Freeport Channel Improvement Project

General Re-Evaluation Report

and

Economic Update

Economic Appendix

Freeport, Texas

February 2018 (Revised 29 March 2018)

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1.0 Introduction

The Freeport Channel Deeping Project General Re-evaluation Report (GRR) and Economic Update includes two components: (1) an Economic Update of the 2012 Feasibility Report authorized in the Water Resources Reform and Development Act (WRRDA) of 2014 and (2) a GRR study. The economic update is intended to confirm Federal Interest of the recommended channel deepening project. The GRR evaluates potential channel deepening and limited widening to allow a larger containership vessel class to call Reach 3 of the study area.

Please reference the main GRR for additional details regarding the Port geography and facility specifications. The 2012 Feasibility Report also provides longer term trends in historical traffic; this update focuses on the most recent five years (2011-2015).

1.1 Economic Evaluation: Overview

Deep draft navigation policies allow projects to account for transportation cost reduction benefits in several ways. In the case of Freeport Harbor, the basis for the economic benefits are primarily captured in two ways. First, a project can reap benefits by achieving savings in loading practices. These type of benefits are common in a channel deepening project. With a deeper channel, the vessel can load more product and/or shift to a larger vessel class, also allowing for additional product per load. The heavier loading allows fewer vessels to transport the same amount of product, thereby reducing the number of round trips. The ocean-going portion of transportation cost savings typically consists of approximately 90 percent of project benefits in a channel deepening project. In other words, multiplying the number of vessel call reductions by round-trip transportation costs will yield the vast majority of benefits of a deepening project.

Key factors affecting the magnitude of loading practices benefits are:

- miles applied in a route round trip
- vessel operating costs
- vessel speeds
- tons per vessel in both the future without-project condition (FWOP) and future with-project condition (FWP)

The tons per vessel analysis requires the following assumptions:

- specific commodities and their future growth rates
- future loading practices for each vessel

The second category of benefits for this project is time savings. These types of benefits are typically accrued by the reduction of transportation costs within a harbor and account for the approximately 10 percent of remaining benefits. Reduced transportation costs may consist of a reduction in delays due to congestion, berth modifications affecting time at dock, and safety concerns, to name a few. Widening projects, including turning basins and bend easings, may influence both loading practices and time savings. A wider channel may allow for a larger vessel class, or faster transit speeds.

Key factors affecting the magnitude of time savings benefits include:

- vessel classes
- loading practices
- Pilot rules

As Figure 1-1 depicts, the WRRDA 2014 study included benefits mostly derived from crude oil imports (72%) and containers imports and exports (16%). Other benefit categories included petroleum products (4%), chemicals (5%), and other vessels (3%). Expected shifts in these commodities will be detailed in the following sections.

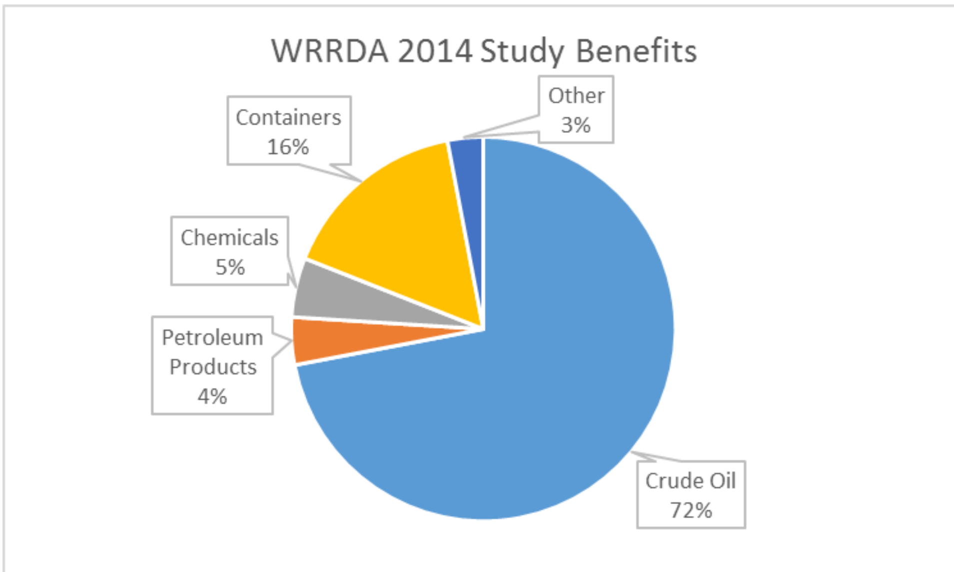


Figure 1-1. WRRDA 2014 Study Benefits by Commodity

A complete discussion of economic benefits for the Freeport Harbor project is presented in Section 6 and Section 7.

1.2 Economic Reaches

The Economic reaches in the Freeport Economic Update are the same as those utilized for the 2012 Feasibility Report (i.e., the project authorized in WRRDA 2014). The current channel is -46 feet below mean lower low water (MLLW) and primarily serves the petrochemical industry. The reaches each serve different commodities.

Reach 1 includes the following facilities:

- Freeport LNG (Liquefied Natural Gas)
- Seaway (crude oil and petroleum products)
- Dow Chemical (chemicals)

Reach 2 includes the following facilities and features:

- Phillips (crude oil, petroleum products, chemicals, LPG) Berths 2 and 3
- Upper Turning Basin
- Berth 6 tangent to the Upper Turning Basin

Brazos Harbor (not included in the deepening project) veers west of the Upper Turning Basin. Brazos Harbor is dredged to -37 feet MLLW and has several docks in the Harbor:

- BASF (chemicals)
- Breakbulk rice exports
- Port Freeport (Containers, Vehicles)

Brazos Harbor previously served the market for containerized banana imports, but those shipments have moved to a newly constructed container facility (Velasco Terminal). The container market now includes resin exports.

Reach 3 includes:

- Velasco Terminal (containers, vehicles)

The Velasco Terminal includes:

- Berth 7 (containers)
- Berth 8 (containers) – future without-project condition and future with-project condition
- Berth 9 (vehicles) – future without-project condition and future with-project condition

Berth 7 was dredged to -46 feet MLLW in 2014; however, the channel tangent to Berth 7 is only -19 feet MLLW. Regardless, Berth 7 connects to the Upper Turning Basin so vessels have access to the berth via the turning basin.

Port Freeport is working to complete berth and terminal improvements to Velasco Terminal prior to the base year (2022) under two phases. Phase I (completed in 2014) allowed for containerships to call at Velasco Terminal through improvements and construction at Berth 7. Phase II will impact an additional 75 acres and will include the construction of an additional 1,200 linear feet of berth and 45 acres of backland development to support additional berths. A new Berth 8 will serve containerships and a future Berth 9 will focus primarily on RoRo traffic.

Reach 4, currently the -19 feet MLLW channel depth services:

- Offshore supply vessels
- Other smaller vessels

Figure 1-2 depicts the Economic Reaches in the study area.

Figure 1-2. Economic Reaches

1.3 Data Sources and Key Assumptions

Data from a number of Gulf ports (Freeport, Houston, and Mobile) was used to derive study assumptions and complete the economic analysis. Waterborne Commerce data (2015) was also used for trend analysis. A summary of key assumptions is provided below:

- Houston and Freeport will likely service different markets, though share the same hinterland. For example, Houston container imports are expected to continue to service "big box stores" while Freeport imports will remain primarily focused on food products.
- Given the proximity to Houston, the growing congestion at Houston both in the channel and landside, and given that both ports serve the petrochemical industry, the analysis assumes the characteristics of Panamax vessels on Caribbean routes currently at Houston will be reflected at Freeport by the year 2040. These characteristics include vessel class distributions, tons per TEU, parcel size, sailing draft distributions, and load factors.
  - Years prior to 2040 were interpolated between Freeport existing conditions and Houston existing conditions for vessel class distributions of Panamax vessels.
  - Given Freeport's relatively short history of container traffic at Velasco and lack of Panamax vessel calls, Houston data (2013) was analyzed as a comparison for future conditions.

- For the economic analysis, the route for Panamax vessels was assumed to service the same world regions currently being served by the Port. In other words, a shift in routes (e.g., longer routes) due to the introduction of Panamax vessels is not assumed.
- No origin or destination shift from Houston to Freeport is assumed.
- Representatives from the Corps completed interviews with Phillips (Reach 2, berths 2 and 3) and Hoegh Autoliners (Reach 3) in October 2017 to verify the following assumptions.
    - Based on input from Phillips, the existing channel dimensions are not the major limiting factor. Under current operations, a deeper channel is not required to meet market demand. However, a deeper channel could be beneficial if the market shifted or Phillips found a customer requiring an increase in amount of cargo that they are able to transport now at one time. Based on the discussion with Phillips, it does not appear that there are additional benefits derived at this time within the existing market.
    - Based on input from Hoegh, newly renovated RoRo vessels (775 LOA x 105 beam) have been added to their existing fleet (656 LOA x 105 beam). These larger RoRo vessels will continue to call Freeport in both the without-project and with-project scenarios. The representatives of Hoegh expressed their wishes to have the daylight only transiting restriction eased with a project in place; however, the harbor pilots have stated that the proposed project would not allow them to begin transiting at night.

2.0 Existing Conditions and Changes in Economic Conditions

Historically, the Freeport channel primarily serviced the markets of crude oil imports, petroleum product imports and exports, and chemical exports. Limited containership traffic used Brazos Harbor to import bananas and other perishables. The crude oil was refined at Sweeny or piped to Cushing, Oklahoma and other facilities to be refined. However, external market influences in the past few years have shifted some of Freeport’s cargo makeup. These changes are summarized in the table below and detailed in the following sections. In addition, this section provides a summary of existing conditions for the hinterland, commodities, vessel traffic, and vessel size guidelines/pilot rules.

Table 2-1. Key Changes Informing Economic Update

	Changes Informing Economic Update

Shift in Commodities	• Eagle Ford Shale, pipeline reversal, crude oil exports ban lifted
	  ○ Crude oil imports decrease
	  ○ Crude oil exports increase
	  ○ Petroleum products exports increase
	• Liquid Natural Gas (LNG) exports rather than imports

Vessel Traffic Changes	• Crude oil: less total tonnage; loading deeper, larger vessels • Petroleum products: exports tonnage increase; similar loading practices • Chemical products: no change

Vessel Traffic Distribution	• Less crude oil imports tonnage
	  ○ Less lightering
	  ○ Suezmax vessels calling to Seaway Dock

Maximum-Sized Vessels	• Crude Oil Tankers: Suezmax (FWOPC & FWPC) • Petro Product Tankers: Aframax (FWOPC & FWPC) • Chemical Tankers: Aframax (FWOPC & FWPC)

2.1 Hinterland

Port Freeport serves a hinterland including Texas, Louisiana and much of the American Midwest. The port's proximity to deep water provides efficient transportation to Houston and beyond via highway, rail, and the inland waterway system. The port is accessible from the landside by State Highway (SH) 36, SH 288, and Farm-to-Market Road (FM) 523. A number of regional rail lines also serve Freeport area, including Union Pacific and Burlington Northern Santa Fe lines to San Antonio, Houston, Dallas, and the American Midwest. Figure 2-1 generally depicts the hinterland for Freeport Harbor. The blue arrows depict regions that the Port is currently serving or attempting to serve and overlap with market areas for other Gulf ports.

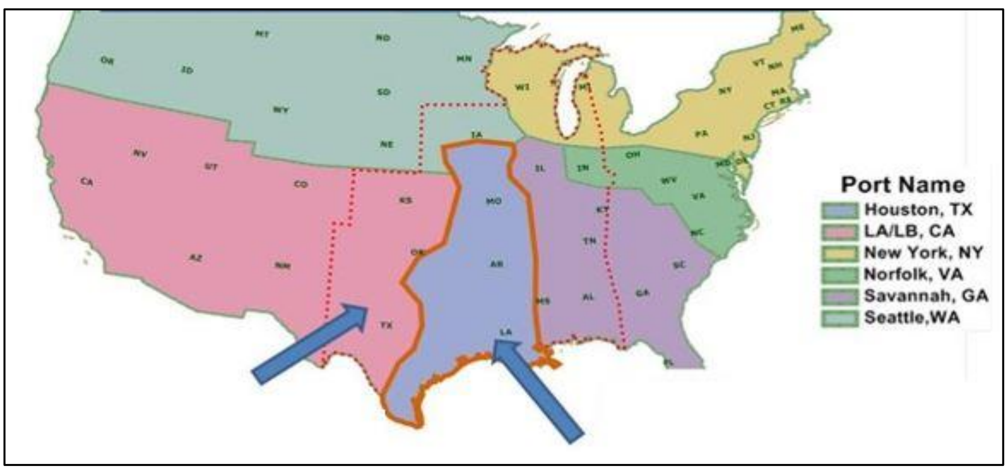


Figure 2-1. Freeport Harbor Hinterland

2.2 Commodities

Figure 2-2 shows the distribution of tonnage by commodity and direction for Freeport. Crude oil imports continues to constitute more than half of channel tonnage. Other recent shifts include the growing market for crude oil and petroleum product exports, the commodity composition in container imports and exports, and the introduction of vehicle imports and exports at Freeport.

