	-
Tanker	282.5k-310k Tanker	-	-	-	-	-	-
Tanker	310k-320k Tanker	-	-	-	-	-	-
Bulker	7.5k-30k Bulker	129	129	121	121	141	141
Bulker	30k-45k Bulker	452	452	552	552	601	601
Bulker	45k-70k Bulker	715	715	779	779	845	845
Bulker	70k-110k Bulker	106	106	113	113	114	114
Bulker	110k-135k Bulker	7	7	7	7	7	7
LNG Tanker	2.5k-13.5k LNG	219	219	122	122	190	190
LNG Tanker	13.5k-33.5k LNG	198	198	210	210	225	225
LNG Tanker	33.5k-49.2k LNG	21	21	16	16	17	17
LNG Tanker	49.2k-64.2k LNG	285	285	302	302	289	289
General Cargo	5.5k-12.5k Gen Cargo	806	806	941	941	1,203	1,203
General Cargo	12.5k-15k General Cargo	248	248	316	316	328	328
General Cargo	15.5k-18k General Cargo	168	168	184	184	208	208
General Cargo	18k-22k General Cargo	202	202	225	225	238	238
General Cargo	22k-27k General Cargo	177	177	186	186	187	187
General Cargo	27k-30k General Cargo	199	199	213	213	235	235
RoRo Carrier	9.15k-15.9k RoRo	51	51	59	59	61	61
RoRo Carrier	15.9k-20.9k RoRo	93	93	110	110	130	130
Chemical Tanker	4.5k-13.5k Chem Tanker	263	263	355	355	402	402
Chemical Tanker	13.5k-21.5k Chem Tank.	526	526	562	562	574	574
Chemical Tanker	21.5-29k Chem Tanker	143	143	140	140	141	141
Chemical Tanker	29k-33k Chem Tanker	208	208	206	206	211	211
Total		**7,851**	**7,525**	**8,404**	**7,953**	**8,959**	**8,571**

Table 5-13: Bulk Vessel Calls No Growth Scenario

Vessel Type	Vessel Class	2029	
		FWOP	FWP
Tanker	10k-30k Tanker	9	9
Tanker	30k-55k Tanker	1,516	1,123
Tanker	55k-75k Tanker	360	360
Tanker	75k-100k Tanker	81	81
Tanker	100k-130k Tanker	571	571
Tanker	130k-157.5k Tanker	45	85
Tanker	157.5k-215k Tanker	53	80
Tanker	215k-282.5k Tanker	-	-

Vessel Type	Vessel Class	2029	
		FWOP	FWP
Tanker	282.5k-310k Tanker	-	-
Tanker	310k-320k Tanker	-	-
Bulker	7.5k-30k Bulker	129	129
Bulker	30k-45k Bulker	452	452
Bulker	45k-70k Bulker	715	715
Bulker	70k-110k Bulker	106	106
Bulker	110k-135k Bulker	7	7
LNG Tanker	2.5k-13.5k LNG	219	219
LNG Tanker	13.5k-33.5k LNG	198	198
LNG Tanker	33.5k-49.2k LNG	21	21
LNG Tanker	49.2k-64.2k LNG	285	285
General Cargo	5.5k-12.5k General Cargo	806	806
General Cargo	12.5k-15k General Cargo	248	248
General Cargo	15.5k-18k General Cargo	168	168
General Cargo	18k-22k General Cargo	202	202
General Cargo	22k-27k General Cargo	177	177
General Cargo	27k-30k General Cargo	199	199
RoRo Carrier	9.15k-15.9k RoRo	51	51
RoRo Carrier	15.9k-20.9k RoRo	93	93
Chemical Tanker	4.5k-13.5k Chem Tanker	263	263
Chemical Tanker	13.5k-21.5k Chem Tanker	526	526
Chemical Tanker	21.5-29k Chem Tanker	143	143
Chemical Tanker	29k-33k Chem Tanker	208	208
Total		**7,851**	**7,525**

Table 5-3 and **Table 5-4** below show the import and export bulk commodity tonnage forecast scenarios, respectively.

Figure 5-3: Bulk Import Trade Scenarios

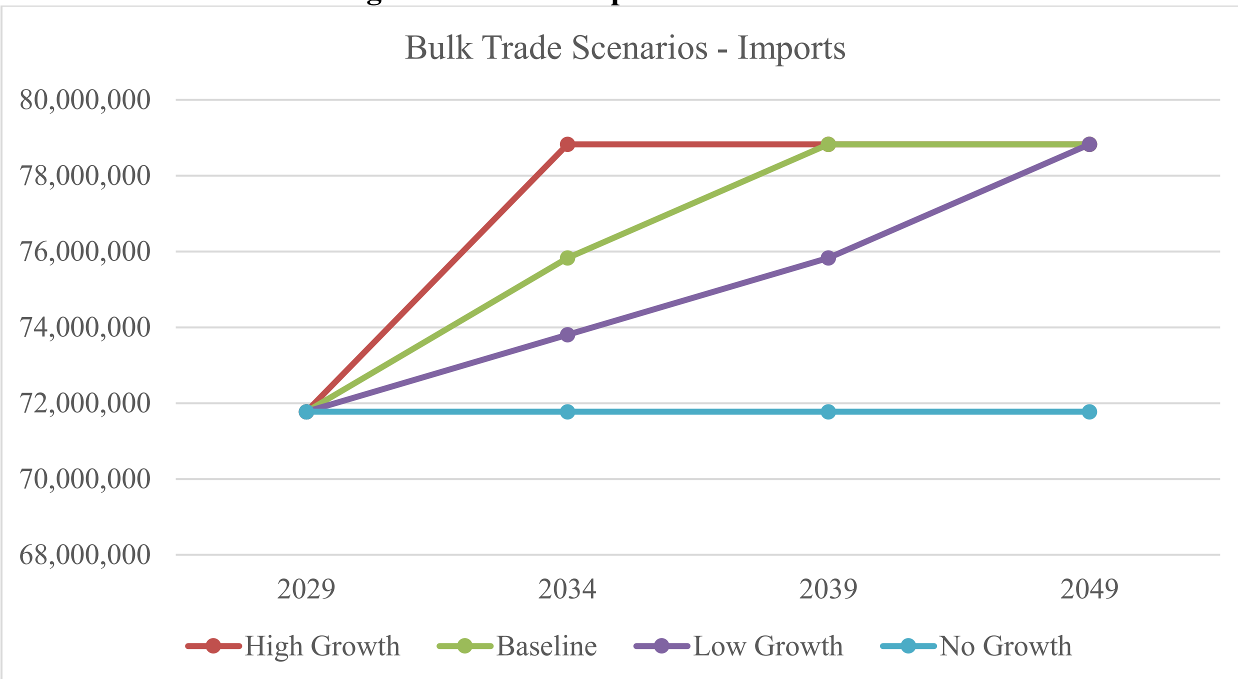
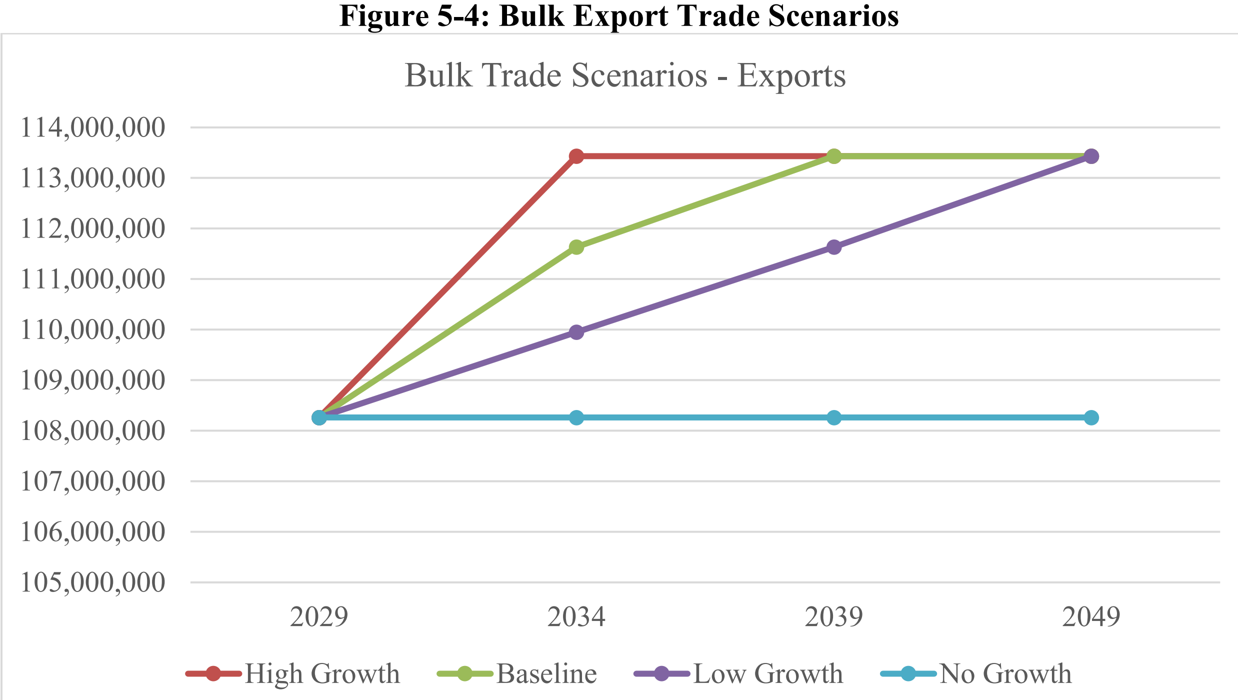


Figure 5-4: Bulk Export Trade Scenarios



5.2.1 Bulk Cost Savings Benefits Sensitivity Analysis Results

Table 5-14 summarizes the benefit cost analysis of the sensitivity analysis for channel deepening and widening in Segment 4. The baseline forecast used in the main analysis is included for comparison. All scenarios (High Growth, Low Growth, and No Growth) indicate deepening and widening Segment 4 is economically justified.

Table 5-14: Segment 4 Summary of Benefits by Channel Depth and Growth Scenario

Measure	Scenario	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
CD4_43.5	High Growth	N/A	$13,200,000	N/A	N/A
	Baseline	N/A	$13,200,000	N/A	N/A
	Low Growth	N/A	$13,200,000	N/A	N/A
	No Growth	N/A	$13,200,000	N/A	N/A
CD4_46.5	High Growth	$1,800,000	$31,100,000	$29,300,000	17.3
	Baseline	$1,800,000	$30,600,000	$28,800,000	17.0
	Low Growth	$1,800,000	$29,800,000	$28,000,000	16.6
	No Growth	$1,800,000	$26,800,000	$25,000,000	14.9
CD4_46.5 CW4_BB-GB_530	High Growth	$4,500,000	$42,900,000	$38,400,000	9.5
	Baseline	$4,500,000	$42,000,000	$37,500,000	9.3
	Low Growth	$4,500,000	$40,500,000	$36,000,000	9.0
	No Growth	$4,500,000	$34,000,000	$29,500,000	7.6

Table 5-15 summarizes the benefit cost analysis of the sensitivity analysis for channel deepening in Segment 5 and Segment 6. The baseline forecast used in the main analysis is included for comparison. All scenarios (High Growth, Low Growth, and No Growth) indicate deepening Segment 5 and Segment 6 is economically justified under any likely scenario.