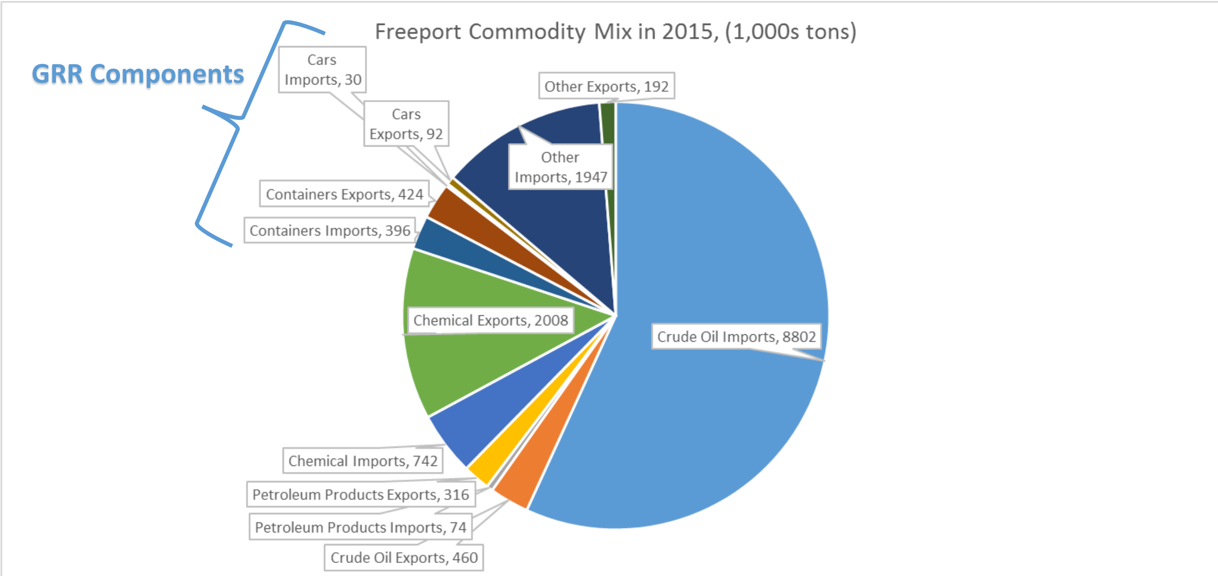


Figure 2-2. Commodity Mix

Source: Waterborne Commerce, 2015

2.2.1 Crude Oil

Recent economic changes resulted from drastic increases in domestic crude oil production, thereby affecting international crude oil activity and petroleum product production along the Gulf Coast.

The import/export activity and domestic production of crude oil is affected by market fluctuations. The domestic production along the Permian Basin will likely decrease as prices fall and increase as prices climb. The historically volatile oil prices during the last 5 years have greatly influenced the import/export markets for crude oil. However, crude oil imports continue to dominate throughput tonnage at Freeport.

The graph below shows crude oil imports at Freeport and its share of the total U.S. market.

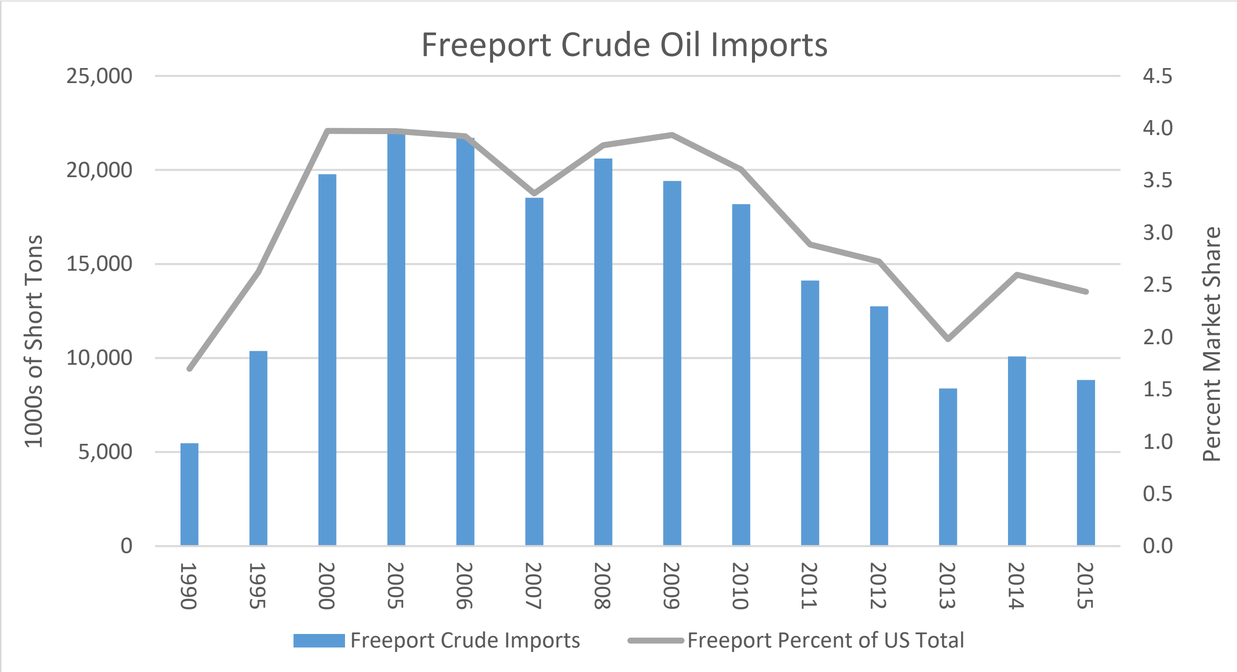


Figure 2-3. Crude Oil Imports

Source: Waterborne Commerce

Oil is not homogeneous, and refineries require a blend of oils. This blend requirement ensures that imports are likely to continue, even if exports increase dramatically.

There are more than 100 different markets of crude oil, but the three primary global markets are:

- **West Texas Intermediate (WTI):** WTI is an extremely high quality light sweet crude oil that enables higher quantity and quality gasoline to be refined per barrel of oil. Its proximity to refineries and end users cause West Texas Intermediate crude oil to sell at a premium compared to Brent Blend and OPEC Basket crude oil.
- **Brent Blend:** Brent Blend crude oil is a combination of oils from the North Sea. Brent Blend crude oil is used for making gasoline and middle distillates, and is most often refined in Europe.
- **Organization of the Petroleum Exporting Countries (OPEC) Basket:** OPEC Basket crude oil is a collective of seven different crude oils from Algeria, Saudi Arabia, Indonesia, Nigeria, Dubai, Venezuela, and the Mexican Isthmus. Although OPEC Basket crude oil is lesser quality, OPEC remains competitive by quickly increasing production when the market necessitates.

The Permian Basin in Texas provides domestic refineries with light sweet crude oil. Due to proximity to refineries and the pipeline network to Freeport, it is cheaper to refine at least some domestic production than import light sweet crude from other parts of the world. Also, the facilities that service Freeport are calibrated for sour crude (not the type of oil in domestic production). Hence, there will likely be a “floor” for imports regardless of prices. Therefore, fluctuating prices will likely create a self-balancing condition. As prices increase, domestic wells will turn on, thereby increasing global supply and suppressing prices. As prices decrease, steady demand for sour crude maintains the demand for sour crude imports.

The forecasts from Global Insight (2013) and the Department of Energy (2015) project annual increases in U.S. crude oil imports. The Department of Energy (2015) and Goldman Sachs Global Investment Research (September 2015) forecast a slight annual increase in West Texas crude oil production from current levels. The amount of crude petroleum imported into Freeport is largely dependent upon the area’s capacity to refine crude and/or deliver by pipeline to other refining complexes.

It should also be noted that with the lift of the crude oil export ban in December 2015, high oil prices will encourage West Texas light crude exports to a portion of the world because production and distribution costs are lower for West Texas crude than for those receiving countries to obtain light crude oil from other countries. Previous analysis did not include crude petroleum exports.

Due to the lift of export restrictions in December 2015, crude oil can now be exported and will likely open up new markets. Previously, crude oil could only be exported in a few circumstances. Condensates, which are lightly processed and so considered a petroleum product in legal terms, were the only significant U.S. crude petroleum export other than Canadian crude being transported through the U.S. Other U.S. crude oil that required a license from the U.S. Department of Commerce to be exported include Alaska’s Cook Inlet, exports to Canada as long as it was consumed there, and small amounts of heavy crude oil produced in California. Also, crude oil transported via the Trans-Alaska Pipeline System, produced overseas and stored in the U.S. Strategic Petroleum Reserve, produced from the outer continental shelf, and other rare cases could formerly be exported.

Over the past decade, the U.S. oil industry has increased oil production in shale formations. The shale formations are naturally more abundant in oil condensates. The Eagle Ford formation (Figure 2-4) is composed of more than 20 percent oil condensate. Condensate is used to “spike” crude oil stream, dilute heavy oil export streams and bitumen, or to be exported after stabilization. Technological innovation and increasing energy demand continue to create demand for condensate. Regulatory permissions granted in 2014 to export “stabilized” condensate (either through reapportioning refineries or using condensate splitters) has led to further demand. U.S. firms also hope to export the condensate to capitalize on the large capacity of overseas condensate-splitters.

The Energy Information Administration (EIA) estimates that U.S. oil condensate production has grown from 173 million barrels in 2008 at an average annual growth rate of 13 percent to 311 million barrels in 2013. The Eagle Ford Shale formation is estimated by EIA to contain 10.8 billion barrels of recoverable oil and 36 percent of all recoverable U.S. tight oil.

To add to this recent market shift of crude oil, the flow was reversed for one of the main pipelines reaching from Cushing, OK to Seaway at Freeport, TX in 2013. This helps facilitate exports rather than imports of crude oil at Seaway.

In summary, petroleum and petroleum product exports are increasing, and petroleum imports and lightering operations have decreased dramatically.

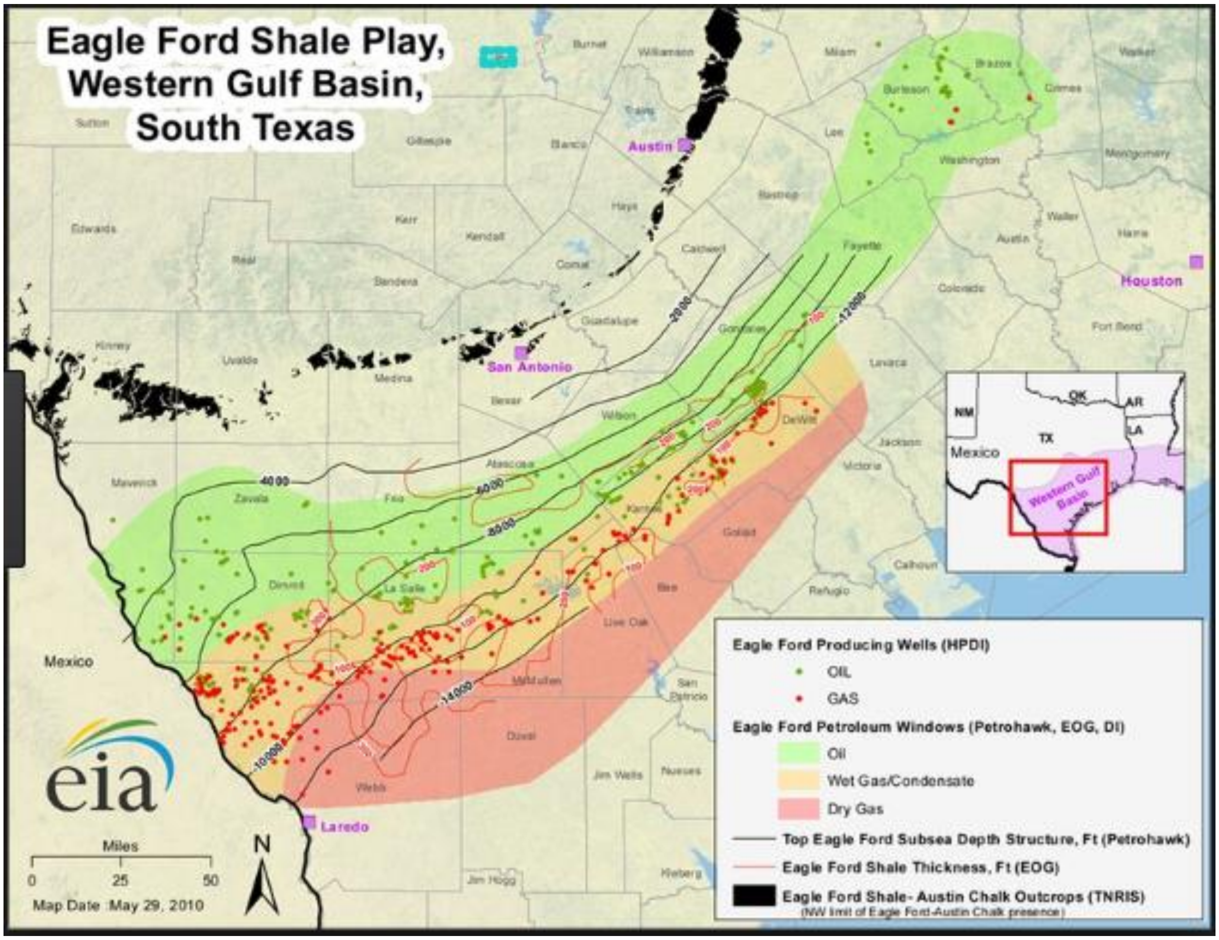


Figure 2-4. Eagle Ford Shale Formation

Source: U.S. Department of Energy

2.2.2 Containers

Table 2-2 and Figure 2-5 includes container composition data for 2014-2015.

While the majority of Freeport's cargo consists of crude oil, bulk fuels, and chemicals, the port has a large general cargo base that includes a variety of temperature-sensitive cargos such as meat and vegetables. Major tenants of the port include Dole Fresh Fruit Company, American Rice, and Chiquita.