Table 5-15: Segments 5-6 Summary of Benefits by Channel Depth and Growth Scenario

Measure	Scenario	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
CD5-6_39.5	High Growth	N/A	$9,200,000	N/A	N/A
	Baseline	N/A	$9,800,000	N/A	N/A
	Low Growth	N/A	$10,000,000	N/A	N/A
	No Growth	N/A	$7,200,000	N/A	N/A
CD5-6_41.5	High Growth	$800,000	$13,300,000	$12,500,000	16.6
	Baseline	$800,000	$14,200,000	$13,400,000	17.8
	Low Growth	$800,000	$14,500,000	$13,700,000	18.1
	No Growth	$800,000	$9,100,000	$8,300,000	11.4

5.3 TRANSPORTATION COST SAVINGS SENSITIVITY

5.3.1 Bay Widening (CW1_BR-Redfish, CW1_Redfish-BSC, CW1_BSC-BCC)

Table 5-16 and **Table 5-17** outline the results of the sensitivity analysis for economic benefits of the proposed bay meeting areas at 650 feet and 820 feet, respectively. The analysis determined the "Low Growth" scenario to be a combination of all the low growth scenarios presented in the previous analyses. This is meant to test meeting benefits given low growth rates for commodities and vessel fleet transition for all channel segments. The same analysis was conducted using all "High Growth" scenarios and all "No Growth" scenarios.

Table 5-16: 650' Widening Benefit Analysis by Growth Scenario

Measure	Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
CW1_BR-Redfish	High Growth	$2,000,000	$10,300,000	$8,300,000	5.2
	Baseline	$2,000,000	$9,800,000	$7,800,000	4.9
	Low Growth	$2,000,000	$9,000,000	$7,000,000	4.5
	No Growth	$2,000,000	$5,800,000	$3,800,000	2.9
CW1_Redfish-BSC	High Growth	$8,200,000	$9,900,000	$1,700,000	1.2
	Baseline	$8,200,000	$9,400,000	$1,200,000	1.1
	Low Growth	$8,200,000	$8,400,000	$200,000	1.0
	No Growth	$8,200,000	$5,400,000	($2,800,000)	0.7
CW1_BSC-BCC	High Growth	$6,100,000	$3,300,000	($2,800,000)	0.5
	Baseline	$6,100,000	$3,200,000	($2,900,000)	0.5
	Low Growth	$6,100,000	$3,000,000	($3,100,000)	0.5
	No Growth	$6,100,000	$2,300,000	($3,800,000)	0.4
CW1_BR-BSC	High Growth	$10,200,000	$21,200,000	$11,000,000	2.1
	Baseline	$10,200,000	$20,200,000	$10,000,000	2.0
	Low Growth	$10,200,000	$18,300,000	$8,100,000	1.8
	No Growth	$10,200,000	$11,700,000	$1,500,000	1.1
CW1_BR-BCC	High Growth	$16,300,000	$28,600,000	$12,300,000	1.8
	Baseline	$16,300,000	$27,280,000	$10,980,000	1.7
	Low Growth	$16,300,000	$24,900,000	$8,600,000	1.5
	No Growth	$16,300,000	$14,500,000	($1,800,000)	0.9

Table 5-17: 820' Widening Benefit Analysis by Growth Scenario

Measure	Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
CW1_BR-Redfish	High Growth	$7,900,000	$10,300,000	$2,400,000	1.3
	Baseline	$7,900,000	$9,800,000	$1,900,000	1.2
	Low Growth	$7,900,000	$9,000,000	$1,100,000	1.1
	No Growth	$7,900,000	$5,800,000	($2,100,000)	0.7
CW1_Redfish-BSC	High Growth	$21,600,000	$9,900,000	($11,700,000)	0.5
	Baseline	$21,600,000	$9,400,000	($12,200,000)	0.4
	Low Growth	$21,600,000	$8,400,000	($13,200,000)	0.4
	No Growth	$21,600,000	$5,400,000	($16,200,000)	0.3
CW1_BSC-BCC	High Growth	$13,900,000	$3,300,000	($10,600,000)	0.2
	Baseline	$13,900,000	$3,200,000	($10,700,000)	0.2
	Low Growth	$13,900,000	$3,000,000	($10,900,000)	0.2
	No Growth	$13,900,000	$2,300,000	($11,600,000)	0.2
CW1_BR-BSC	High Growth	$29,500,000	$21,200,000	($8,300,000)	0.7
	Baseline	$29,500,000	$20,200,000	($9,300,000)	0.7

Measure	Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
	Low Growth	$29,500,000	$18,300,000	($11,200,000)	0.6
	No Growth	$29,500,000	$11,700,000	($17,800,000)	0.4
CW1_BR-BCC	High Growth	$43,400,000	$28,600,000	($14,800,000)	0.7
	Baseline	$43,400,000	$27,280,000	($16,120,000)	0.6
	Low Growth	$43,400,000	$24,900,000	($18,500,000)	0.6
	No Growth	$43,400,000	$14,500,000	($28,900,000)	0.3

5.3.2 San Jacinto to Boggy Bayou Meeting Area (CW1_SJM-BB_530)

Table 5-18 outlines the sensitivity analysis conducted for benefits of a proposed meeting area from San Jacinto Monument to Boggy Bayou. The sensitivity analysis was conducted in the same way as the Bay Widening analysis previously described. The results indicate that the proposed meeting area is unjustified at all likely scenarios.

Table 5-18: SJM-BB Widening Benefit Analysis by Growth Scenario

Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
High Growth	$1,500,000	$200,000	($1,300,000)	0.1
Baseline	$1,500,000	$200,000	($1,300,000)	0.1
Low Growth	$1,500,000	$200,000	($1,300,000)	0.1
No Growth	$1,500,000	$200,000	($1,300,000)	0.1

5.3.3 Mooring Facilities

Table 5-19 outlines the sensitivity analysis conducted for benefits of a proposed mooring facilities in the bay and in the bayou. The sensitivity analysis was conducted in the same way as the Bay Widening analysis previously described. The results indicate that the proposed meeting area at Mile Marker 520+00 is justified under all scenarios. The other mooring areas remain unjustified under all conditions.

Table 5-19: Mooring Facilities Benefit Analysis by Growth Scenario

Measure	Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
MM1_520+00	High Growth	$3,300,000	$4,800,000	$1,500,000	1.5
	Baseline	$3,300,000	$4,800,000	$1,500,000	1.5
	Low Growth	$3,300,000	$4,700,000	$1,400,000	1.4
	No Growth	$3,300,000	$4,500,000	$1,200,000	1.4
MM2_BSC_1800	High Growth	$5,100,000	$3,400,000	($1,700,000)	0.7
	Baseline	$5,100,000	$3,400,000	($1,700,000)	0.7
	Low Growth	$5,100,000	$3,300,000	($1,800,000)	0.6
	No Growth	$5,100,000	$3,100,000	($2,000,000)	0.6
MM1_AI(d)	High Growth	$6,700,000	$4,500,000	($2,200,000)	0.7
	Baseline	$6,700,000	$4,400,000	($2,300,000)	0.7
	Low Growth	$6,700,000	$4,300,000	($2,400,000)	0.6
	No Growth	$6,700,000	$4,100,000	($2,600,000)	0.6

5.3.4 BSC Turning Basin

Table 5-20 outlines the sensitivity analysis conducted for benefits of a proposed turning basin at Bayport Ship Channel. The sensitivity analysis was conducted in the same way as the Bay Widening analysis previously described. The results indicate that the proposed turning basin remains unjustified under all conditions.

Table 5-20: BSC Turning Basin Benefit Analysis by Growth Scenario

Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BC Ratio
High Growth	$2,900,000	$1,300,000	($1,600,000)	0.4
Baseline	$2,900,000	$1,300,000	($1,600,000)	0.4
Low Growth	$2,900,000	$1,200,000	($1,700,000)	0.4
No Growth	$2,900,000	$900,000	($2,000,000)	0.3

5.4 RESULTS SUMMARY

Table 5-21, **Table 5-22**, and **Table 5-23** summarize the results of the sensitivity analysis by alternative for the High Growth, Low Growth, and No Growth Scenarios. The results of the sensitivity analysis confirm the selection of Alternative 8. All measures with economic justification remain justified in all growth scenarios with the exception of Bay Widening from Bolivar Roads to Barbours Cut in the no growth scenario. In this case, only Bolivar Roads to Bayport Ship Channel would be justified.

Table 5-21: Summary of Alternatives - High Growth Scenario

Alternative	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
1	$27,100,000	$106,000,000	**$78,900,000**	**3.9**
2	$40,000,000	$90,200,000	**$50,200,000**	**2.3**
3	$30,800,000	$29,900,000	**($900,000)**	**1.0**
4	$8,700,000	$43,100,000	**$34,400,000**	**5.0**
5	$4,400,000	$44,400,000	**$40,000,000**	**10.1**
6	$5,100,000	$3,400,000	**($1,700,000)**	**0.7**
7	$3,300,000	$4,800,000	**$1,500,000**	**1.5**
8 (650)	$55,700,000	$151,400,000	**$95,700,000**	**2.7**
8 (820)	$83,100,000	$151,400,000	**$68,300,000**	**1.8**

Table 5-22: Summary of Alternatives - Low Growth Scenario

Alternative	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
1	$27,100,000	$88,300,000	**$78,900,000**	**3.9**
2	$40,000,000	$68,900,000	**$50,200,000**	**2.3**
3	$30,800,000	$26,200,000	**($900,000)**	**1.0**
4	$8,700,000	$40,700,000	**$32,000,000**	**4.7**

Alternative	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
5	$4,400,000	$44,300,000	**$39,900,000**	**10.1**
6	$5,100,000	$3,300,000	**($1,800,000)**	**0.6**
7	$3,300,000	$4,700,000	**$1,400,000**	**1.4**
8 (650)	$55,700,000	$128,800,000	**$73,100,000**	**2.3**
8 (820)	$83,100,000	$128,800,000	**$45,700,000**	**1.5**

Table 5-23: Summary of Alternatives - No Growth Scenario

Alternative	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
1	$27,100,000	$52,200,000	**$78,900,000**	**3.9**
2	$40,000,000	$30,800,000	**$50,200,000**	**2.3**
3	$30,800,000	$15,900,000	**($900,000)**	**1.0**
4	$8,700,000	$34,200,000	**$25,500,000**	**3.9**
5	$4,400,000	$35,900,000	**$31,500,000**	**8.2**
6	$5,100,000	$3,100,000	**($2,000,000)**	**0.6**
7	$3,300,000	$4,500,000	**$1,200,000**	**1.4**
8 (650)	$55,700,000	$78,600,000	**$22,900,000**	**1.4**
8 (820)	$83,100,000	$78,600,000	**($4,500,000)**	**0.9**

6 MULTIPORT ANALYSIS

Qualitative analysis of multiport competition to Houston Ship Channel was completed for this study as it relates to shifting of cargo from one port to another port based on study measures such as deepening and widening. The recommended plan includes measures that will deepen, widen, and reduce in-port inefficiencies throughout HSC. These measures will accommodate the design vessels for this study over the study period. While this is expected to reduce transportation costs for cargo shipment at HSC, the recommended measures are not anticipated to significantly change the relative competitiveness of HSC over other Gulf Coast or National Port. Many exogenous factors may influence throughput tonnage at a port including landside infrastructure, location of distribution centers, source locations for exports, population and income growth, port logistics and fees, business climate and taxes, carrier preferences, labor stability, and business relationships. These factors were taken into account when completing the commodity and fleet forecasts for this study, and it was determined that HSC would receive the same total import and export cargo in both the Future Without-Project and the Future With-Project Scenarios.