In October 2014, Phase I of the Velasco Terminal was completed. This phase included the construction of an 800 foot dock, the purchase of two cranes, and landside improvements. Phase I allowed containerships to transfer to Berth 7 instead of calling to Brazos Harbor. In conjunction with these improvements, Dow Chemical and other local facilities grew their resins exports markets. Freeport captured that market and now exports plastic resins in addition to importing perishables. Approximately one-third of the tonnage on containers now consist of resins, and half of the container tonnage at Freeport is related to the petrochemical industry. Table 2-2 summarizes containerized imports and exports by commodity group. Import tonnage fell from 2014 to 2015. The study assumes that this drop in tonnage is the result of short-term variability. Since 2012 to 2016, total TEU imports have grown at an average annual rate of 3.2 percent.

Table 2-2. Containers Composition – Tonnage

Containers Composition, 2014-2015								
Commodity Code	Commodity Group	2014 Import	2014 Export	2014 Total	2015 Import	2015 Export	2015 Total	% Share
0	Other (Fluids, Textiles, Plastics)	28,108	49,571	77,679	29,255	76,254	105,509	13%
2	Petroleum Products	28	3,194	3,222	58	6,088	6,146	1%
3	Chemicals (Resins)	4,040	175,011	179,051	388	279,533	279,921	33%
4	Crude Materials	11,231	156	11,387	2,741	5,090	7,831	1%
5	Manufactured Goods	777	1,033	1,810	-	2,270	2,270	0%
6	Food Products	345,915	7,705	353,620	329,796	19,036	348,832	51%
7	Wood and Paper	3,829	98	3,927	1,016	8,020	9,036	1%
Total		**393,928**	**236,768**	**630,696**	**363,254**	**396,291**	**759,545**	**100%**

Source: Waterborne Commerce, 2014-2015

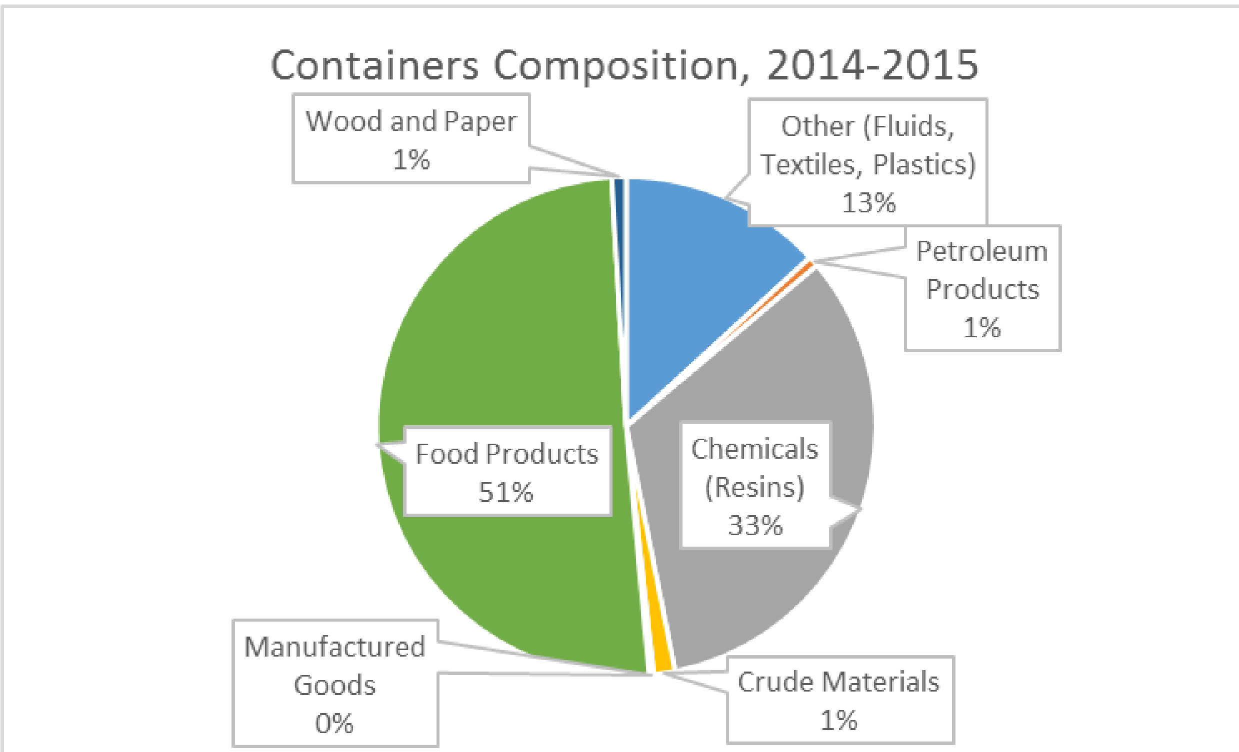


Figure 2-5. Containers Composition

Source: Waterborne Commerce, 2014-2015

New data from the Waterborne Commerce Statistics Center (2015) indicate food products are decreasing to 37% of the total container tonnage and plastic resin is now 32% of the total.

Evidence from Table 2-2 and Figure 2-5 indicate a drop of nearly 30 thousand tons in total containerized imports from 2014 to 2015. Over half of this drop (53 percent) is the result of a reduction in food product imports. The remaining drop comes from imports of crude materials (28 percent), chemicals (12 percent), and wood and paper (9 percent). The study assumes that this decrease in imports is a short-term trend due to market variability. The study assumes long-term growth in imports to continue.

Table 2-2 also presents the commodity distribution of containerized exports for Port Freeport. The table shows growth of nearly 160 thousand tons from 2014 to 2015. The majority of this growth is due to chemical exports, mostly chemical resins (66 percent of totally chemical exports). This export category is expected to continue to grow over the study period, as described in Section 3.1

2.2.3 Vehicles

The transfer of containerships to the Velasco Terminal has enabled Port Freeport to use the old containership docks in Brazos Harbor for vehicle transport. Therefore, RoRo vessels began calling on a regular basis in 2015. Landside improvements have been made to accommodate the staging of these vehicles, thereby allowing larger RoRo vessels and additional tonnage on those vessels. Based on expected continued growth in this market, RoRo vessels are expected to dock both at Berth 9 and Brazos Harbor Berths 2 and 3.

2.3 Vessel Traffic

The Freeport Harbor layout can be found in Figure 1-2. The current channel configuration limits container traffic to Sub-Panamax vessels. The channel was designed and authorized for an Aframax tanker vessel (64,000 deadweight tons with dimensions of 790 feet LOA, beam of 109 feet, and draft of 41 feet, and a 79,000 deadweight ton vessel that is light-loaded) in the 1970s (45-foot project). Traffic above the Upper Turning Basin was not an economic consideration at the time.

Reach 1 Traffic

Seaway is located in Reach 1 and services the crude petroleum vessels. Seaway currently receives lightened Suezmax vessels up to 165,000 DWT and would have the opportunity to come in the channel more fully loaded with a deeper channel, thereby contributing to benefits.

Reach 2 Traffic

The Aframax vessel utilizes the existing Phillips Berths 2 and 3 to haul petroleum and petroleum products as the channel was designed to accommodate. Phillips' owned Berth 2 and Berth 3 (differentiated from Brazos Harbor Berths 2 and 3) are located across the channel from Dow Thumb in Reach 2. Phillips is converting Berth 2 to an LPG facility, and Berth 3 will serve other petrochemical products. The docking of an LPG vessel at Berth 2 poses a safety concern for pilots utilizing the channel. The pilots indicate with a 20 mile per hour (mph) wind, a vessel transiting the channel could be blown into Berth 2 even with the use of tugs. According to the pilots, the length of vessels matters more than the width for safety concerns because of fetch from wind as well as visibility as they are transiting the bend. Any vessel longer than 600 feet pose a concern under existing conditions for the pilots. Therefore, a bend easing component would greatly help alleviate pilot concerns. Any hardened structures along the bend are not preferred by pilots because the pilots currently use the hydrodynamic forces of the bank to turn in the bend. A hard structure could make it more difficult to navigate and could remove room for tugs to maneuver.

Finally, Berth 6 is located tangent to the Upper Turning Basin and accommodates rock ships (general cargo/aggregate).

Reach 3 Traffic

Port Freeport expansions now seek traffic in Reach 3 to go to the Velasco Terminal. Berth 7, which is already constructed and has two cranes, is used for the Velasco Terminal containers. Plans also include Berth 8 so the design containership can dock simultaneously with another Panamax-sized containership. Three additional cranes will be purchased.

Berth 7 is currently dredged to -46 feet MLLW and connects to the Upper Turning Basin. The channel in Reach 3 has a depth of -19 feet MLLW, so existing and future vessels can only enter Berth 7 from the Upper Turning Basin and must either back in or back out using only the 300 foot wide berth space. Berth 6 is adjacent to Berth 7 and blocks Berth 7 if a vessel is docked at Berth 6. Likewise, Berth 7 blocks Berth 6 if a vessel is docked at Berth 7. With Reach 3 dredged, the Berths will not block each other from docking.

Brazos Harbor Traffic

Brazos Harbor consists of multiple docks. RoRo vessels currently use Docks 2 and 3. Dock 2 blocks Dock 3 when it is occupied, and vice-versa. By constructing Berth 9 in Reach 3, some of the RoRo traffic can be diverted to Berth 9 so that two RoRo ships can be accommodated at a time, one at Berth 9 and another at either Dock 2 or 3.

2.3.1 Vessel Class Size Considerations

There are several factors in vessel class size in crude petroleum. In addition to transportation cost incentives, vessel selection is also related to the way crude petroleum is currently sold and how crude oil is shipped. Presently, parcels are generally sold in 500,000 to 650,000 barrels. A 500,000 to 650,000 barrel parcel converts to approximately 75,000 to 95,000 short tons. Many vessels arrive in the international waters of the Gulf of Mexico with double parcels. Generally, the most economically-sized vessel for single parcels is between 75,000 and 100,000 DWT given the existing channel depth of -40 feet MLLW. For double parcels, the most efficient size is between 150,000 and 175,000 DWT. This is why the vessels associated with direct shipments are typically 90,000-120,000 DWT, shuttle vessels are typically around 80,000 DWT, and lightened vessels are typically approaching 175,000 DWT. Associated ship size is primarily a function of the existing channel dimensions given the parcel size. An increase in channel dimensions would likely result in a shift to larger parcel sizes and larger vessels.

Table 2-3 summarizes the mode of shipment and size of vessels by region generally. The actual operations and practices may vary due to market volatility, timeliness, and other factors.

Table 2-3. Mode of Transports by Region

Region	Crude Oil Type	Shipment Type	Vessel Size (DWT 1,000s)
Caribbean	Light Sour	Direct	90-120
		Transshipped	90-114
Mexico	Heavy Sour	Direct	90-120
EC South America	Heavy Sour	Direct	90-120
WC South America	Heavy Sour	Direct	90-120
		Lightened	MV 120-175 SV 75-120
Europe	Mid-Light Sweet	Direct	90-120
		Lightened	MV 120-175 SV 75-120
North Africa	Heavy Sweet	Direct	90-120
		Lightened	MV 120-175 SV 75-120
Middle East	Heavy Sour	Lightered	VLCC 300-350 SV 75-120
Far East	Heavy Sweet	Lightered	VLCC 300-350 SV 75-120

For shipments from Africa, Mediterranean, and Europe, the difference in direct shipment costs with lightering or lightening is less than either Mexico/South America or Middle East and Far East origins. Hence, routes from Africa, Mediterranean, and Europe usually show a higher percentage of direct shipment than what is optimally least cost, likely due to the day-to-day fluctuations in the market whereas our computations are based on annual averages. Logistical uncertainties regarding offshore transfers may also be a factor. An increase in channel dimensions would probably result in an increase in direct shipment movements for Africa, Mediterranean, and Europe shipments. For Eastern South America and the Persian Gulf, channel depth increases likely will not change current practices.

Generally, the mode of shipments can be summarized to: (1) direct shipment for the Americas; (2) lightering for the Middle East and Far East; and (3) lightening for Africa, Europe, and the Mediterranean for the existing channel with a transition to direct shipment for increased channel depth.

2.3.2 Vessel Traffic Distribution

The following Table 2-4 and Table 2-5 show the distributions of historic traffic under existing conditions. Table 2-4 displays the distribution of foreign tonnage by commodity type and year. Table 2-5 displays the import and export tonnage for 2014-2015.

Table 2-4. Tonnage Distribution by Commodity Type

Commodity	2010	2011	2012	2013	2014	2015
Barge	42,339	36,182	43,301	46,478	8,191	-
Bulk	276,672	150,888	294,574	378,741	1,429,629	1,932,353
Container	249,366	180,762	219,908	386,421	678,247	759,545
Crude Petroleum	14,189,229	12,354,325	10,134,077	8,101,060	10,434,358	8,742,107
LNG	416,046	746,791	255,778	122,664	260,683	301,595
LPG	431,753	466,457	444,349	541,826	545,261	590,372
Petroleum Products	1,921,642	1,992,164	1,557,707	1,734,345	2,713,197	3,324,082
Vehicles	-	-	1,759	-	1,684	78,556
Grand Total	**17,527,047**	**15,927,569**	**12,951,453**	**11,311,535**	**16,071,250**	**15,728,610**

Source: Waterborne Commerce, 2010-2015 (foreign short tons)

Table 2-5. Imports and Exports Tonnage Distribution by Commodity Type

Commodity	2014 Imports	2014 Exports	2015 Imports	2015 Exports
Barge	7,496	695	-	-
Bulk	1,275,723	153,906	1,695,406	236,947
Container	413,167	265,080	363,254	396,291
Crude Petroleum	9,476,981	957,377	8,125,228	616,879
LNG	199,144	61,539	145,997	155,598
LPG	544,105	1,156	590,372	-
Petroleum Products	869,710	1,843,487	1,099,221	2,224,861
Vehicles	4	1,680	29,130	49,426
Grand Total	**12,786,330**	**3,284,920**	**12,048,608**	**3,680,002**

Source: Waterborne Commerce, 2014-2015 (foreign short tons)

Table 2-6 summarizes the number of transits and tonnage for commodities in the entire channel excluding containers.

Table 2-6. Transit and Tonnage Distribution by Vessel Type (Excluding Containers)

Vessel Type	Transits	Tonnage
Total Vessel Calls	**987**	**13,293,099**
Tankers	540	11,101,765
Dry Cargo	338	2,191,081
Other	109	253
Import Calls	**404**	**12,538,800**
Tankers	208	10,780,340

Vessel Type	Transits	Tonnage
Dry Cargo	182	1,758,368
Other	14	91
Export Calls	**155**	**566,028**
Tankers	9	133,155
Dry Cargo	143	432,713
Other	3	161
No Direction	**428**	**188,271**
Tankers	322	188,270
Dry Cargo	7	0
Other	99	1

Source: Port Freeport, 2014 data

The following graphs show the number of trips by loaded draft. The trend shows that even though the number of trips are decreasing in recent years, the number of vessels using the entire channel depth is increasing (41 feet and greater).

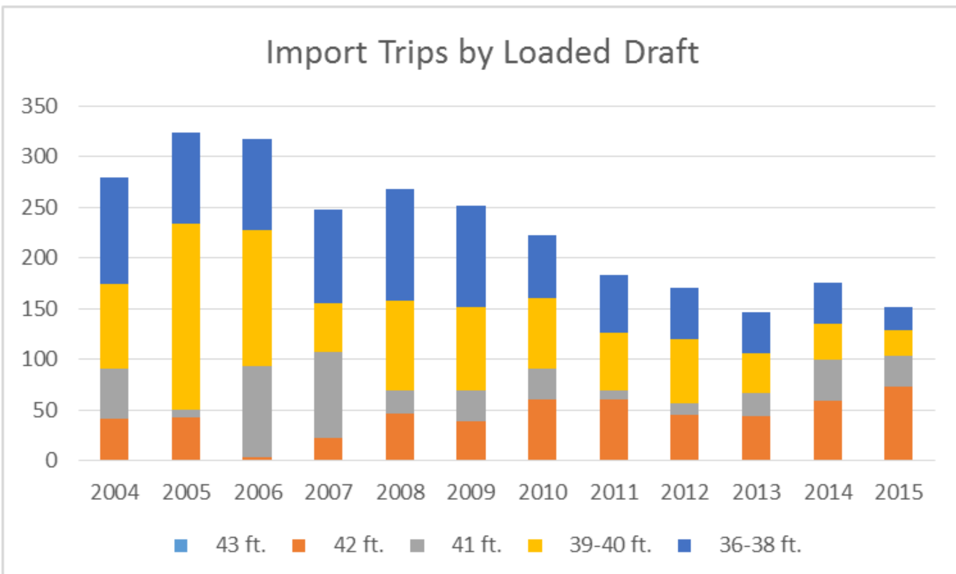


Figure 2-6. Import Trips by Loaded Draft

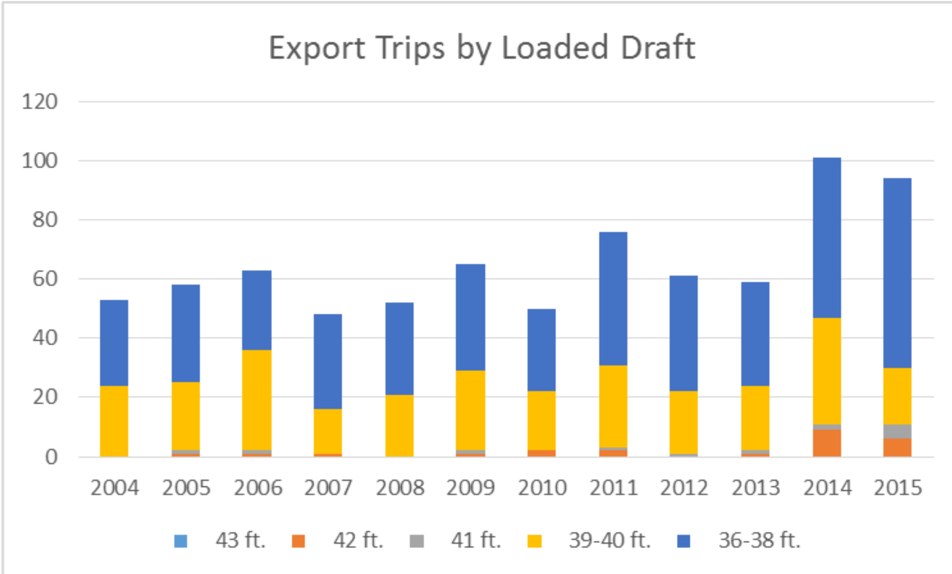


Figure 2-7. Export Trips by Loaded Draft

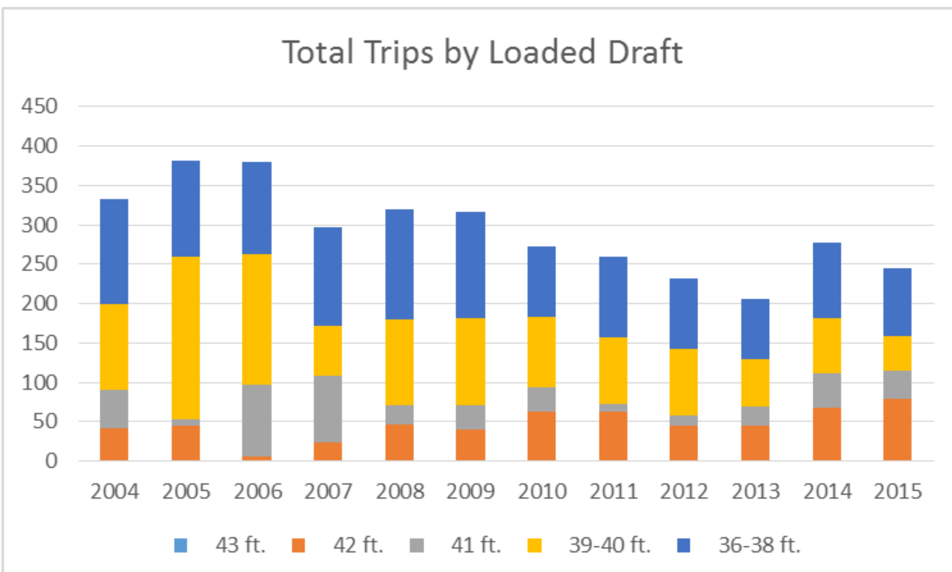


Figure 2-8. Total Trips by Loaded Draft

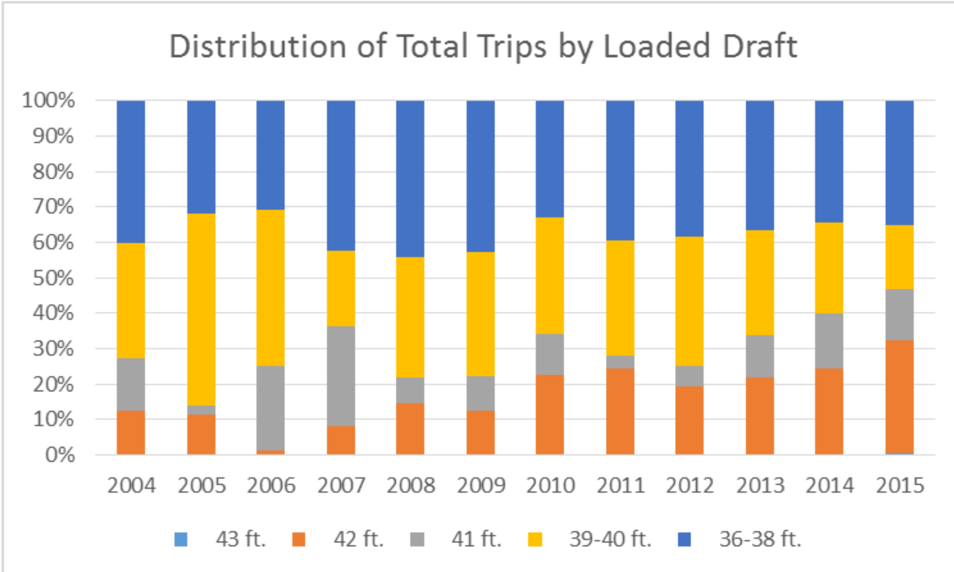


Figure 2-9. Distribution of Total Trips by Loaded Draft

Crude oil imports are a major contributor to the decline of trips and tonnage at Freeport in recent years, but a greater percentage of vessels are utilizing the full channel depth.

While crude oil tonnage is decreasing in the channel, container traffic is increasing. Table 2-7 shows the distribution of TEUs by route group. From October to December in 2014, 85 percent of the Freeport TEUs made trips between the Caribbean and East Coast South America. According to the data received by Port Freeport, 100 percent of TEUs were from East Coast South America in 2015. Waterborne Commerce data shows a mix of these short trips between East Coast South America and Caribbean routes in 2015, as described in Section 4.3.2.

Table 2-7. Container Distribution by Route Group Calling to Velasco Terminal

Region	2014		2015	
	TEUs*	% Share	TEUs	% Share
Africa	3,124	6	0	0
Caribbean	32,050	61	0	0
East Coast South America	12,410	24	100,482	100
Far East	1,916	4	0	0
North Europe	2,380	5	0	0
West Coast South America	332	1	0	0
Total	**52,212**	**100**	**100,482**	**100**

Source: Port Freeport, October 2014-December 2015
**41,830 TEUs had a "blank" region in the data*

Table 2-8 shows total Twenty Equivalent Units (TEUs) by arrival draft and departure draft for the year 2015. Although 46 feet of water depth was available to Berth 7, only 34 feet of sailing draft was used. This is due to the current configuration of the Dow Thumb which limits container traffic to Sub-Panamax vessels. The design draft of Sub-Panamax vessels ranges from around 34 to 39 feet. Exports were loaded heavier than imports.

Table 2-8. TEUs by Vessel Arrival Draft (Rows) and Departure Draft (Columns)

Sum of TEUs	Column Labels														
Row Labels	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**Grand Total**
19		10													10
23			846												846
24	2706	3780	736												7222
25	2026	1934	848	868	1534										7210
26		968	1002	1854	8762		2016								14602
27			952	2474	2642	888									6956
28					6710	3944	1028		3802	2218		2624	1546		21872
29						942		846	1306	3830	5220	1266	1004	1582	15996
30										2676	4390	3190		2686	12942
31											2124	3440	852		6416
32									1006			1938		1002	3946
33												1618			1618
34													846		846
Grand Total	**4732**	**6692**	**4384**	**5196**	**19648**	**5774**	**3044**	**846**	**6114**	**8724**	**11734**	**14076**	**4248**	**5270**	**100482**

Source: Port Freeport, 2015 data

Table 2-9 shows TEUs by departure draft and Length Overall (LOA). The longest containership vessel that called Freeport in 2015 was 706 feet. According to Lloyd's Registry of the World Fleet, a 706 foot LOA equates to a container vessel with design drafts ranging from 31 feet to 42 feet with a median of 38 feet. A 689-foot LOA equates to a container vessel with design drafts ranging from 29 feet to 40 feet with a median of 36 feet. A 510-foot LOA equates to a container vessel with 29-foot design draft. Modifications of the Dow Thumb proposed under the future with-project would allow shippers to transition a percentage of their Sub-Panamax fleet to more efficient Panamax vessels. The study assumes that a range of Panamax-sized vessels will call Port Freeport under the Future With-Project condition. This range will include vessels with dimensions up to the 965 feet LOA and 44-foot design draft. With a three foot underkeel clearance requirement per pilot consultation, the Panamax class vessel would max out at a 47 foot channel depth.

Table 2-9. Containership TEUs by LOA (rows) and Departure Draft (columns)

Sum of TEUs	Column Labels														
Row Labels	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Grand Total
510	4732	6682	2696												14110
530		10													10
540			1688	5196	18720	4850	1028								31482
620						924									924
660					928										928
690							2016	846	6114	7838	11734	11578	4248	5270	49644
700												834			834
710										886		1664			2550
Grand Total	**4732**	**6692**	**4384**	**5196**	**19648**	**5774**	**3044**	**846**	**6114**	**8724**	**11734**	**14076**	**4248**	**5270**	**100482**

Source: Port Freeport, 2015 data

2.4 Vessel Size Guidelines and Pilot Rules

The maximum ship dimensions permitted by the Brazos River Pilots Association (BRPA), without a waiver, are 820-foot LOA and 145-foot maximum beam, as shown in Table 2-10. Vessel length limitations are enforced because crosswinds and crosscurrents force tankers to "crab" at an angle though the entrance Jetty Channel.

Oversized, excessive draft or unusual type vessels will be handled on a "per job" basis with a one-time waiver to the Basic Operating Procedures. These vessels will be billed under "special services" and will be by "specific agreement" prior to the move. Pilots reserve the right to deny movement of any vessel during times of excessive wind, excessive current or at times of low water.

Table 2-10. Brazos River Pilots Association Maximum Ship Dimension Guidelines

Vessel Dimensions:	**Feet**	**Meters**
Maximum Length	820	249.9
Maximum Beam	145	44.2
Draft Restrictions:		
Maximum Draft	46	13.7
Recommended Draft	43	12.8
Brazos Harbor and BASF Channel Maximum Draft	37	10.9
Old River Channel Maximum Draft	15	4.5
Special Services / Operations		
1. Oversize (LOA >820' or beam >145') or unusual types of floating equipment such as drilling rigs and operations in the sink hole		
2. Vessels with draft in excess of 42'FW or current recommended operating draft		
3. Shifting vessels without power and vessels leaving the ship channel		
4. Dow A14 dock vessels with a beam >125'		
5. Dow A13 all vessels		

Daylight-only operation (Table 2-11) is enforced for vessels greater than 750 feet long or 107 feet wide. Additionally, the beam constraints for existing traffic and introduction of LNG and container vessels are anticipated to exacerbate traffic delays.