7 ECONOMIC EVALUATION UPDATE

This section includes updates to the economic evaluation completed July 2019 based on changes since release of the Draft Feasibility Report and Environmental Impact Statement in August 2017. Benefit and costs included in this section are the final feasibility-level estimates. Updates led to refinement of the NED plan (**Section 7.1.1**). Port Houston requested inclusion of a Locally Preferred Plan (LPP), which includes additional features not included in the NED plan (**Section 7.1.2**).

Section 7.1 outlines the final project footprint. **Section 7.2** details final updates to the commodity forecast (**Section 7.2.1**), fleet forecast (**Section 7.2.2**), transportation cost model (**Section 7.2.3**), costs (**Section 7.2.4**), benefits (**Section 7.2.5**), and benefit-cost summary (**Section 7.2.6**). **Section 7.3** presents the results of a high growth scenario.

7.1 REFINEMENT OF THE PROJECT FOOTPRINT

7.1.1 NED Plan

Additional economic analysis and feasibility-level ship simulation further refined the NED plan. In Segment 1, ship simulation led to a recommended channel width of 700 feet. Subsequent cost-benefit analysis of the 700-foot width showed economic justification for widening from Bolivar Roads to Redfish Reef only (**Section 7.2.5**). Channel widening features around Hog Island did not accrue economic benefit and have been removed from the recommended plan. The multipurpose mooring facility lacked non-federal support and has been removed. In Segment 2, further analysis showed that the Shoaling Attenuation would not be the least cost alternative; therefore, it was replaced by standard O&M dredging. The NED Plan includes the following features by Study Segment:

Segment 1 – Bolivar Roads to Boggy Bayou
- Widen HSC from Bolivar Roads to Redfish Reef to 700 feet with barge lane relocation
- Bend Easing at 078+844 and 028+605

Segment 2 – Bayport Ship Channel
- BSC Flare expansion
- Widen BSC to 455 feet

Segment 3 – Barbours Cut Channel
- Widen BCC to 455 feet
- BCC Combined Flare and Turning Basin

Segment 4 – Boggy Bayou to Sims Bayou
- Deepen HSC from Boggy Bayou to Sims Bayou to 46.5 feet
- Widen HSC from Boggy to Greens Bayou up to 530 feet
- Improvements to Hunting Turning Basin

Segment 5 – Sims Bayou to I-610 Bridge

- Deepen HSC from Sims Bayou to I-610 Bridge up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin

- Deepen HSC from I-610 Bridge to Main Turning Basin up to 41.5 feet
- Improvements to Turning Basin near Brady's Island

7.1.2 LPP Features and Recommended Plan

Upon refinement of the NED plan, Port Houston requested inclusion of an LPP which retained bay widening measures from Redfish Reef to Barbours Cut Channel, which were not carried forward as part of the NED plan due to lack of economic justification. Preliminary ship simulation showed that widening from Redfish Reef to Barbours Cut likely eliminates the need for the Bayport Flare; therefore, the BSC Flare features and costs are not included in the recommended plan. Together, the NED and LPP features compose the HSC ECIP recommended plan, which consists of the following measures by segment:

Segment 1 – Bolivar Roads to Boggy Bayou

- Four bend easings on main HSC channel with associated relocation of barge lanes
- Widen HSC from Bolivar Roads to BCC to 700 feet with barge lane relocation

Segment 2 – Bayport Ship Channel

- Widen BSC to 455 feet

Segment 3 – Barbours Cut Channel

- Widen BCC to 455 feet
- BCC Combined Flare and Turning Basin

Segment 4 – Boggy Bayou to Sims Bayou

- Deepen HSC from Boggy Bayou to Hunting Turning Basin to 46.5 feet
- Widen HSC from Boggy to Greens Bayou up to 530 feet
- Improvements to Hunting Turning Basin

Segment 5 – Sims Bayou to I-610 Bridge

- Deepen HSC from Sims Bayou to I-610 Bridge up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin

- Deepen HSC from I-610 Bridge to Main Turning Basin up to 41.5 feet
- Improvements to Turning Basin near Brady's Island

7.2 UPDATES TO ECONOMIC EVALUATION INPUTS

An Economic Summit took place January 18, 2018 between PHA and USACE. At this meeting, the economics vertical team and PHA agreed to update the commodity forecast, fleet forecast, and HarborSym model with 2017 baseline data, the most recent available growth data from AEO 2018, and updates to pilot practice. This section describes the updates to the commodity forecast, vessel fleet forecast, and HarborSym model per the January 2018 Economic Summit.

7.2.1 Commodity Forecast Update

Previous analysis used throughput tonnage data from 2012 through 2014 to develop the forecast baseline. Rapid export growth occurred in the petroleum and petroleum products export category after 2014 due to accelerating extraction in the Permian Basin and easing crude oil export restrictions. To account for this trend and its potential impacts, the economic update uses WCSC throughput tonnage data from 2014 through 2016 to establish a new forecast baseline. At the time of this analysis, 2016 was the most recent available data from WCSC. To further update the forecast, the analysis uses actual growth rates from the baseline to 2017 using US Customs data. While trade volume for US Customs varies from WCSC totals, the trends between the data sources year-to-year are consistent; therefore, the analysis assumed that this was a relatively accurate way of capturing trade trends through 2017, especially growth in crude oil exports since 2015. Growth rates for key commodities (i.e., crude oil and petroleum products) were also updated with the American Energy Outlook 2018 growth rates.

Table 7-1 and Table 7-2 present historical trade volumes for bulk commodities from 2014 through 2016. The resulting import baseline represents a 13 percent drop from the 2012 through 2014 forecast baseline, mainly as a result of falling petroleum product imports. The resulting export baseline represents a 9 percent increase over the 2012 through 2014 forecast baseline, mainly from accelerating petroleum exports.

Table 7-1: Bulk Imports (2014-2016)

Commodity (Bulk Only)	2014	2015	2016	Baseline
1 Coal, Lignite & Coal Coke	-	-	-	-
2 Petroleum Products	42,240,000	36,984,000	40,572,000	39,932,000
3 Chemical Products	4,759,000	4,923,000	4,181,000	4,621,000
4 Crude Materials	3,021,000	2,774,000	1,673,000	2,489,000
5 Primary Manufactured Goods	9,305,000	9,247,000	6,023,000	8,192,000
6 Food and Farm Products	385,000	376,000	366,000	376,000
7 Manufactured Equipment	857,000	1,074,000	916,000	949,000
8 Waste Material	-	-	-	-
9 Unknown	965,000	615,000	517,000	699,000
Grand Total	**61,532,000**	**55,994,000**	**54,248,000**	**57,258,000**

Table 7-2: Bulk Exports (2014-2016)

Commodity (Bulk Only)	2014	2015	2016	Baseline
1 Coal, Lignite & Coal Coke	1,923,000	468,000	175,000	856,000
2 Petroleum Products	46,701,000	56,274,000	57,636,000	53,537,000
3 Chemical Products	9,518,000	10,199,000	10,432,000	10,050,000
4 Crude Materials	700,000	544,000	266,000	503,000
5 Primary Manufactured Goods	353,000	244,000	216,000	271,000
6 Food and Farm Products	6,064,000	4,787,000	6,840,000	5,897,000

7 Manufactured Equipment	747,000	706,000	564,000	672,000
8 Waste Material	-	-	-	-
9 Unknown	760,000	702,000	676,000	713,000
Grand Total	**66,766,000**	**73,924,000**	**76,805,000**	**72,498,000**

Table 7-3 presents containerized trade volumes from 2015 through 2017 received from Port Houston. The analysis used tonnage through 2017 in the containerized forecast because it was the most recent data available. The resulting forecast baseline is 32 percent higher than the 2012 through 2014 baseline estimate, including a 42 percent and 23 percent increase in baseline imports and exports, respectively.

Table 7-3: Containerized Trade (2015-2017)

Year	2015	2016	2017	Baseline
Import	8,580,000	9,086,000	10,961,000	9,543,000
Export	9,849,000	9,990,000	10,061,000	9,967,000
Total	**18,430,000**	**19,076,000**	**21,022,000**	**19,509,000**

Table 7-4 and Table 7-5 summarize the results of the economic update to the commodity forecast. Overall, the economic update increased baseline volume by over 12 million tons, resulting in higher call volumes and channel congestion over the study period (Section 7.2.2).

Table 7-4 : Import Commodity Forecast (Metric Tons)

Commodity	Baseline	2029	2034	2039
1 Coal, Lignite & Coal Coke	-	17,000	16,000	16,000
2 Petroleum Products	39,932,000	30,687,000	30,732,000	31,614,000
3 Chemical Products	4,621,000	4,627,000	5,019,000	5,500,000
4 Crude Materials	2,489,000	2,815,000	3,045,000	3,306,000
5 Primary Manufactured Goods	8,192,000	10,057,000	11,474,000	12,747,000
6 Food and Farm Products	376,000	350,000	355,000	360,000
7 Manufactured Equipment	949,000	1,503,000	1,713,000	1,921,000
8 Waste Material	-	-	-	-
9 Unknown	699,000	699,000	699,000	699,000
Containerized Tonnage	9,543,000	15,940,000	18,911,000	21,377,000
Grand Total	**66,801,000**	**66,695,000**	**71,964,000**	**77,540,000**

Table 7-5 Export Commodity Forecast

Commodity	Baseline	2029	2034	2039
1 Coal, Lignite & Coal Coke	856,000	333,000	344,000	400,000
2 Petroleum Products	53,537,000	85,936,000	91,190,000	92,263,000
3 Chemical Products	10,050,000	12,503,000	13,016,000	13,883,000
4 Crude Materials	503,000	459,000	484,000	524,000
5 Primary Manufactured Goods	271,000	345,000	403,000	453,000
6 Food and Farm Products	5,897,000	6,764,000	7,156,000	7,576,000

7 Manufactured Equipment	672,000	764,000	887,000	1,007,000
8 Waste Material	-	-	-	-
9 Unknown	713,000	713,000	713,000	713,000
Containerized Tonnage	9,967,000	18,025,000	22,508,000	26,906,000
Grand Total	**82,466,000**	**125,842,000**	**136,701,000**	**143,725,000**

Compared to the previous analysis, baseline imports fell by approximately 10 percent, baseline exports increased 6 percent, and overall baseline tonnage dropped by 2 percent. The analysis incorporated 2017 growth rates from U.S. Customs released in 2018 to replace commodity growth rates between the baseline and 2017 in order to use the most recent available data. **Table 7-6** compares forecasted tonnage for 2017 (bulk tonnage increased by the actual 2017 growth rate from US Customs) to WCSC 2017 trade data for Houston Ship Channel. The forecast overestimates tonnage by approximately 3.2 million metric tons. At the time of the original analysis, only U.S. Customs 2017 data was available and growth rates often vary between WCSC and U.S. Customs data. The HSC ECIP is meant as a long-term growth forecast. This comparison is only meant as a check on the forecast baseline. Long term trends are more important to determining project benefits over the 50-year period of analysis.

Table 7-6 Forecast vs. WCSC 2017 Data

Direction	WCSC - 2017	HSC ECIP Forecast - 2017
Import	65,667,000	64,426,000
Export	91,467,000	95,912,000
Total	**157,134,000**	**160,338,000**

7.2.2 Fleet Forecast Update

The analysis applied the updated commodity forecast to the fleet forecast using the Container Loading Tool and the Bulk Loading Tool using the methodology described in **Section 4.1. Table 7-7** and **Table 7-8** summarize the results of the loading analysis for the FWOP and FWP conditions, respectively.

Table 7-7 : Updated Fleet Forecast FWOP

Vessel Type	*Vessel Class*	2014-2016 Average*	FWOP Calls			
			2029	2034	2039	2044
Bulker	7.5k-30k	57	60	122	133	133
	30k-45k	202	285	299	344	344
	45k-70k	479	586	592	628	628
	70k-110k	48	71	75	79	79
Chemical Tanker	4.5k-13.5k	388	473	506	507	507
	13.5k-21.5k	342	574	618	653	653
	21.5k-29k	61	110	118	128	128
	29k-33k	247	359	380	402	402
General Cargo	5.5k-12.5k	401	500	582	654	654
	12.5k-15k	145	209	236	260	260
	15.5k-18k	79	115	126	136	136
	18k-22k	49	95	117	128	128
	22k-27k	50	87	106	116	116
	27k-30k	159	213	225	247	247
LPG	2.5k-13.5k	234	246	410	387	387
	13.5k-33.5k	142	271	239	249	249
	33.5k-49.2k	15	54	50	58	58
	49.2k-64.2k	254	453	469	474	474
Tanker	10k-30k	430	418	332	389	389
	30k-55k	1,211	1,105	949	746	746
	55k-75k	236	267	255	230	230
	75k-100k	37	131	148	162	162
	100k-130k	409	497	536	527	527
	130k-157.5k	18	66	106	140	140
	157.5k-215k	33	60	80	110	110
RoRo	15.9k-20.9k	113	138	155	176	176
	3.65k-9.15k	2	5	4	4	4
	9.15k-15.9k	26	35	43	42	42
Containership	Sub-Panamax	296	355	442	522	512
	Panamax	439	595	642	643	511
	PPX Generation I	199	348	402	479	470
	PPX Generation II	2	217	339	482	565
Chemical Tanker – Interport Transits		797	916	980	1,021	1,021
Total		**7,600**	**9,914**	**10,683**	**11,256**	**11,188**

*Excludes Upper Channel Shifts/between-berth shifts/duplicates/data issue/non-commodity moves (chemical tanker transits added back in for future scenarios)

Table 7-8: Updated Fleet Forecast FWP

Vessel Type	*Vessel Class*	2014-2016 Average*	FWP Calls			
			2029	2034	2039	2044
Bulker	7.5k-30k	57	52	115	115	115
	30k-45k	202	278	292	343	343
	45k-70k	479	586	592	628	628
	70k-110k	48	71	75	79	79
Chemical Tanker	4.5k-13.5k	318	377	404	402	402
	13.5k-21.5k	110	178	194	212	212
	21.5k-29k	22	40	43	50	50
	29k-33k	62	98	100	111	111
General Cargo	5.5k-12.5k	401	482	561	634	634
	12.5k-15k	145	209	236	260	260
	15.5k-18k	79	115	126	136	136
	18k-22k	49	95	117	128	128
	22k-27k	50	87	106	116	116
	27k-30k	159	213	225	247	247
LPG	2.5k-13.5k	234	246	410	387	387
	13.5k-33.5k	142	271	239	249	249
	33.5k-49.2k	15	54	50	58	58
	49.2k-64.2k	254	453	469	474	474
Tanker	10k-30k	430	392	331	384	384
	30k-55k	1,211	1,039	845	588	588
	55k-75k	236	244	229	205	205
	75k-100k	37	140	156	175	175
	100k-130k	409	533	586	595	595
	130k-157.5k	18	69	110	145	145
	157.5k-215k	33	62	84	115	115
RoRo	15.9k-20.9k	2	5	4	4	4
	3.65k-9.15k	26	35	43	42	42
	9.15k-15.9k	113	138	155	176	176
Containership	Sub-Panamax	296	360	442	522	512
	Panamax	439	594	642	643	511
	PPX Generation I	199	346	402	479	470
	PPX Generation II	-	94	144	193	207
	PPX Generation III	-	112	184	253	315
Chemical Tanker – Interport Transits		-	-	-	-	-
Total		**6,275**	**8,068**	**8,711**	**9,148**	**9,073**

*Excludes Upper Channel Shifts/between-berth shifts/duplicates/data issue/non-commodity moves (chemical tanker transits added back in for future scenarios)

7.2.3 HarborSym Model Update

The January 2018 Economic Summit and subsequent meetings led to five updates to the HarborSym transportation cost model for the HSC ECIP study based on recent and expected changes to operations within the Houston Ship Channel. The analysis incorporated the following five items based on the updated operating practices listed below:

- ITEM 1 *(Pilot Rule): "Any widebody tanker proceeding with cargo will be daylight restricted above Buoy 18."* Modeling prior to ADM restricted Suezmax tankers to daylight only transits, which overestimated restrictions to Suezmax tankers given that ballasted, widebody tankers are allowed to move at night. Modeling prior to ADM also allowed Aframax tankers that did not face draft, combined beam, or other meeting restrictions to move at night. The model has been updated to insure that all loaded widebody tankers are daylight restricted and all ballasted widebody tankers are allowed to move at night if not restricted by another rule.
- ITEM 2 *(Pilot Rule): "LPG tankers proceeding with cargo whose LOA is greater than 560 feet will be daylight restricted above Buoy 18."* Modeling prior to ADM did not specifically restrict loaded LPG tankers other than widebody LPG tankers or those affected by other rules. The model has been updated to restrict all loaded LPG tankers with an LOA greater than 560 ft. to daylight only movement. Ballasted LPG tankers with a beam less than 120 feet are allowed to move at night.
- ITEM 3 *(Model Detail): Concern that aggregated dock and channel configuration in the upper channel for the widening scenario reduces overall widening benefits.* All scenarios evaluating widening benefits prior to ADM aggregated docks and channel configuration in the upper channel (Buffalo Bayou to HSC Turning Basin). The model has been updated to include all docks and channel dimensions in the upper channel.
- ITEM 4 (*New Pilot Rule): Containerships with an LOA greater than 1100' (PPXIII) will not be met by any vessel and no vessel will leave dock until the 1100' LOA containership is within 30 minutes of BSC/BCC.* ADM Modeling did not allow any vessel to meet the PPXIII containership vessel; however, vessels were allowed to leave dock and time their transit of the main channel. The model was updated to restrict vessels from leaving until the PPXIII vessel is within 30 minutes of BSC/BCC.
- ITEM 5 *(2,030' Combined LOA)*: The model has been updated to include a 2,030 combined LOA limit in the main channel, restricting PPXII containership meeting.

7.2.4 Cost Updates

Feasibility-level cost estimates were developed for the NED plan and LPP at the October 2019 price level. They reflect the change in channel footprint described in **Section 7.1**. Total project cost and economic benefits are presented in AAEQ values. AAEQ values are calculated by discounting the benefit stream, deferred installation costs, and Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs to the beginning of the period of analysis using the existing FY19 discount rate (2.875 percent). Installation expenditures are brought forward to the end of the period of installation by charging compound interest at the project discount rate from the date the costs are incurred. Using AAEQ values allows for a direct comparison of costs and benefits over the 50-year study period. The BCR is calculated by dividing AAEQ Benefits by AAEQ costs and is used to determine if the project is justified (BCR $\geq$ 1.0).

7.2.4.1 Interest during Construction (IDC)

Table 7-9 details the estimated construction schedule for the NED plan (4-year duration). **Table 7-10** provides the estimated construction schedule for the LPP (5-year duration). IDC calculations use a middle-of-month payment schedule, October 2019 price level, and the FY19 discount rate of 2.875 percent. **Table 7-11** and **Table 7-12** provide a detailed breakdown of IDC for the NED plan and LPP, respectively.

Table 7-9: IDC (NED Plan)

Measure(s)	Duration (months)	Start	Finish
CW1_BR-Redfish_700	8	Jan 2023	Aug 2023
BE1_078+844_530 NED	8	Jan 2023	Aug 2023
BE1_028+605_530 NED	3	Jan 2023	Mar 2023
CW2_BSC_455	12	May 2024	April 2025
BE2_BSCFlare NED	12	May 2024	April 2025
CW3_BCC_455, BETB3_BCCFlare_1800NS	7	May 2025	Nov 2025
CD4_Whole	13	April 2023	April 2024
CD5 + CD6	10	Jan 2026	Oct 2026

Table 7-10: IDC (LPP)

Contract	Duration (months)	Start	Finish
CW1_BR-Redfish_700	8	Jan 2023	Aug 2023
CW1_Redfish-BSC_700	15	Jan 2024	Sep 2024
CW1_BSC-BCC_700	24	Jan 2026	Aug 2026
CW2_BSC_455	15	Apr 2024	Mar 2025
CW3_BCC_455, BETB3_BCCFlare_1800NS	24	Apr 2025	Oct 2025
CD4_Whole, CW4_BB-GB, TB4_Hunting	13	Apr 2023	Apr 2024
CD5_Whole + CD6_Whole	10	Apr 2027	Jan 2028

Table 7-11: Detailed IDC Summary (NED Plan)

Measures	AAEQ IDC
CW1_BR-Redfish_700 BE1_138+369_700 NED BE1_078+844_530 NED BE1_028+605_530 NED	$1,156,000
CW2_BSC_455 BE2_BSCFlare NED CW3_BCC_455, BETB3_BCCFlare_1800NS	$7,610,000
CD4_Whole	$3,241,000
CD5 + CD6	$606,000
Total	**$12,612,000**

Table 7-12: Detailed IDC (LPP)

Measures	AAEQ IDC
CW1_BR-Redfish_700	$1,009,000
CW1_Redfish-BSC_700	$3,428,000
CW1_BSC-BCC_700	$3,078,000
CW2_BSC_455 CW3_BCC_455, BETB3_BCCFlare_1800NS	$8,033,000
CD4_Whole, CW4_BB-GB, TB4_Hunting	$3,309,000
CD5_Whole + CD6_Whole	$619,000
All Measures	**$19,477,000**

7.2.4.2 Total Project Cost Summary

Table 7-13 summarizes the cost information for the NED plan and LPP used in the economic evaluation. Estimated construction costs were revised to $730,218,000 for the NED plan and $937,655,000 for the LPP. Total investment cost is the sum of the construction first cost and interest during construction. Total investment costs for the NED is $742,830,000 and $957,132,000 for the LPP.

Table 7-13: HSC ECIP Average Annual Equivalent Costs ($000s)

Category	NED Plan	Recommended Plan
	October 2019 Price Levels, 2.75% Discount Rate	
Total Project Construction Costs	$746,649	$959,661
Interest During Construction	$12,612	$19,477
Total Investments Cost	**$759,261**	**$979,138**
Construction Average Annual Costs	$28,123	$36,268
OMRR&R	$13,883	$16,983
Total Average Annual Costs	**$42,006**	**$53,251**

7.2.5 Transportation Cost Savings

Transportation cost savings were re-evaluated in October 2019 on the NED plan and LPP to reflect the commodity, fleet, and modelling updates.

Table 7-14 summarizes the results of the updated analysis for the NED plan. All analysis uses FY19 Vessel Operating Costs, October 2019 price level, and the FY20 Federal discount rate (2.75 percent). **Table 7-15** summarizes results of the updated analysis for the LPP. The LPP includes channel widening from Redfish Reef to Barbours Cut Channel (CW1_RF-BSC and CW1_BSC-BCC). These features were not economically justified, but will be included as part of the recommended plan as a 100 percent non-Federal cost.