Underkeel clearance is determined by the discretion of Pilots within the range recommended by the industry. Empirical data demonstrated that underkeel clearance can range from one to four feet. Panamax vessels are assumed to operate with three feet underkeel clearance, and tankers with four feet. This is assumed to be the most likely operating practice at Port Freeport under all project conditions. Tide is one foot at Freeport and not typically considered in daily operations.

Table 2-11. Daylight Restrictions

Inbound Vessels:	
1.	Vessels over 750 feet LOA
2.	Vessels over 107 feet Beam
3.	Vessels with Draft over 36.5 feet and LOA greater than 700 feet
4.	All vessel movements at Dow A-13
5.	All vessel movements at Dow A-14 with LOA greater than 600 feet or with a Beam greater than 100 feet
Outbound Vessels:	
1.	All vessel movements at Dow A-13
2.	All vessel movements at Dow A-14 with LOA greater than 600 feet or with a Beam greater than 100 feet
3.	Vessels sailing from berths above Phillips Bend (Phillips Petroleum Docks, BASF, and Brazos Harbor) with greater than 750 feet. LOA will require two pilots be handled on a per job basis and be billed under the "special services" agreement. One time deviation waiver from standard operating procedures, signed.
4.	Vessels judged unsafe for handling after dark will be limited to daylight hours. Night operations will be suspended during times when weather conditions do not permit safe navigation.

Source: http://www.brazospilots.com/operatingprocedures.html

3.0 Future Without-Project Conditions

3.1 Commodities

Much of the commodities mix in the existing condition is expected to continue in the future without-project condition. Freeport has a long history of importing food products in Sub-Panamax containers. As described in Section 2.3.2, from October to December in 2014, 85 percent of the Freeport TEUs made trips between the Caribbean and East Coast of South America. Furthermore, Panamax vessels currently calling ports in the Gulf region are already on Caribbean routes undergoing food product shipments. These trips of food product shipments are expected to continue; however, additional routes or longer routes are not expected in the future.

In addition to importing of food products, the export market of resins is still developing and quickly growing. There are several petrochemical facilities that are expanding in the Freeport area and coming online between 2017 and 2019. Dow Chemical, Chevron Phillips Chemical, and Formosa are expected to increase capacity of polyethylene resin production by more than 2.6 million tons annually by 2019. In other areas of Texas, including Deer Park, Mont Belvieu, Beaumont, and LaPort, an additional 2.3 million tons of polyethylene resin are anticipated to be produced with other expansion projects. It is highly likely that Freeport will capture some of that market, especially the facilities near Freeport, to supplement the resin exports currently on Sub-Panamax vessels. This would reflect organic growth in the forecasts.

Freeport offers some competitive advantages for increased resin exports for the facilities to the south and west of Houston, TX. First, the trucking and rail freight cost to deliver loaded containers from Dow Chemical, Chevron Phillips Chemical, and Formosa to the Freeport Harbor will be lower in comparison to the costs to move these materials to Houston. Second, Port Freeport has a heavy lift truck corridor in place which includes Dow and Chevron Phillips and allows manufacturers to load containers heavier, thus saving them 20 percent of their drayage and ocean freight cost.

3.2 Vessel Traffic

The main channel will not be able to accommodate larger than Aframax-sized vessels with the exception of Suezmax vessels going to Seaway in Reach 1. Containerships will remain as Sub-Panamax vessels limited to 721-feet LOA. The maximum sized RoRo ships will be neo-Panamax, limited to approximately 700-feet LOA. Based on input from Hoegh, newly renovated vessels (775-foot LOA x 105-foot beam) have recently been added to their existing fleet (656-foot LOA x 105-foot beam). These larger RoRo vessels will continue to call Freeport in both the without- and with-project scenarios but will not be constrained by channel depth since they currently draft at approximately 30 feet or less.

Berth 2 at Phillips currently has approximately 10 vessels per month, and Berth 3 has more than 10 vessels per month. It takes between 2 and 24 hours to load, depending on the commodity type. These vessels go to the Upper Turning Basin to turn prior to loading. It is expected in the future, Berth 2 and 3 will have a 66% utilization rate on each dock according to discussions with Phillips. Freeport LNG (in Reach 1) will be online around 2018. LNG vessels were not included in this benefit analysis.

Regarding future conditions associated with the GRR, the without-project condition includes traffic at Berth 7 and the Velasco Terminal since they are both currently existing. Velasco Terminal is expected to service primarily container imports of food products and exports of resins in the future. Containerships are anticipated to continue calling at Berth 7, but at a limited capacity and with a maximum size of Sub-Panamax. Containerships will only be able to call to Berth 7 if Berth 6 is empty. Also, the larger containerships will not be able to call if there is a vessel at Berth 2 due to safety concerns associated with clearance between the berthed vessel and transiting vessel. As previously mentioned, Phillips anticipates Berth 2 to be occupied 66% of the time in the future. Containerships will also be restricted to daylight only transits. Therefore, the feasibility of a larger sized containership being able to call to Berth 7 in the future without-project condition is extremely limited, with less than 20% window of opportunity to call.

Containerships rely on maintaining regular schedules. The vessels that do call will likely be small Sub-Panamax containerships that are making trips from the Caribbean, and Central and South America; additional routes are not expected in the future. Therefore, it is expected that existing vessel fleet will continue in the future without-project condition.

Table 3-1 shows the fleet forecast for containers in the future without-project condition.

Table 3-1. Fleet Forecast Without-Project Condition (Containers Calls)

Vessel Type	2015	2022	2030	2040
Sub Panamax	206	274	369	512
Panamax	0	0	0	0

3.3 Vessel Size Guidelines and Pilot Rules

Vessel size guidelines and Pilot rules are not expected to change in the future without-project condition. Existing pilot rules will likely remain the same for the future with-project condition with the exception of Panamax vessels, which will require an additional tug. While, this is an added cost of the larger vessel, it is likely a relatively low cost and, consistent with most USACE navigation projects, not included in the NED benefit calculation.

4.0 Future With-Project Conditions

In the future with-project condition for the GRR, Panamax containership vessels are anticipated to call at Freeport. By utilizing larger vessels, it will require less vessels to transport the same amount of goods, thereby decreasing at-sea transit costs. The ship simulation showed three tugs are necessary for Panamax vessels instead of the standard two tugs for Sub-Panamax vessels.

As detailed in the main report, for the Panamax vessels to be able to call, a bend easing, limited widening, and notch is needed as additional features in the GRR, as presented in the figure below.

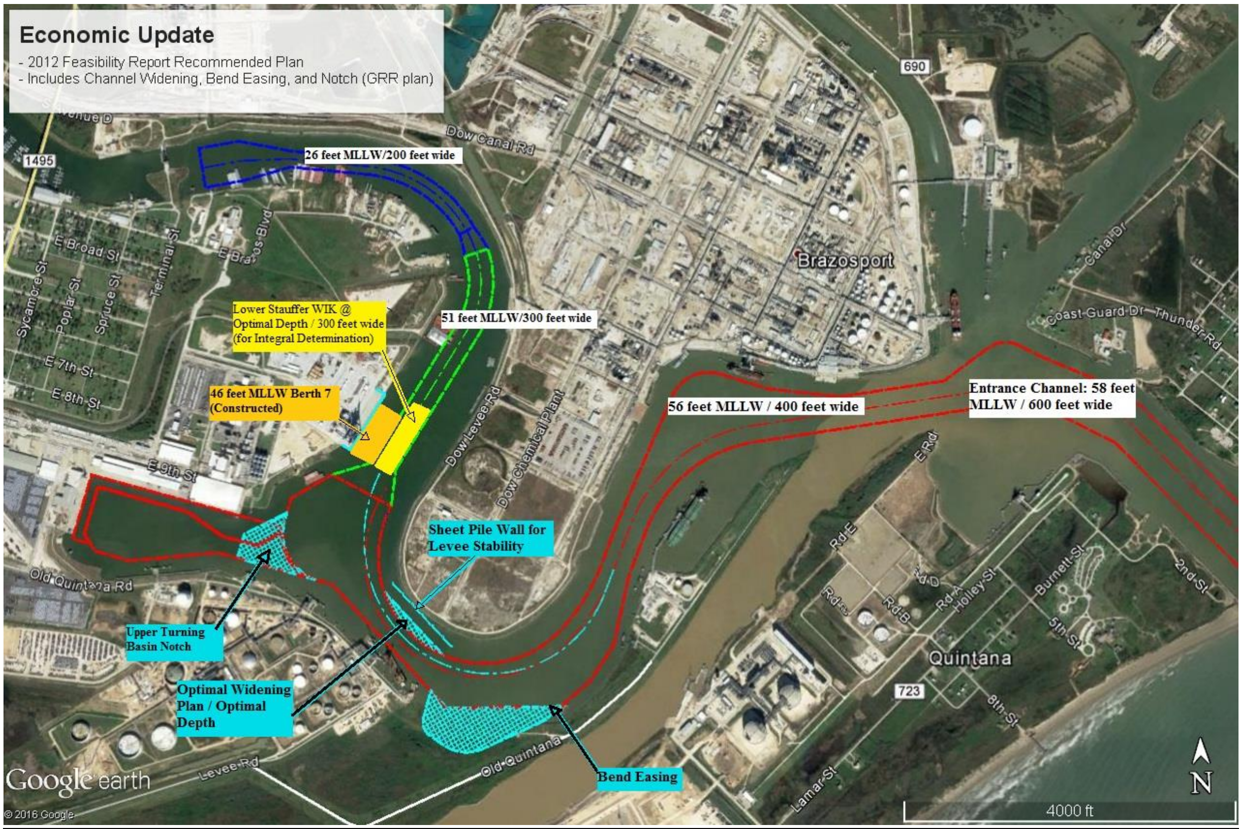


Figure 4-1. Features in the GRR

4.1 Hinterland

Freeport is expected to continue to serve the same hinterland in the future with-project condition and will continue to compete for the market with other Gulf ports. Many factors influence the growth of a particular harbor: land side development and infrastructure, location of distribution centers for imports, source locations for exports, population and income growth and location, port logistics and fees, business climate and taxes, carrier preferences, labor stability and volatility, and business relationships. Harbor depth is just one of the many factors involved.

4.2 Commodities

4.2.1 Commodity Forecast

Commodity forecasts were prepared for crude petroleum, petroleum products, chemical products, and containers. The remaining oceangoing commodity groups were analyzed in the aggregate, which were found either not to be transported in draft-constrained vessels at the current time or were of limited volumes.

National forecast data and general indicators were assessed in relationship to the study area's historical commodity-specific tonnage flows for the purpose of evaluating the relationship between historical U.S. tonnage volumes and study area tonnage.

The outputs of the commodity projections were based on forecasts published by USDOE's EIA Annual Energy Outlook (AEO2015); Global Insight, The U.S. Economy, The 30-Year Focus, 2013; and from indices developed from historical trend data. The EIA and Global Insight forecasts extend through 2040. The commodity forecasts presented in this document were prepared in 2016.

The commodity forecasts for the economic update were derived using the Department of Energy's Annual Energy Outlook forecasts for crude oil and petroleum products. Chemicals tonnage was derived from trend analysis. Containers and cars forecasts were acquired from Port Freeport projections as well as forecasts by Global Insight used for the Gulf region. Baseline tonnages were updated to the most recent data available from the Waterborne Commerce Statistics Center (2015). The growth rates derived and rooted in the published forecasts listed above were applied to these new baseline tonnages to compute tonnage by commodity for 2022, 2030, and 2040. The in-between years were interpolated. These tonnages were applied to the loading pattern distributions to determine the number of calls needed to transport each commodity in the given years. These call lists were loaded into HarborSym to calculate transportation costs for the FWOP and FWP conditions.

4.2.2 Container Forecast in the GRR

Currently, polyethylene resin from Dow Chemical and other facilities is being exported in containers out of Freeport as well as being railed to Houston, Savannah, Charleston, Los Angeles, and other ports. With the Freeport channel being able to accommodate Panamax containerships, and additional manufacturing capacity in the Freeport area, some of that extra tonnage will likely be exported from Freeport because it will be more economical.

For container imports, growing demand in the hinterland due to population growth will likely yield increased imports of food products approximately at the rate of population growth. The Dallas, Fort Worth, San Antonio, and Austin area alone has 20 million people and is growing at one of the fastest rates in the country.

Export growth will be led by the emerging resins export market. Significant investment in resin packaging facilities and export capacity support the export growth rates provided in Table 4-1. The study assumes that like other Gulf Coast ports, Port Freeport will export chemical resins on backhaul to Latin American ports.

Growth on food product imports and resin exports at the rate forecasted by Global Insight for general containers were applied to the 2015 tonnage to determine tonnages for 2022, 2030, and 2040 in the analysis.

According to the managers at Port Freeport, the Velasco Terminal will have a total estimated throughput capacity of at least 500,000 TEUs, well above the maximum annual containerized cargo forecasted for the study period. Port Freeport has purchased two cranes that can transfer 30-35 boxes per hour. Most boxes are FEUs, therefore the transfer rate per vessel is 100-140 TEUs per hour.

Table 4-1 indicates the compound annual growth rate (CAGR) for containers in the future conditions. Given the uncertainty of the growth rates, the analysis uses no growth beyond the year 2045. The forecast was derived from data provided by the forecast from Global Insight for the Caribbean and ECSA routes. These growth rates from Global Insight were compared to Port Freeport's outlook, and both showed similar growth rates on average through the year 2030. Therefore, these growth rates were applied to the base tonnage to establish the containers forecast for imports and exports.