Table 7-14: Benefit Cost Analysis of the NED Plan ($000)

Alternative	Measure(s)	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Widening	CW1_BR-Redfish_700	$6,059	$11,276	$5,217	1.86
Containership Benefits (BSC & BCC)	BE1_078+844_530 NED BE1_028+605_530 NED BE2_BSCFlare NED CW2_BSC_455 CW3_BCC_455, BETB3_BCCFlare_1800NS	$20,409	$52,720	$32,311	2.58
Segment 4	CD4_Whole, CW4_BB-GB, TB4_Hunting	$12,246	$40,249	$28,003	3.29
Segment 5 & Segment 6	CD5_Whole CD6_Whole	$2,683	$10,438	$7,755	3.89
NED Total*		**$42,006**	**$114,683**	**$72,677**	**2.73**

*Includes air quality certificate cost

Table 7-15: Benefit Cost Analysis of the LPP

Alternative	Measure(s)	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Bay Widening	CW1_BR-Redfish_700	$4,595	$11,276	$6,681	2.44
	CW1_Redfish-BSC_700	$12,670	$11,248	$(1,422)	0.88
	CW1_BSC-BCC_700	$6,858	$7,620	$762	1.11
Containership Benefits (BSC & BCC)	CW2_BSC_455 CW3_BCC_455, BETB3_BCCFlare	$13,166	$52,720	$39,554	4.0
Segment 4	CD4_Whole, CW4_BB-GB, TB4_Hunting	$12,420	$40,249	$27,829	3.2
Segment 5 & Segment 6	CD5_Whole CD6_Whole	$2,727	$10,438	$7,711	3.8
LPP Total*		**$53,251**	**$133,551**	**$80,300**	**2.51**

*Includes air quality certificate cost

7.2.6 Net Benefits and Benefit-Cost Summary

Table 7-16 displays the updated costs, benefits, and net benefits of the NED plan and LPP at October 2019 price level and FY20 discount rate.

Table 7-16: Updated Benefit Cost Summary

Category	NED Plan	Recommended Plan
	October 2019 Price Levels, 2.75% Discount Rate	
Total Project Construction Costs	$746,649	$959,661
Interest During Construction	$12,612	$19,477
Total Investments Cost	**$759,261**	**$979,138**
Construction Average Annual Costs	$28,123	$36,268
OMRR&R	$13,883	$16,983
Total Average Annual Costs	**$42,006**	**$53,251**
Average Annual Benefits	$114,683	$133,551
Net Annual Benefits	$72,677	$80,300
Benefit to Cost Ratio	**2.73**	**2.51**

7.3 SENSITIVITY ANALYSES

7.3.1 High Commodity Growth Scenario

Per agreement between the USACE economic team and Port Houston, analysis of a potential high commodity growth scenario is included in this report. The scenario is based on commodity growth assumptions prepared by Port Houston. **Table 7-17** and **Table 7-18** summarize the import and export high growth forecasts, respectively.

Table 7-17: High Growth Scenario Import Forecast

Vessel Type	Baseline	2029	2034	2039	2044
Bulk Carrier	9,220,000	11,262,000	12,604,000	13,871,000	13,871,000
Chemical Tanker	1,144,000	1,152,000	1,206,000	1,293,000	1,293,000
General Cargo	1,797,000	2,660,000	3,062,000	3,434,000	3,434,000
LPG Tanker	410,000	505,000	561,000	620,000	620,000
Tanker	43,266,000	34,752,000	35,132,000	36,398,000	36,398,000
RoRo	257,000	411,000	474,000	532,000	532,000
Containership	9,543,000	15,940,000	18,911,000	21,377,000	21,377,000
Grand Total	**65,637,000**	**66,682,000**	**71,950,000**	**77,525,000**	**77,525,000**

Table 7-18: High Growth Scenario Export Forecast

Vessel Type	Baseline	2029	2034	2039	2044
Bulk Carrier	11,788,000	14,446,000	15,305,000	15,884,000	15,884,000
Chemical Tanker	3,343,000	4,218,000	4,439,000	4,674,000	4,674,000
General Cargo	1,712,000	2,028,000	2,202,000	2,362,000	2,362,000
LPG Tanker	13,498,000	32,971,000	36,290,000	40,018,000	40,018,000
Tanker	38,765,000	82,076,000	88,196,000	92,700,000	92,700,000
RoRo	99,000	112,000	126,000	140,000	140,000
Containership	9,967,000	20,595,000	22,508,000	26,906,000	26,906,000
Grand Total	**79,172,000**	**156,446,000**	**169,066,000**	**182,684,000**	**182,684,000**

The high growth commodity forecast was run through the Container Loading Tool and Bulk Loading Tool using the same methodology described in **Section 4.1** to develop the high growth fleet forecast. **Table 7-19** and **Table 7-20** provide the estimated future fleet by study year under the high growth scenario.

Table 7-19: High Growth Scenario FWOP Calls

Vessel Type	Vessel Class	FWOP Calls			
		2029	2034	2039	2044
Bulker	7.5k-30k	60	122	133	133
	30k-45k	285	299	344	344
	45k-70k	586	592	628	628
	70k-110k	71	75	79	79
Chemical Tanker	4.5k-13.5k	473	506	507	507
	13.5k-21.5k	574	618	653	653
	21.5k-29k	110	118	128	128
	29k-33k	359	380	402	402
General Cargo	5.5k-12.5k	500	582	654	654
	12.5k-15k	209	236	260	260
	15.5k-18k	115	126	136	136
	18k-22k	95	117	128	128
	22k-27k	87	106	116	116
	27k-30k	213	225	247	247
LPG	2.5k-13.5k	246	410	387	387
	13.5k-33.5k	271	239	249	249
	33.5k-49.2k	54	50	58	58
	49.2k-64.2k	453	469	474	474
Tanker	10k-30k	210	228	393	393
	30k-55k	1,208	1,081	730	730
	55k-75k	313	308	293	293
	75k-100k	185	180	250	250
	100k-130k	584	650	660	660
	130k-157.5k	110	150	200	200
	157.5k-215k	89	110	170	170
RoRo	15.9k-20.9k	138	155	176	176
	3.65k-9.15k	5	4	4	4
	9.15k-15.9k	35	43	42	42
Containership	Sub-Panamax	355	442	522	512
	Panamax	595	642	643	511
	PPX Generation I	348	402	479	470
	PPX Generation II	217	339	482	565
Chemical Tanker – Interport Transits		916	916	980	1,021
Total		**10,069**	**10,984**	**11,648**	**11,580**

Table 7-20: High Growth Scenario FWP Calls

Vessel Type	Vessel Class	FWP Calls			
		2029	2034	2039	2044
Bulker	7.5k-30k	52	115	115	115
	30k-45k	264	292	343	343
	45k-70k	571	592	628	628
	70k-110k	67	75	79	79
Chemical Tanker	4.5k-13.5k	377	403	387	402
	13.5k-21.5k	178	191	194	212
	21.5k-29k	40	43	50	50
	29k-33k	98	98	111	111
General Cargo	5.5k-12.5k	469	561	634	634
	12.5k-15k	208	236	260	260
	15.5k-18k	115	126	136	136
	18k-22k	94	117	128	128
	22k-27k	87	106	116	116
	27k-30k	211	225	247	247
LPG	2.5k-13.5k	328	577	310	310
	13.5k-33.5k	341	337	367	367
	33.5k-49.2k	68	79	95	95
	49.2k-64.2k	614	660	764	764
Tanker	10k-30k	208	257	391	391
	30k-55k	1133	975	735	735
	55k-75k	291	282	293	293
	75k-100k	197	184.8	249.8	249.9
	100k-130k	624	707	660	660
	130k-157.5k	110	150	200	200
	157.5k-215k	89	110	170	170
RoRo	15.9k-20.9k	5	4	5	5
	3.65k-9.15k	35	43	42	42
	9.15k-15.9k	138	155	176	176
Containership	Sub-Panamax	435	432	551	496
	Panamax	665	647	636	525
	PPX Generation I	398	398	480	470
	PPX Generation II	113	144	193	207
Chemical Tanker – Interport Transits		916	124	184	253
Total		**8,747**	**9,506**	**9,999**	**9,932**

The high growth scenario primarily increases benefits to the bay widening measures. This is because the high growth scenario is based on increases in exports of crude petroleum and hydrocarbon & petrol gases, liquefied and gaseous. These commodities are primarily traded through Segment 1, which does not include deepening alternatives. **Table 7-21** summarizes the benefit-cost summary for the bay widening features under the high growth scenario. Benefits are higher given the higher traffic volumes under the high growth scenario.

Table 7-21: High Growth Scenario Widening Benefit-Cost Summary

Segment	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
BRDs to Redfish	$4,595,000	$12,078,000	$7,483,000	2.63
Redfish to BSC	$12,670,000	$12,791,000	$121,000	1.01
BSC to BCC	$6,858,000	$9,634,000	$2,776,000	1.40

7.3.2 Other Growth Scenarios

To further test the sensitivity of bay widening features, **Table 7-22** presents the results of no growth and low growth scenarios. The no growth scenario assumes no additional trade volume growth beyond the base year, 2029. Additionally, this scenario holds the fleet distribution constant. The low growth scenario tests the impact of a lower commodity growth scenario. For this sensitivity, the analysis assumes a 50 percent reduction in overall growth. This roughly corresponds to the AEO low growth scenario. The low growth scenario also assumes that the fleet transition will take place at half the speed as the baseline scenario. This sensitivity analysis shows that under less optimistic commodity growth scenarios, Redfish to BSC and BSC to BCC widening measures are not justified. Widening from Bolivar Roads to Redfish, however, is justified under all growth scenarios.

Table 7-22: Widening No Growth and Low Growth Scenarios

Segment	Growth Scenario	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
BRDs to Redfish	No Growth	$4,595,000	$5,193,000	$598,000	1.13
	Low Growth	$4,595,000	$7,417,000	$2,822,000	1.61
Redfish to BSC	No Growth	$12,670,000	$5,557,000	($7,113,000)	0.44
	Low Growth	$12,670,000	$7,997,000	($4,673,000)	0.63
BSC to BCC	No Growth	$6,858,000	$4,766,000	($2,092,000)	0.69
	Low Growth	$6,858,000	$5,816,000	($1,042,000)	0.85

Compared to widening sensitivity analyses, which have change the most under the economic update, the results presented in **Section 5.3** for all other project measures are relatively predictive of benefit cost analysis for the economic update. The results of the preliminary sensitivity analysis in **Section 5.3** indicate lower risk for project justification for all other project measures included in the recommended plan; however, the benefits of all other measures remain sensitive to weaker commodity growth scenarios.

8 SOCIOECONOMIC AND REGIONAL ANALYSIS

8.1 SOCIOECONOMIC ANALYSIS

The socioeconomics of the community area are summarized in this section. The parameters used to describe the demographic and socioeconomic environment include recent trends in population for three counties that make up the immediate economic study area of the HSC, private sector employment, wage earnings by sectors for Texas. Other social characteristics such as race composition, age distribution, poverty, and environmental justice (EJ) issues will be examined within the tri-county region, whose communities may be directly impacted by the channel improvements to the HSC system.

8.1.1 Population

Texas is ranked as the 2nd largest state in the U.S. in terms of resident population, as of April 1, 2010, with 25.1 million residents. Between the years 1990 and 2010, Texas' population increased by 48 percent, from 17 million to 25 million persons, as shown below in **Table 8-1**, which is almost twice the national growth over the same historical period. All counties within the immediate economic region of the HSC have seen a population growth during this period.

Nearly all the study area is within the Houston Urbanized Area, which has a 2010 population of 4.9 million and is second largest urbanized area in the state. Of the 254 counties in Texas, Chambers County is the 13th fastest growing, Harris County the 36th, and Galveston County the 48th fastest growing from 2000 to 2010. The tri-county area has a 2010 population of 4.4 million with about a 45 percent growth rate from 1990 to 2010.

Table 8-1: Texas Population Trends 1990 to 2010 (1,000s)

Geography	Population			Percentage Change		
	1990	2000	2010	1990-2000	2000-2010	1990-2010
Chambers County	20	26	35	29.6%	34.8%	74.7%
Galveston County	217	250	291	15.1%	16.4%	34.0%
Harris County	2,818	3,401	4,093	20.7%	20.4%	45.2%
Tri-County Region	3,056	3,677	4,419	20.3%	20.2%	44.6%
Texas	16,987	20,852	25,146	22.8%	20.6%	48.0%
United States	248,710	281,422	309,348	13.2%	9.9%	24.4%

8.1.2 Employment

Texas employment in 2010 totaled 10.1 million as shown in **Table 8-2**. Statewide the retail trade and health care are the largest employment sectors, each with about 11 percent of total employment, followed by accommodations & food services and manufacturing each with about 8 percent of total employment.

Within the tri-county study area, Harris County makes up about 94 percent of employment, Galveston County about 5 percent and Chambers County less than one percent. Within Chambers County, manufacturing is about 18 percent of total county employment. Manufacturing represents about 7 percent of Galveston County employment and about 10 percent of Harris County employment. In Galveston County, retail trade and accommodations & food services are the major employment sectors with each at about 12 percent of total employment. In Harris County, health care is about 12 percent of total employment and retail trade is about 11 percent.

Note that the mining sector includes oil and gas extraction as well as oil and gas support operations. Oil and gas refining is listed under manufacturing.

Table 8-2: Texas Private Sector Employment – 2010

NAICS Industry Sector		County			Tri-County	Texas
		Chambers	Galveston	Harris		
11	Agriculture, Forestry, Fishing and Hunting	79	40	1,269	1,388	58,134
21	Mining	359	535	72,898	73,792	204,570
22	Utilities	(n)	282	13,934	14,216	48,299
23	Construction	474	6,252	132,880	139,606	564,591
31-33	Manufacturing	1,729	6,745	168,527	177,001	810,160
42	Wholesale Trade	513	1,769	114,527	116,809	497,400
44-45	Retail Trade	711	11,653	194,017	206,381	1,136,136
48-49	Transportation/Warehousing	(n)	2,686	93,227	95,913	355,038
51	Information	(n)	705	28,414	29,119	195,506
52	Finance and Insurance	133	3,917	70,534	74,584	445,262
53	Real Estate, Rental & Leasing	632	1,534	41,640	43,806	170,851
54	Professional & Tech. services	280	2,556	155,951	158,787	567,448
55	Management	(n)	157	18,575	18,732	79,272
56	Admin & Support & Waste Mgmt. & Remediation Serv.	(n)	2,815	142,997	145,812	627,400
61	Educational Services	(n)	581	31,126	31,707	122,064
62	Healthcare	(n)	8,088	205,742	213,830	1,176,645
71	Arts, Entertainment, and Recreation	205	2,094	19,356	21,655	109,624
72	Accommodation and Food Services	774	12,136	158,162	171,072	896,630
81	Other Services (Except Public Administration)	268	2,651	59,878	62,797	293,793
92	Public Administration	427	3,157	49,289	52,873	459,573
	Total, Private & Government	9,434	94,160	1,724,278	1,827,872	10,182,150

Source: U. S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages (QCEW).

8.1.3 Wage Earnings by Sector

Texas employees earned an average annual wage of $46,952 in 2010 as shown in **Table 8-3**. Statewide the highest paying employment sector is mining, which includes oil and gas extraction and support industries.

Both mining and manufacturing, which includes petroleum refining, are the highest paying employment sectors in Chambers County and in Galveston County. In Harris County, the highest paying sector is mining followed by management of companies and enterprises. Given the heavy weighting towards Harris County within the tri-county area, mining and management of companies and enterprises are the highest paying sectors in the tri-county area. Of the three counties, Harris County has the highest average wage of $59,185, followed by Chambers County with $46,757 and then Galveston County with $43,131.

Table 8-3: Texas Average Annual Wage Earnings per Employee – 2010

NAICS Industry Sector		County			Tri-County	Texas
		Chambers	Galveston	Harris		
11	Agriculture, Forestry, Fishing and Hunting	$21,737	$61,372	$35,280	$35,261	$28,410
21	Mining	$90,856	$105,248	$164,825	$164,033	$117,867
22	Utilities	(n)	$73,899	$110,213	$109,493	$89,914
23	Construction	$44,327	$68,049	$56,363	$56,845	$49,236
31-33	Manufacturing	$75,141	$86,676	$74,670	$75,132	$63,266
42	Wholesale Trade	$54,208	$54,177	$76,273	$75,841	$67,926
44-45	Retail Trade	$29,625	$24,836	$28,468	$28,267	$27,129
48-49	Transportation/Warehousing	(n)	$44,710	$68,405	$67,741	$51,709
51	Information	(n)	$52,683	$67,881	$67,513	$67,456
52	Finance and Insurance	$36,115	$55,520	$89,606	$87,720	$68,605
53	Real Estate, Rental & Leasing	$42,185	$29,313	$50,263	$49,413	$45,814
54	Professional & Tech. services	$60,858	$61,344	$92,311	$91,757	$76,640
55	Management	(n)	$74,744	$140,094	$139,546	$100,019
56	Admin & Support & Waste Mgmt. & Remediation Serv.	(n)	$35,418	$41,011	$40,903	$36,039
61	Educational Services	(n)	$25,553	$53,137	$52,632	$40,840
62	Healthcare	(n)	$32,627	$45,914	$45,411	$41,122
71	Arts, Entertainment, and Recreation	$15,474	$18,520	$41,940	$39,425	$29,340
72	Accommodation and Food Services	$11,403	$15,899	$18,080	$17,895	$16,660
81	Other Services (Except Public Administration)	$40,330	$28,189	$32,911	$32,743	$29,743
92	Public Administration	$39,091	$48,995	$65,289	$316	$51,816
	Total, Private & Government	$46,757	$43,131	$59,185	$58,294	$46,952

Source: U. S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages (QCEW).

8.1.4 Median Household Income for Selected Counties

Median household incomes for three counties in 2010 are shown in **Table 8-4**, with Chambers County showing the highest median household income, followed by Galveston County, and Harris County. Median household incomes for all three counties are higher than the State average of $48,622.

Table 8-4: Texas Median Household Income for Selected Counties – 2010

Geography	Median Household Income	% of State Median Household Income
Chambers County	$69,491	143%
Galveston County	$57,124	117%
Harris County	$50,437	104%
Texas	$48,622	

As shown in **Table 8-5** below, the 2010 unemployment rate in Harris County was above the state average of 7.0 percent. The 2010 unemployment rates in Chambers and Galveston counties were below the state average with Chambers County being the lowest at 6.2 percent.

Table 8-5: Texas Unemployment for Selected Counties – 2010

Geography	Unemployment Rate
Chambers County	6.2%
Galveston County	6.9%
Harris County	7.3%
Texas	7.0%

8.1.5 Social Characteristics

This section describes social characteristics of the tri-county region, and each county within the region. The social characteristics that are assessed in this section include population, race, age, education, income, poverty, and unemployment.

Population Trends

The population growth trends from 1980 through 2010 for the tri-county region are shown in **Table 8-6**. The tri-county region as a whole has experienced a rapid rate of growth since 1980. According to 2010 U.S. Census, the tri-county region has a 68.4 percent growth between 1980 and 2010, with a net population increase of about 1.8 million residents.

Table 8-6: Tri-County Region: Population Growth – 1980 to 2010

Place	1980	1990	2000	2010	% Increase 1980-2010
Chambers County	18,538	20,088	26,031	35,096	89.3%
Galveston County	195,738	217,396	250,158	291,304	48.8%
Harris County	2,409,547	2,818,101	3,400,578	4,093,076	69.9%

Tri-County Region	2,623,823	3,055,585	3,676,767	4,419,476	68.4%
Texas	14,229,191	16,986,510	20,851,820	25,145,561	76.7%
Source: U.S. Census Bureau					

The 2010 population density for the tri-county region estimated by the U.S. Census Bureau is about 1,650 persons per square mile. Population density varied extensively for the three counties from a low of 59 persons per square mile in Chambers County, 770 persons per square mile in Galveston County, and a high of 2,402 persons per square mile in Harris County.

Racial Composition

As shown in **Table 8-7**, Galveston and Harris counties, the tri-county region, and the State of Texas have higher percentages of minority populations than the United States according to the 2010 census. Chambers County has lower percent minority than the national average. Harris County and the State of Texas have about 40 percent Hispanic population, which is more than twice the national average. In 2010, the tri-county region as a whole had more minority composition than the State of Texas, with approximately 58 percent white, 19 percent of the population black, 21 percent of the population either American Indian, Asian, or other race, and about 40 percent of the population Hispanic (of any race).

Table 8-7: Tri-County Region: Racial Composition – 2010

Race	Chambers County		Galveston County		Harris County		Tri-County Region		TX	U.S.
	No.	%	No.	%	No.	%	No.	%	%	%
White	27,582	79%	211,088	73%	2,318,256	57%	2,556,926	58%	70%	72%
Black	2,872	8%	40,112	14%	775,492	19%	818,476	19%	12%	13%
American Indian	219	1%	1,748	1%	27,763	1%	29,730	1%	1%	1%
Asian, Pacific	360	1%	8,839	3%	256,050	6%	265,249	6%	4%	5%
Hispanic	6,635	19%	65,270	22%	1,671,540	41%	1,743,445	40%	38%	16%
Other	3,320	10%	21,631	7%	583,566	14%	608,517	14%	11%	6%
Total Minority	13,406	38%	137,600	47%	3,314,411	81%	3,465,417	78%	65%	41%

Source: U.S. Census Bureau, Census 2010
Note: Percentages do not add to 100% because Hispanic population overlaps with races.

Age Distribution

The age characteristics of the tri-county region are shown in **Table 8-8** according to the 2010 census. Galveston County has a median age similar to the national average. Harris County and the tri-county region have similar median ages which are less than the state average. The median ages for the State of Texas and the nation were 33.5 and 37.0, respectively. Both Chambers and Harris counties have higher percentages of children under the age of 18 than the State of Texas or the nation.

Table 8-8: Tri-County Region Age Characteristics – 2010

Age Group	Chambers County		Galveston County		Harris County		Tri-County Region		TX	U.S.
	No.	%	No.	%	No.	%	No.	%	%	%
Under 18	9,689	29%	73,887	26%	1,132,861	28%	1,216,437	28%	27%	24%
18-64	20,868	62%	183,391	63%	2,571,234	64%	2,775,493	64%	62%	63%
65 or above	3,163	9%	32,281	11%	323,977	8%	359,421	8%	10%	13%
Median Age	35.5		37.3		32.0		32.4		33.5	37.0

Source: U.S. Census Bureau, Census 2010

Educational Attainment

The 2010 educational attainment levels of the population 25 years and older for the tri-county region are presented in the **Table 8-9**. In terms of high school through bachelor's degrees, the State of Texas is similar to the national average. However, Texas has a higher percent than the national average with less than a high school education and a lower percent with graduate and professional degrees.