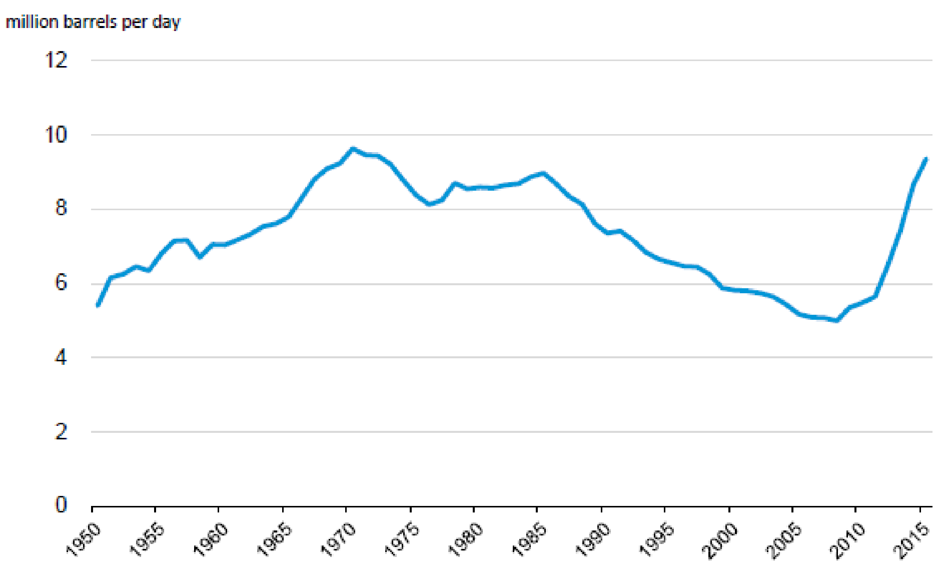
Table 4-1. CAGR Commodity Forecast (Containers)

	2017-2025	2025-2035	2035-2045	2045-2055	2055-2066
Imports	3.33%	3.02%	2.5%	0%	0%
Exports	4.94%	3.83%	3.5%	0%	0%

Source: Derived from Global Insight, 2013, Port Freeport

4.2.3 Petroleum Forecast in the Economic Update

The recent drop in crude oil imports is expected to stabilize, then grow to meet future refineries' demand for heavy crude oil. With the expansion of refineries in the Gulf Coast, crude production will likely continue to increase due to the widespread application of advanced drilling techniques. Texas light sweet crude oil has an API gravity of about 51 degrees. Refineries typically mix different grades of crude oil to maintain an API gravity between 30 and 32 degrees. The light crude oil needed to meet this gravity degree is now being produced domestically at lower cost, leading to a drop in imports of light sweet crude. Figure 4-3 and Figure 4-4 from the EIA shows the reduction in light sweet crude oil imports from 2008 to 2013.



Source: U.S. Energy Information Administration, *Petroleum Supply Annual* and *Short-Term Energy Outlook*.
Note: 2015 crude oil production is a forecast from August 2015 *Short-Term Energy Outlook*.

Figure 4-2. Annual U.S. Crude Oil Production, 1950-2015

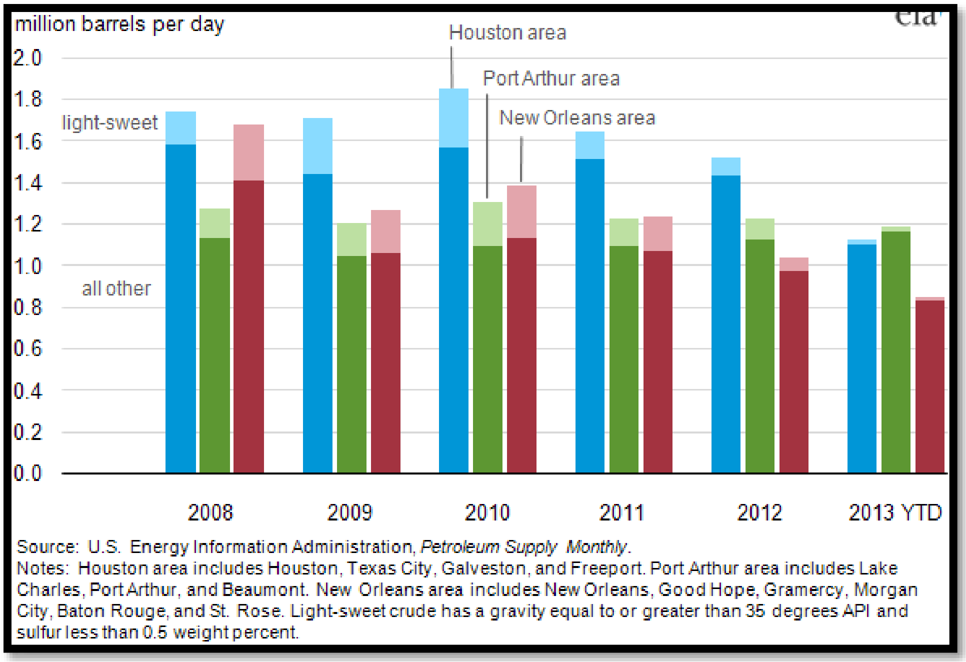


Figure 4-3. Crude Oil Imports by Quality

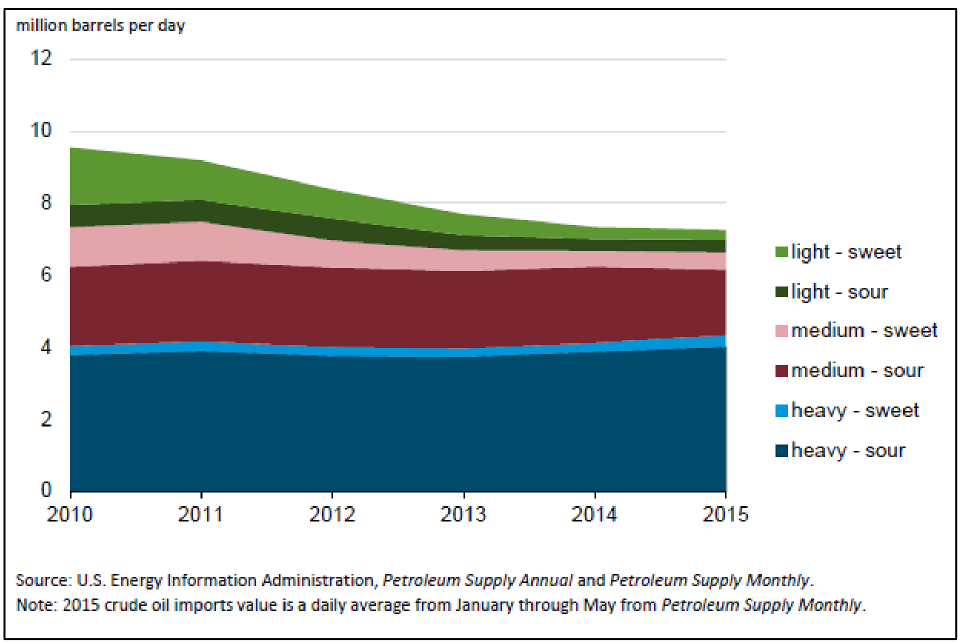


Figure 4-4. Annual U.S. Crude Oil Imports by Type, 2010-2015

In the 2015 AEO, the EIA predicts that U.S. production of crude oil in the lower 48 states will increase at a CAGR of 1.0 percent from 2013 to 2040, while foreign imports will increase by a CAGR of 0.2 percent from 2013 to 2040. The forecast shows a CAGR of 0.74 percent from 2015 to 2040.

In addition, Table 4-2 provides a summary of growth rates for imports and exports from 2013 to 2016 and Figure 4-5 provides the EIA forecast for 2016.

Table 4-2. Summary of Growth Rates

	Growth Rates				
	2016	**2015**	**2014**	**2013**	**4-Year Average**
Imports					
Crude Oil	0.20%	-0.10%	0.30%	-0.20%	0.05%
Petroleum and Other Liquids	-0.30%	0.40%	-0.20%	-0.30%	-0.10%
Exports					
Petroleum and Other Liquids	0.80%	2.10%	2.40%	0.70%	1.50%

Source: U.S. Energy Information Administration

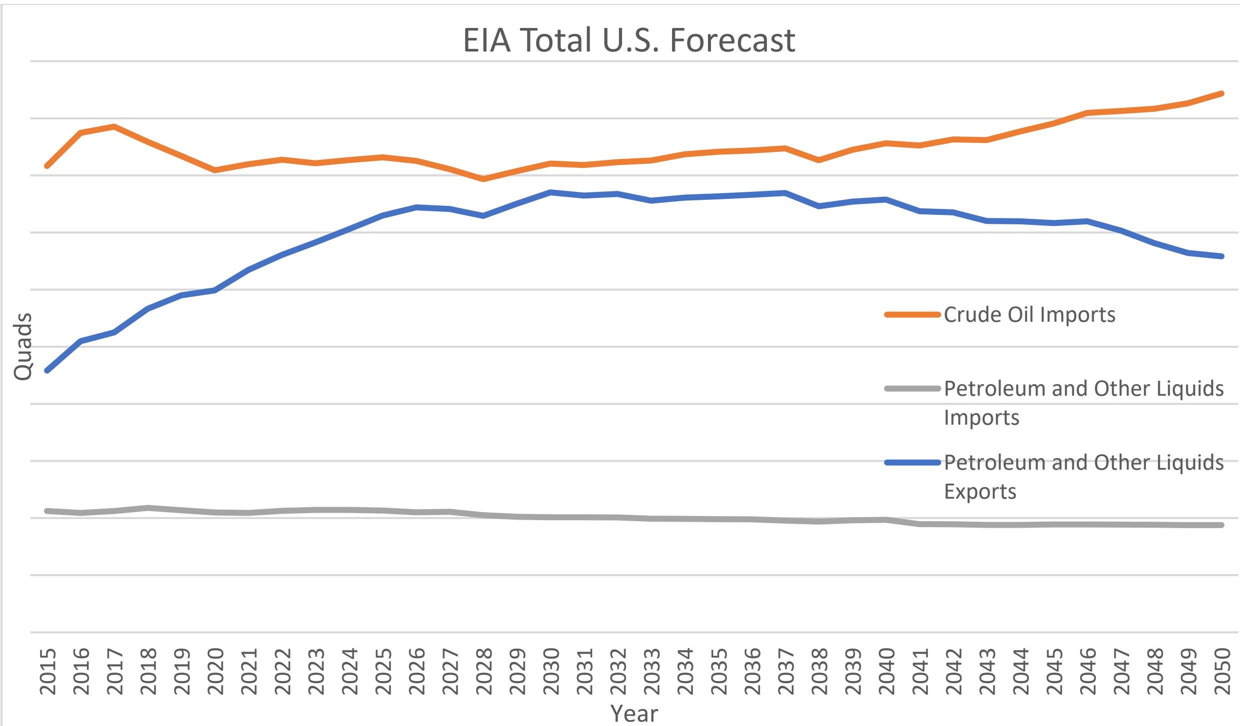


Figure 4-5. EIA Total U.S. Forecast (2016)

In the past, USACE has also relied on global commodity forecasts from Global Insight's (GI) publication "*U.S. Energy Outlook*". In its 2013 online navigator, GI shows an increase in U.S. crude oil imports. While taking into account the most recent policies relevant to energy consumption, GI still forecasts a strong U.S. dependency on foreign oil. In its 2013 report, GI forecasts crude oil imports in the Gulf of Mexico to reach 268 million metric tons in 2030, which is a 0.85% compounded annual growth rate from 2013 to 2030.

Many expansion projects are occurring in reaction and anticipation to the emerging energy markets. For example, Enterprise Products is constructing a new 540,000 bpd pipeline from Midland, Texas to Houston that will connect with their existing pipeline network. This new pipeline will enable Houston, Texas City, Beaumont, and Port Arthur to export West Texas crude oil and condensate from the Permian Basin, starting in 2017.

The Eagle Ford domestic production will likely decrease as prices fall and increase as prices climb. However, Eagle Ford will likely have some domestic production because refineries require a blend, and due to proximity to refineries, it is cheaper for at least some domestic production than imports of light crude. Therefore, fluctuating prices will create a self-balancing condition. Also, most of the facilities are calibrated for sour crude (not the type of oil for domestic production). Hence, there will likely be a “floor” for imports regardless of prices.

Figure 4-6 shows the production cost curve for various countries. This figure is simplified because it does not take into consideration the type of crude oil. For example, OPEC crude oil is cheaper than US crude oil because it is a lesser quality and costs more to refine per barrel of oil than US oil (refer to Section 1.0). However, this figure is helpful in demonstrating that production at Eagle Ford will dramatically increase when the price of crude oil climbs between $50 and $60 per barrel. This increase in production will provide for shortfalls in global supply and will put downward pressure on crude oil prices. Hence, given today’s cost structures, oil prices are likely to hover between $30-$60 until global demand approaches 30,000 kbopd, according to Goldman Sachs Global Investment Research, May 2016.