Chambers County has the highest percent with high school, some college and associate's degrees. Harris County has the highest percent with less than a high school education, bachelor's degrees, and graduate and professional degrees. Overall, the tri-county region has about 21.6 percent with less than a high school education, 23.7 percent with a high school education, and a 21.6 percent with some college. About 18 percent have bachelor's degrees and 9.5 percent have graduate or professional degrees.

Table 8-9: Tri-County Region Education Characteristics – 2010

Age Group	County						Tri-County		TX	U.S.
	Chambers		Galveston		Harris					
	No.	%	No.	%	No.	%	No.	%	%	%
Less than High School	4,822	14%	39,380	14%	894,232	22%	938,434	22%	20%	15%
High School	9,610	29%	76,733	27%	946,597	24%	1,032,940	24%	25%	28%
Some College	10,959	33%	72,969	25%	857,979	21%	941,907	22%	23%	21%
Associate's degree	2,967	9%	22,875	8%	221,544	6%	247,386	6%	6%	8%
Bachelor's degree	3,912	12%	50,673	18%	729,081	18%	783,665	18%	17%	18%
Graduate or professional degree	1,450	4%	27,219	9%	382,667	9%	411,335	10%	9%	10%

Source: U.S. Census Bureau, Census 2010

Income and Poverty

The 2010 census income and poverty data for the tri-county region are summarized in **Table 8-10**. All three counties in the region had median household incomes and per capita incomes higher than that for the state. Chambers County had a median household income greater than the national average while Galveston County had both median household income and per capita income greater than the national average.

Both Harris County and the State of Texas have a higher percent of their population below the poverty level than the nation. Chambers and Galveston counties have lower than national average persons below the poverty level.

Table 8-10: Regional Income and Poverty Data – 2010

Metric	County			TX	U.S.
	Chambers	Galveston	Harris		
Median Household Income	$69,491	$57,124	$50,437	$48,622	$51,914
Per Capita Income	$26,453	$28,959	$26,788	$24,870	$27,334
Persons determined poverty status	33,538	285,759	3,987,911	24,190,492	298,931,525
Persons Below Poverty Level	3,259	36,673	686,821	4,120,572	42,931,760
Percent Below Poverty Level	9.70%	12.80%	17.20%	17.00%	14.40%
Persons Below 50% Poverty Level	1,370	16,384	275,993	1,701,125	18,723,394
Percent Below 50% Poverty Level	4.1%	5.7%	6.9%	7.0%	6.3%

Source: U.S. Census Bureau, Census 2010

8.1.6 Environmental Justice

An EJ analysis was conducted to assess whether the populations currently residing in the vicinity of the HSC can be defined as minority and/or low-income populations. Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, provides that:

> "*…each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations*."

The first 25 miles of the HSC transects Galveston Bay to Morgan's Point passing the communities of Seabrook and Shoreacres. Above Morgan's Point the ship channel passes within vicinity of La Porte, Baytown, Channelview, Galena Park, Pasadena, and Deer Park before entering the City of Houston. The BSC is adjacent to community of Shoreacres and Pasadena while the BCC is adjacent to Morgan's Point and La Porte.

Any individual with total income less than an amount deemed to be sufficient to purchase basic needs of food and shelter, clothing, and other essential goods and services is classified as poor. The amount of income necessary to purchase these basic needs is the poverty line or threshold and is set by the Office of Management and Budget. The 2010 poverty line for an individual under 65 years of age is $11,344. The poverty line for a three-person family with one child and two adults is $15,030. For a family with two adults and two children the poverty line is $22,491.

Table 8-11 shows the 2010 Census percent of population at or below the poverty level, and the percent below 50 percent of the poverty level for the HSC vicinity communities. Galena Park is the most impoverished community with 24 percent of the population below the poverty level and almost 10 percent below half of the poverty level. The City of Houston also has relatively high poverty levels. Baytown, Channelview, and Pasadena have poverty levels between 16 and 20 percent of population. Deer Park and La Porte have poverty levels of about 8 percent and less than 4 percent at half the poverty level.

Most of these communities have a high percent of the population that are minorities or Hispanic. Channelview and Galena Park are almost all (98 percent) minority or Hispanic, and Pasadena is about 95 percent minority or Hispanic. The City of Houston is about 88 percent minority or Hispanic and Baytown is about 75 percent. The remaining communities are at less than 50 percent minority or Hispanic with La Porte at 48 percent, Morgan's Point at 40 percent, Deer Park at 38 percent, Seabrook at 27 percent, and Shoreacres at 25 percent.

Table 8-11: Socioeconomics of HSC Vicinity Communities – 2010

Census Place (TX)	Persons Determined Poverty Status	Less than Poverty level	Less than 50% poverty level	Minority & Hispanic
Houston city	2,038,184	21.0%	8.6%	87.7%
Baytown city	69,883	17.0%	5.7%	75.2%
Channelview CDP	37,837	16.7%	8.1%	98.4%
Deer Park city	31,037	8.4%	3.4%	37.8%
Galena Park City	10,784	24.1%	9.7%	98.4%
La Porte city	33,074	8.0%	3.2%	47.9%
Morgan's Point City	398	17.1%	n/a	40.0%
Pasadena City	145,942	19.6%	6.6%	94.6%
Shoreacres City	1,755	4.4%	n/a	24.5%
Seabrook City	11,460	7.1%	n/a	26.8%

Source: Census

The proposed improvements consist of deepening and widening of the HSC. These improvements are intended to increase the economic efficiency of cargo vessel operations and to accommodate larger container and tanker ships, which are already calling at the port and projected to increase in number in the future.

Since the number of containers per year is not predicted to increase as a result of the deepening, no landside changes in emissions would occur as a result of the deepening. The USACE predicts a reduction in the number of vessels used to transport the number of containers for each year (when compared to without project conditions) if the harbor is deepened. As a result, total emissions would decrease in a given year if the harbor is deepened (when compared to without project conditions). Since overall air emissions in the port would decrease slightly as a result of the project (when compared to without conditions), there is no technical need for the project to conduct a detailed analysis of the how those emissions disperse. Additionally, since there would be an overall decrease in emissions (including air toxins when compared to without project conditions), the USACE does not expect any National Ambient Air Quality Standards (NAAQS) violations as a result of harbor deepening. Therefore, a risk-based assessment of the health effects associated with the proposed action is not warranted. Any potential adverse effects of the presently permitted air emissions would be reduced if the harbor is deepened because of the reduction in vessels (when compared to without project conditions).

The USACE evaluated potential project impacts of the proposed channel deepening and found that the information shows that the proposed action would not cause disproportionately high and adverse impacts to minority populations, low-income populations, or children.

8.2 REGIONAL ECONOMIC DEVELOPMENT ANALYSIS

In the fourth quarter of 2016, Texas had the fastest growing state economy in the United States with 3.4 percent growth. The Texas economy is second to California as a state economy and represents 9 percent of the U.S. economy. Internationally, Texas ranks 10th as a national economy between Brazil and Canada[41]. Houston has a tremendously productive economy; if it were a state, its economy would rank ninth in the United States[42].

Texas has 11 ports with international trade and 28 border crossings with Mexico in combination with the most extensive freight rail system in the country and an extensive interstate system. There are 32 FTZs in the state and Texas is a top-ranked destination for foreign direct investment. Texas has led the nation in exports since 2002[43]. The Houston region is a top destination for foreign direct investment attracting 38 percent of the state's foreign investment over the past five years.

In 2015, Texas ports impacted over 5 million jobs nationally, of which 1.56 million jobs were in Texas, including 116,175 direct employees. The ports of Texas generated $1.135 trillion nationwide in direct revenue, local purchases and related user output nation-wide, including $359 billion in Texas[44].

More than two-thirds of the container cargo in the U.S. Gulf of Mexico comes through Port Houston, making it the top port in the U.S. Gulf Coast in tonnage[45]. It is the largest Texas port with 46 percent of the state market share by tonnage and 95 percent of the state market share in containers by total TEUs[46]. In 2016, Port Houston was ranked #1 in U.S. in foreign tonnage, #3 in

[41] https://blog.bea.gov/category/gross-domestic-product-by-state-2/
[42] Greater Houston Partnership 2016 Report, accessed at http://www.houston.org/assets/pdf/2016_Annual_Report.pdf
[43] https://texaswideopenforbusiness.com/sites/default/files/07/13/16/fdireport.pdf
[44] http://www.texasports.org/wp-content/uploads/2017/04/NationalEconomicImpactoftheTexasPorts8-05-2016final.pdf
[45] http://porthouston.com/portweb/wp-content/uploads/2016/11/Port-of-Houston9689-Port-Fact-Sheet.pdf
[46] http://porthouston.com/portweb/about-us/statistics/

total foreign cargo value, and #6 in total TEUs. Port Houston is home to the largest petrochemical complex in the United States, which is also the second largest in the world[47].

The Port of Houston Authority is the grantee for Foreign Trade Zone (FTZ) No. 84, which is one of the largest FTZs in the country and is made up of various storage facilities and manufacturing facilities. FTZ 84 includes 13 special purpose subzones for use by individual companies for specific activities. FTZ 84 is ranked #1 in the country in total merchandise received and #8 in exports. FTZ 84 directly has 17,369 employees and has 196 active firms[48].

Port Houston generates about 651,524 jobs directly and indirectly from activity at its terminals. Of these about 56,113 are direct jobs. The 56,113 direct employees received an average annual salary of $61,710, which is 36 percent higher than the average statewide salary. The port generates about $264 million in annual economic value to the state, including $19.2 million in direct business revenue (2014). The economic impact of Port Houston accounts for about 16 percent of the Texas GDP[49]. Since 2002, Port Houston has awarded more than $404 million in contracts to small businesses[50].

8.2.1 Regional Analysis

The USACE Online Regional Economic System (RECONS) is a system designed to provide estimates of regional, state, and national contributions of federal spending associated with Civil Works and American Recovery and Reinvestment Act (ARRA) Projects. It also provides a means for estimating the forward linked benefits (stemming from effects) associated with non-federal expenditures sustained, enabled, or generated by USACE Recreation, Navigation, and Formally Utilized Sites Remedial Action Program (FUSRAP). Contributions are measured in terms of economic output, jobs, earnings, and/or value added. The system was used to perform the regional analysis for the Charleston Harbor Deepening and Widening Project.

This report provides estimates of the economic impacts of Civil Works Budget Analysis for New Analysis Project. The Corps' IWR, the Louis Berger Group, and Michigan State University developed RECONS to provide estimates of regional and national job creation, and retention and other economic measures such as income, value added, and sales. This modeling tool automates calculations and generates estimates of jobs and other economic measures, such as income and sales associated with USACE's ARRA spending, annual Civil Work program spending, and stem-from effects for Ports, Inland Water Way, FUSRAP, and Recreation. This is done by extracting multipliers and other economic measures from more than 1,500 regional economic models that were built specifically for USACE project locations. These multipliers were then imported to a

47 http://porthouston.com/portweb/wp-content/uploads/2016/08/Economic_Impact_2015_Executive_Summary1.pdf
48 http://gov.texas.gov/files/ecodev/TexasFTZs.pdf and http://porthouston.com/portweb/ftz/
49 http://porthouston.com/portweb/wp-content/uploads/2016/08/Economic_Impact_2015_Executive_Summary1.pdf
50 http://porthouston.com/portweb/wp-content/uploads/2016/11/Port-of-Houston9689-Port-Fact-Sheet.pdf

database and the tool matches various spending profiles to the matching industry sectors by location to produce economic impact estimates.

Table 8-12 provides the project information while **Table 8-13** provides the economic impact regions for the HSC analysis.

Table 8-12: RECONS Project Description

Project Name:	HSC ECIP
Division:	SWD
District:	Galveston
Type of Analysis:	Civil Works Budget Analysis
Business Line:	Navigation
Work Activity:	CWB - Navigation

Table 8-13: RECONS Regional Impact Area

Local Impact Area	Austin (TX), Brazoria (TX), Chambers (TX), Fort Bend (TX), Galveston (TX), Harris (TX), Liberty (TX), Montgomery (TX), Waller (TX)
Counties included	Austin (TX), Brazoria (TX), Chambers (TX), Fort Bend (TX), Galveston (TX), Harris (TX), Liberty (TX), Montgomery (TX), Waller (TX)
State Impact Area	Texas
State(s) included	Texas

8.2.2 Results of the Economic Impact Analysis

The RED impact analysis was evaluated at three geographical levels: Local, State, and National. The Local analysis represents the Houston impact area which encompasses the area included in about a 50-mile radius around the project area. The State level analysis includes the State of Texas. The National level includes the 48 contiguous U.S.

Table 8-14 displays the overall spending profile that makes up the dispersion of the total project construction cost among the major industry sectors. The spending profile also identifies the geographical capture rate, also called Local Purchase Coefficient (LPC) in RECONS, of the cost components. The geographic capture rate is the portion of USACE spending on industries (sales) captured by industries located within the impact area. In many cases, IMPLAN's trade flows Regional Purchase Coefficients (RPCs) are utilized as a proxy to estimate where the money flows for each of the receiving industry sectors of the cost components within each of the impact areas.

Table 8-14: Input Assumptions (Spending and LPCs)

IMPLAN Code	Industry	Expenditure	Local Purchase Coefficients		
		($000)	Local	State	US
58	Construction of other new nonresidential structures	$78,916	100%	100%	100%
105	All other food manufacturing	$16,511	10%	18%	91%
156	Petroleum refineries	$65,252	79%	79%	81%
205	Cement manufacturing	$6,879	20%	79%	87%
217	Iron and steel mills and ferroalloy manufacturing	$21,703	15%	28%	74%
254	Valve and fittings, other than plumbing, manufacturing	$29,958	36%	36%	52%
271	All other industrial machinery manufacturing	$7,946	8%	18%	69%
334	Switchgear and switchboard apparatus manufacturing	$14,972	30%	30%	54%
363	Ship building and repairing	$94,580	82%	82%	98%
395	Wholesale trade	$26,895	100%	100%	100%
399	Retail - Building material and garden equipment and supplies stores	$4,713	81%	97%	100%
408	Air transportation	$549	80%	80%	80%
409	Rail transportation	$972	36%	78%	99%
410	Water transportation	$537	100%	100%	100%
411	Truck transportation	$5,199	98%	98%	99%
413	Pipeline transportation	$1,461	100%	100%	100%
437	Insurance carriers	$17,537	46%	75%	87%
455	Environmental and other technical consulting services	$8,768	100%	100%	100%
462	Office administrative services	$61,379	100%	100%	100%
502	Limited-service restaurants	$8,768	100%	100%	100%
507	Commercial and industrial machinery and equipment repair and maintenance	$149,064	100%	100%	100%
535	Employment and payroll of federal govt, non-military	$113,990	100%	100%	100%
5001	Private Labor	$140,296	100%	100%	100%
	Total	**$876,848**			

Total project cost is $876,848. Of this total project expenditure $759 million will be captured within the regional impact area. The rest will be leaked out to the state or the nation. The expenditures made by the USACE for various services and products are expected to generate additional economic activity that can be measured in jobs, income, sales and gross regional product as summarized in the following table and includes impacts to the region, the State impact area, and the Nation. **Table 8-15** is the overall economic impacts for this analysis.

Table 8-15: Overall Summary of Economic Impacts

Area	Local Capture ($000)	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
Local					
Direct Impact		$759,076	2,660.3	$316,526	$431,499
Secondary Impact		$416,495	2,218.0	$155,687	$253,599
Total Impact	$759,076	$1,175,571	4,878.3	$472,214	$685,098
State					
Direct Impact		$774,446	3,066.3	$319,650	$438,348
Secondary Impact		$543,784	2,951.3	$186,482	$309,493
Total Impact	$774,446	$1,318,229	6,017.6	$506,132	$747,841
US					
Direct Impact		$828,637	3,372.0	$333,155	$457,495
Secondary Impact		$1,052,213	5,041.7	$328,487	$556,711
Total Impact	$828,637	$1,880,850	8,413.7	$661,642	$1,014,206

* Jobs are presented in full-time equivalence (FTE)

Table 8-16, **Table 8-17**, and **Table 8-18** present the economic impacts by industry sector both for the local, state, and national impact regions, respectively. Impacts at the National level show a tremendous expansion most certainly due to the many multiple turnover of money that ripples throughout the National economy. RECONS estimates the total direct and indirect outputs associated with construction of the recommended plan amount $1,833,647 and an additional 8,203 full time jobs. The RECONS model estimates that 63 percent of the total impacts resulting from the recommended plan will be captured locally, an additional 8 percent will be captured at the state level, and the remaining 30 percent will be captured nationally.

Table 8-16: Local Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$78,916	413.8	$36,330	$46,175
105	All other food manufacturing	$1,644	4.5	$189	$235
156	Petroleum refineries	$51,460	6.9	$3,368	$19,592
205	Cement manufacturing	$1,354	2.1	$155	$517
217	Iron and steel mills and ferroalloy manufacturing	$3,323	2.9	$225	$527
254	Valve and fittings, other than plumbing, manufacturing	$10,675	24.6	$2,766	$4,720
271	All other industrial machinery manufacturing	$608	2.0	$182	$230
334	Switchgear and switchboard apparatus manufacturing	$4,445	11.4	$1,051	$1,347
363	Ship building and repairing	$78,008	249.8	$31,176	$36,705
395	Wholesale trade	$26,894	77.3	$9,662	$19,226
399	Retail - Building material and garden equipment and supplies stores	$3,813	29.8	$1,600	$2,553
408	Air transportation	$442	1.0	$119	$188
409	Rail transportation	$348	0.7	$116	$208
410	Water transportation	$537	0.5	$81	$175
411	Truck transportation	$5,119	25.3	$2,126	$2,339
413	Pipeline transportation	$1,461	2.0	$1,801	$986
437	Insurance carriers	$7,986	14.9	$2,004	$4,372
455	Environmental and other technical consulting services	$8,768	60.6	$8,272	$6,446
462	Office administrative services	$61,174	455.8	$49,825	$52,415
502	Limited-service restaurants	$8,761	77.7	$2,126	$5,176
507	Commercial and industrial machinery and equipment repair and maintenance	$149,054	624.1	$77,750	$113,377
535	Employment and payroll of federal govt, non-military	$113,990	572.9	$85,601	$113,990
5001	Private Labor	$140,296	0.0	$0	$0
	Direct Impact	**$759,076**	**2660.3**	**$316,526**	**$431,499**
	Secondary Impact	**$416,495**	**2218.0**	**$155,687**	**$253,599**
	Total Impact	**$1,175,571**	**4878.3**	**$472,214**	**$685,098**

* Jobs are presented in full-time equivalence (FTE)

Table 8-17: Regional Impact

Table 8 - State Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$78,916	462.3	$36,330	$46,175
105	All other food manufacturing	$2,923	8.1	$336	$419
156	Petroleum refineries	$51,460	7.3	$3,368	$19,592
205	Cement manufacturing	$5,414	8.3	$794	$2,642
217	Iron and steel mills and ferroalloy manufacturing	$6,092	5.3	$422	$965
254	Valve and fittings, other than plumbing, manufacturing	$10,675	24.9	$2,766	$4,720
271	All other industrial machinery manufacturing	$1,470	4.9	$491	$618
334	Switchgear and switchboard apparatus manufacturing	$4,445	11.4	$1,106	$1,415
363	Ship building and repairing	$78,008	280.2	$31,176	$36,705
395	Wholesale trade	$26,894	86.4	$9,662	$19,226
399	Retail - Building material and garden equipment and supplies stores	$4,583	37.2	$1,923	$3,069
408	Air transportation	$442	1.0	$126	$195
409	Rail transportation	$761	1.6	$254	$456
410	Water transportation	$537	0.6	$81	$175
411	Truck transportation	$5,119	27.6	$2,126	$2,339
413	Pipeline transportation	$1,461	2.0	$1,801	$1,006
437	Insurance carriers	$13,199	26.7	$3,312	$7,227
455	Environmental and other technical consulting services	$8,768	73.9	$8,272	$6,446
462	Office administrative services	$61,174	551.9	$49,825	$52,415
502	Limited-service restaurants	$8,763	78.5	$2,127	$5,177
507	Commercial and industrial machinery and equipment repair and maintenance	$149,054	681.5	$77,750	$113,377
535	Employment and payroll of federal govt, non-military	$113,990	684.9	$85,601	$113,990
5001	Private Labor	$140,296	0.0	$0	$0
	Direct Impact	**$774,446**	**3066.3**	**$319,650**	**$438,348**
	Secondary Impact	**$543,784**	**2951.3**	**$186,482**	**$309,493**
	Total Impact	**$1,318,229**	**6017.6**	**$506,132**	**$747,841**

* Jobs are presented in full-time equivalence (FTE)

Table 8-18: National Impact

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$78,916	484.2	$36,330	$46,175
105	All other food manufacturing	$15,045	41.6	$2,235	$2,845
156	Petroleum refineries	$52,657	7.7	$3,446	$20,048
205	Cement manufacturing	$5,953	9.2	$915	$2,906
217	Iron and steel mills and ferroalloy manufacturing	$16,073	13.9	$1,443	$2,966
254	Valve and fittings, other than plumbing, manufacturing	$15,605	38.8	$4,044	$6,900
271	All other industrial machinery manufacturing	$5,492	19.3	$1,835	$2,309
334	Switchgear and switchboard apparatus manufacturing	$8,046	20.6	$2,002	$2,825
363	Ship building and repairing	$93,103	341.2	$37,209	$43,807
395	Wholesale trade	$26,895	96.8	$9,662	$19,227
399	Retail - Building material and garden equipment and supplies stores	$4,713	39.8	$1,978	$3,156
408	Air transportation	$442	1.0	$126	$195
409	Rail transportation	$966	2.1	$322	$578
410	Water transportation	$537	0.6	$81	$175
411	Truck transportation	$5,123	27.6	$2,128	$2,341
413	Pipeline transportation	$1,461	2.0	$1,802	$1,051
437	Insurance carriers	$15,344	31.1	$3,850	$8,401
455	Environmental and other technical consulting services	$8,768	88.1	$8,272	$6,447
462	Office administrative services	$61,379	597.4	$49,992	$52,590
502	Limited-service restaurants	$8,768	79.1	$2,128	$5,180
507	Commercial and industrial machinery and equipment repair and maintenance	$149,064	745.3	$77,756	$113,384
535	Employment and payroll of federal govt, non-military	$113,990	684.9	$85,601	$113,990
5001	Private Labor	$140,296	0.0	$0	$0
	Direct Impact	**$828,637**	**3372.0**	**$333,155**	**$457,495**
	Secondary Impact	**$1,052,213**	**5041.7**	**$328,487**	**$556,711**
	Total Impact	**$1,880,850**	**8413.7**	**$661,642**	**$1,014,206**

* Jobs are presented in full-time equivalence (FTE)