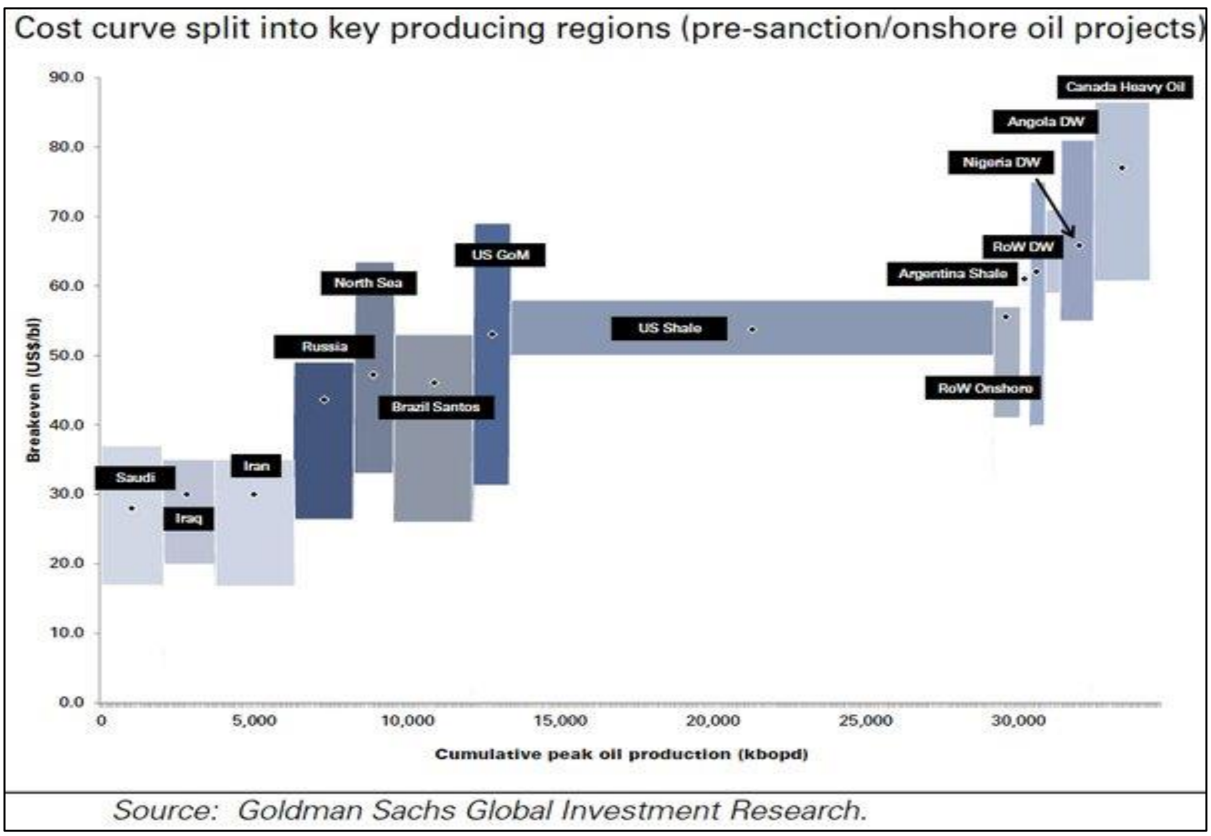


Figure 4-6. Production Cost Curve

The 2015 AEO forecasts crude oil exports to grow by 13.7 percent CAGR from 2013-2025, with no growth from 2025-2040. The exporting crude oil consists of light sweet crude and condensate petroleum oil (classified as a petroleum product). Light sweet crude and petroleum oil condensate has similarities in loading patterns and trade routes as petroleum products. Therefore, for the analysis, crude oil exports are included with petroleum products.

The U.S. Energy Information Administration (EIA) predicts that tight oil (roughly 9 percent of which is defined as lease condensate) production will grow at approximately 8 percent per annum before peaking in 2020. The EIA's prediction is based on an estimate of 47 billion barrels of recovered tight oil in the U.S. by 2040 with peak production around 1.7 million barrels in 2020.

The Permian Basin constitutes roughly 23 percent of U.S. tight oil production. EIA projects that the Permian Basin will produce 9.8 billion barrels of oil between 2014 and 2040. EIA predicts that this production will peak in 2021 at over 400 million barrels.

The Global Insight forecast from 2013 differed significantly from the 2015 AEO forecast. This difference is likely due to the emerging crude condensate exports market not being reflected in the Global Insight forecast. For this reason, the AEO forecast was used for crude oil exports.

4.2.4 Summary of Commodity Forecasts

The projected growth rates and tonnages are shown in Table 4-3 below. Fluctuations in the growth rates are subject to oil price variability, macroeconomic policies, exchange rate fluctuations, and a number of other factors.

Table 4-3. Commodity Forecast (Short Tons)

Commodity Name	2015*	2022	2030	2040	CAGR (2015-2040)
Liquid Bulk-Crude Oil	9,262,425	9,075,201	9,849,606	11,320,975	0.81%
Liquid Bulk-Petroleum Prod.	316,123	435,474	472,367	497,534	1.83%
Liquid Bulk-Chemicals[1]	603,410	742,118	940,093	1,263,407	3.00%
Liquid Bulk-LPG	241,797	738,228	905,433	975,184	5.74%
Dry Bulk-Chemicals	2,147,540	2,641,203	3,345,797	4,496,472	3.00%
General Cargo	125,029	125,029	125,029	125,029	0.00%
Containers	820,490	1,091,927	1,470,918	2,038,322	3.71%
Cars	122,139	166,781	228,234	321,309	3.94%
Aggregate	1,842,775	1,842,775	1,842,775	1,842,775	0.00%
Total	**15,481,728**	**16,858,736**	**19,180,253**	**22,881,007**	**1.57%**

**Source: Port Freeport, 2015*

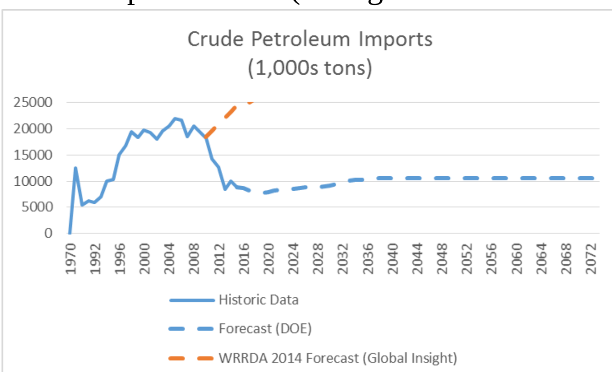
The following sections include forecasts for each commodity beginning in 2022. Baseline tonnage starts in 2015.

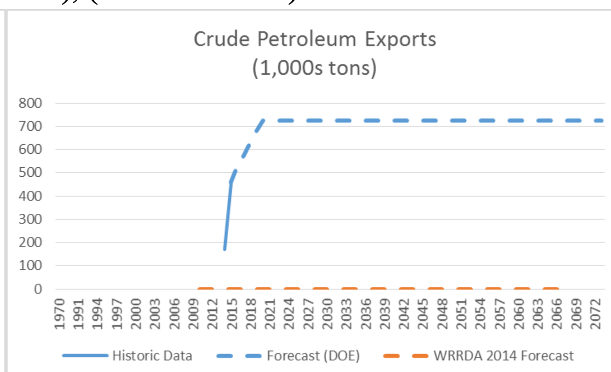
[1] Liquid Bulk – Chemicals are not likely to benefit from project modifications as this cargo is carried on vessels with drafts that are not restricted by current channel depths. The commodity was not included in the final HarborSym model.

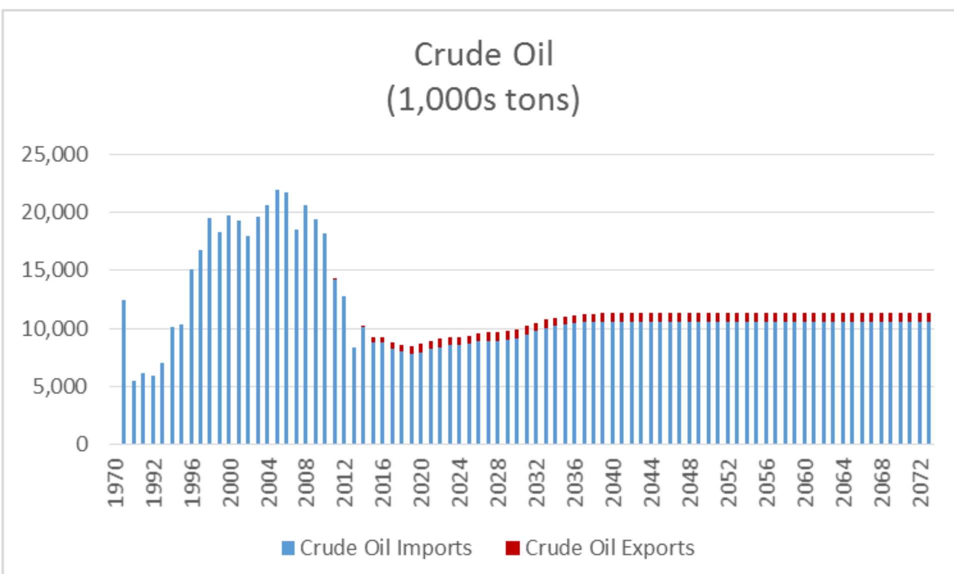
4.2.4.1 Crude Petroleum (DOE, 2015)

Crude petroleum trade accounts for approximately 60 percent of throughput tonnage at Port Freeport. As outlined in Section 4.2, Crude Petroleum trade forecasts for this study relied on the U.S. Department of Energy's Annual Energy Outlook. The general trends expected for Gulf Coast and Texas ports also hold true for Port Freeport. Imports of crude petroleum are expected to grow slowly as domestic tight oil production continues to increase over the study period. Crude exports are included with the petroleum product export forecast.

- Imports 0.74% CAGR (2015-2040), (0% 2040-2071)
- Exports 0.00% (50% growth from 2015-2020), (0% 2020-2071)



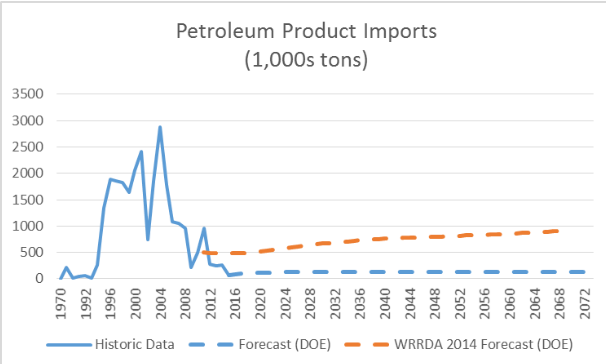


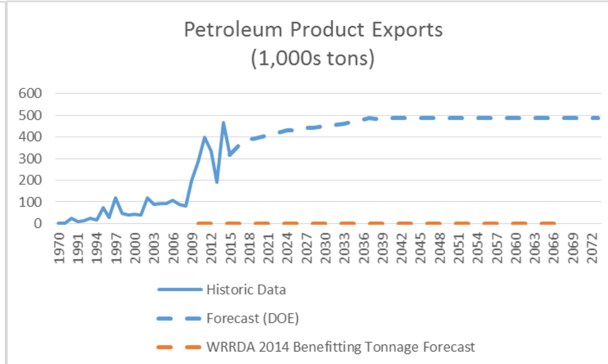


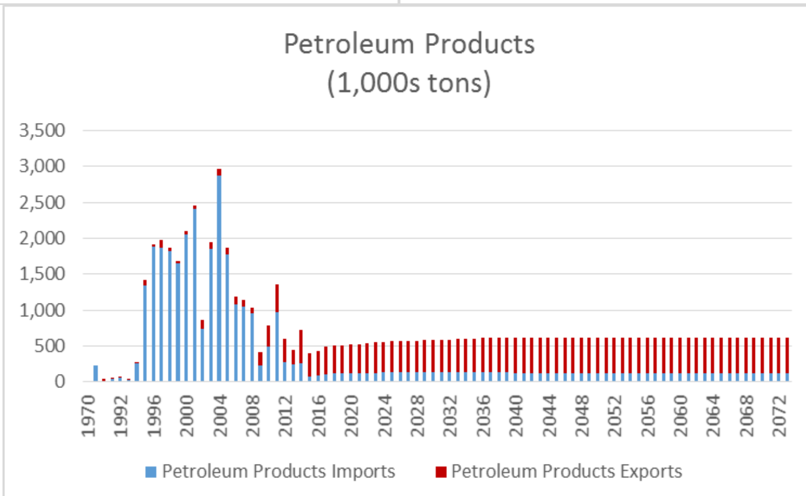
4.2.4.2 Petroleum Products (DOE, 2015)

Section 4.2 details the trade forecast for petroleum products. Market volatility will continue to influence short-term petroleum trade trends, but long-term petroleum product trade will likely remain relatively stable over the forecast period. Petroleum Product Imports are expected to grow at a slow pace as domestic production continues to grow, replacing some national import needs. Petroleum product exports, including crude oil, will also grow as a result of this trend.

- Imports 0.20% (63% growth from 2015-2020)
- Exports 1.01% (26% growth from 2015-2020)



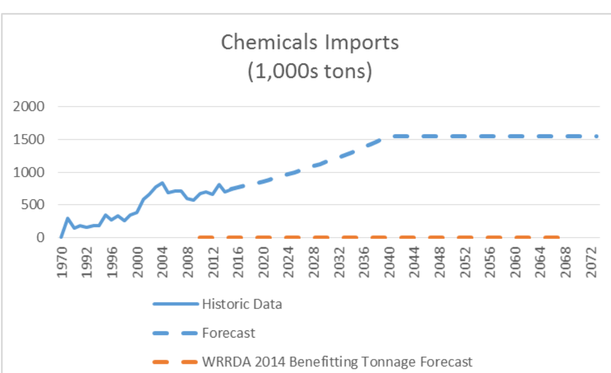


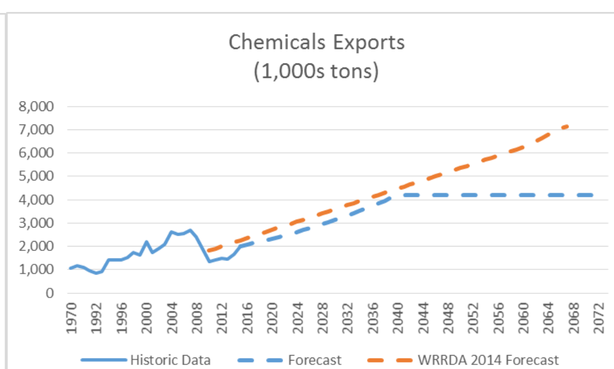


4.2.4.3 Chemicals (Trend, 10-year)

Import growth rates of chemical products will likely remain stable through the forecast period based on demand outlook. Continued growth in regional chemical production for products such as plastics, organic compounds, and hydrocarbons will likely lead to similar growth rates in chemical exports.

- Imports 3.0% (2015-2040), 0% (2040-2071)
- Exports 3.0% (2015-2040), 0% (2040-2071)

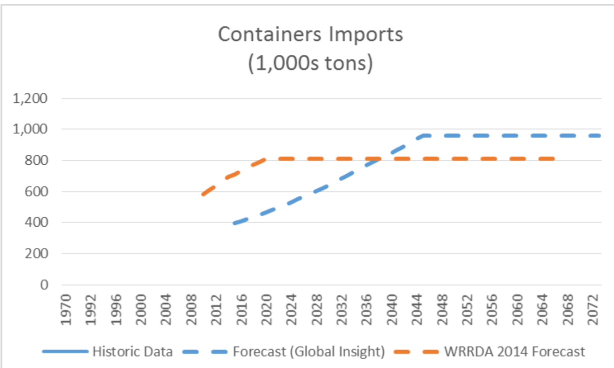


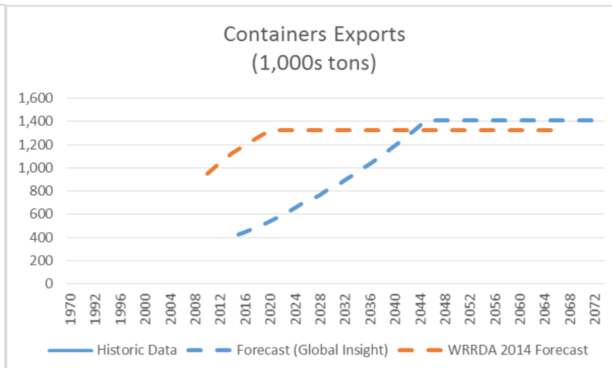


4.2.4.4 Containers (Global Insight, 2013)

As outlined in Section 4.2, containerized commodity forecasts for this study are based on Global Insights forecasts by trade region for national, Gulf Coast, and Port Freeport. Growth rates take into account macroeconomic factors by trade region to develop growth rates for containerized cargo. The forecast used in this study is summarized by the following growth assumptions:

- Imports 3.33% (2015-2025), 3.02% (2025-2035), 2.50% (2035-2045), 0% (2045-2071)
- Exports 4.94% (2015-2025), 3.83% (2025-2035), 3.5% (2035-2045), 0% (2045-2071)
- Empties and Vacants same as 2012 Houston analysis
- Metric Tons per TEU same as 2012 Houston analysis (10.0 for Caribbean, ECSA routes)

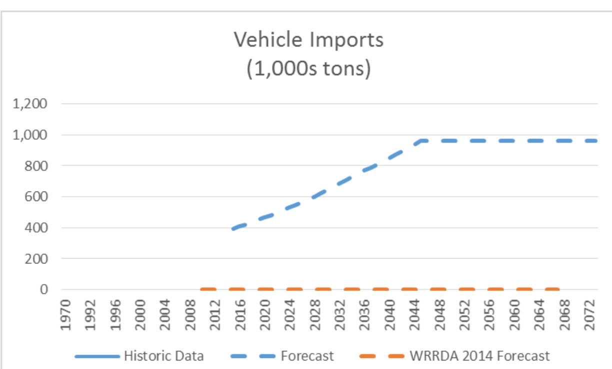


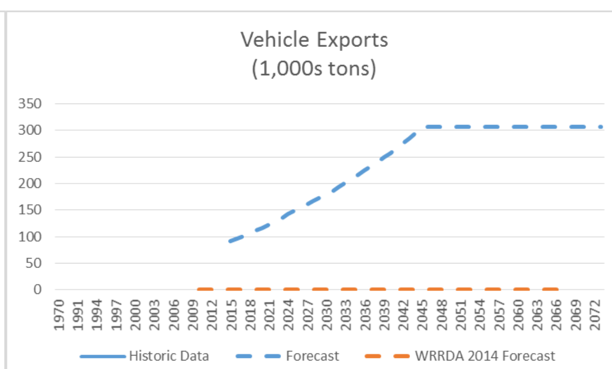


4.2.4.5 RoRos

The forecast used for containerized trade forecasts contains much of the same cargo carried on RoRo vessels. Growth in vehicle trade at Freeport is relatively new as of 2015. Additionally, RoRo vessels are not expected to experience significant transportation cost savings as a result of the project. For this reason, the same growth rates for containerized trade are used for RoRo cargo.

- Imports Same as containers
- Exports Same as containers





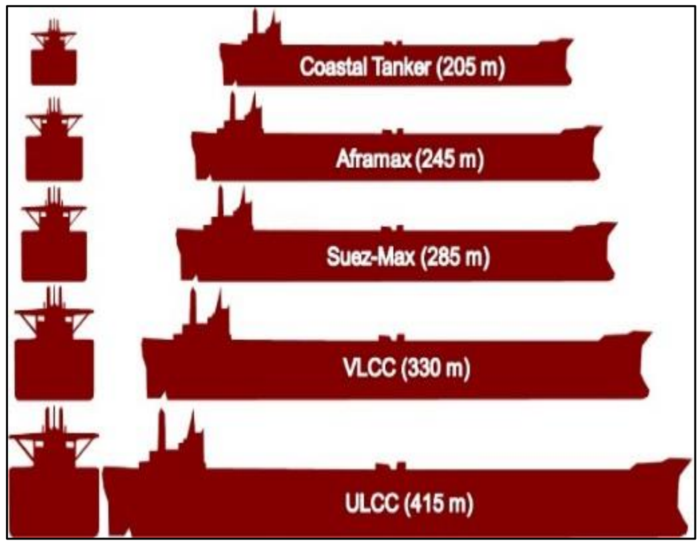
4.2.4.6 Upper Stauffer (Reach 4) Vessels

- 0% (2015-2071)

4.3 Vessel Traffic

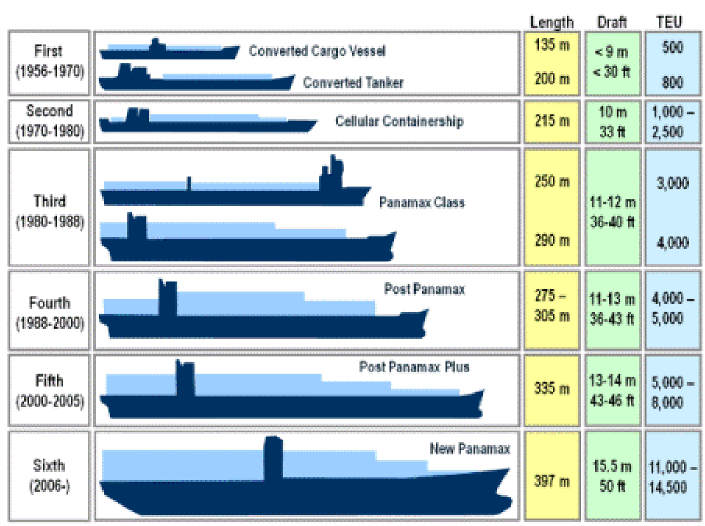
4.3.1 Vessel Fleet

For the Economic Update, the fleet forecast distributions were derived from a combination of 2015 Port Freeport data and previous analysis.



For **Reach 1**, the fleet for Crude Oil is projected to have a maximum 165,000 DWT Suezmax with dimensions of 936 feet LOA x 160 feet beam x 60 feet draft. The Panamax and Suezmax vessels will need to use 3 tugs. Shuttle vessel sizes are 70,000-120,000 DWT tankers. The Aframax fleet for Chemical Products are projected to be up to 80,000 DWT.

In **Reach 2**, the Aframax fleet for petroleum products are anticipated to be 100,000 DWT with dimensions of 806 feet LOA x 138 feet beam x 49 feet draft.

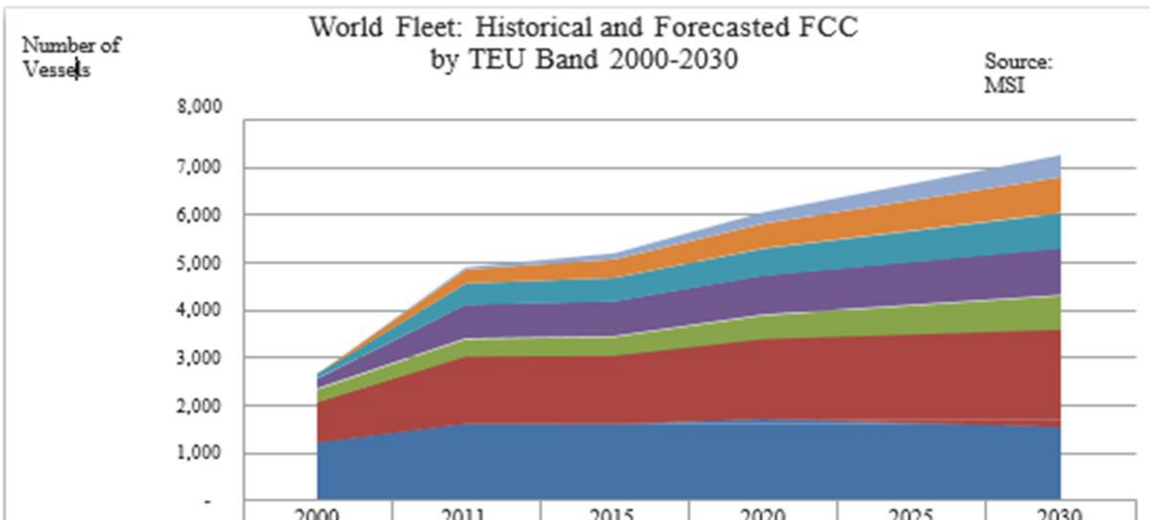


For the GRR in **Reach 3**, the recent ship simulation results detailed in the main report show Panamax containerships with dimensions of 965 feet LOA x 106 feet beam x 44 feet draft with 65,890 DWT and 5,095 TEU Capacity. This sized vessel was determined to be the design vessel for the GRR, which is described in more detail below.

In **Reach 4**, the same vessels that were used in the 2012 analysis is assumed for future conditions.

4.3.1.1 Design Vessel

Per EM 1110-2-1613, the design vessel is defined as "…the largest ship of the major commodity movers expected to use the project improvements on a frequent and continuing basis." The design vessel for Reach 3 is assumed to be a Panamax containership with dimensions of 965 feet LOA, 106 feet beam, and 44 feet maximum summer load-line draft. This selection is based on analysis of the world and regional fleet of containerships most likely to use Port Freeport over the study period. Figure 4-7 summarizes the anticipated world containership fleet for the study period. Panamax vessels, typically in the 1.3 to 5.2 thousand TEU range, will continue to make up approximately 50 percent of the world fleet. Given the size constraints of ports along South American and Central American container services, the maximum vessel size likely to be used over the study period will be a Panamax vessel. This is echoed in data from similar services that visit ports along the Gulf Coast, including Houston Ship Channel and Mobile Harbor. Additionally, evidence from cargo data from other Gulf Coast ports indicate that similar materials to those at Port Freeport (e.g. chemical resins) are shipped to Latin American Ports on vessels with dimensions similar to this study's design vessel.



	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 4-7. Containership World Fleet (2000-2030)

Table 4-4 provides arrival draft detail for Panamax vessels at Houston Ship Channel. Channel depth at this time (2014) for Bayport and Barbours Cut Container Terminals was approximately -41.5 feet MLLW.

Table 4-4. Houston Ship Channel Panamax Arrival Draft Summary

		Sailing Draft														
		27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total Trips
Design Draft	40						1				1					2
	43			1					7						2	10
	44	1	1	1	3	12	12	19	16	39	20	12	27	22	6	191
	45					1	1	3		1				2		8

Container Traffic

Freeport has carrier contracts and services that are expected to grow with their representative portion of traffic. This growth will occur at the general rate of regional demand growth. As such, it is reasonable to assume that the fleet composition at Freeport will be similar to the current traffic pattern calling on Houston by the year 2040 when evaluating the overall share of Sub-Panamax compared to Panamax vessels. Therefore, Houston data was analyzed as a proxy for Freeport future conditions since Freeport does not have a long history of container traffic at Velasco, and presently does not have any Panamax vessels calling Freeport due to the Dow Thumb channel configuration.

Port Freeport has three regular container services – Mediterranean Shipping Co., Great White Fleet (United Fruit Company), and Dole Fresh Fruit. The study assumes that by the base year (2022) in the future with-project condition 13 percent of total vessels used on these route will transition to a Panamax vessel, 18 percent in 2030, and 47 percent in 2040. Additionally, only a small percentage (roughly 10 percent) of these vessel are expected to match the largest Panamax containership dimensions. Evidence from Houston Ship Channel, New Orleans, and Mobile suggests that Panamax vessels are already carrying cargo similar to what is expected to be handled at Freeport.

RoRo Traffic

Based on input from Hoegh, newly renovated vessels (775-foot LOA x 105-foot beam) have recently been added to their existing fleet (656-foot LOA x 105-foot beam). These larger RoRo vessels will continue to call Freeport in both the without- and with-project scenarios.

Other Traffic

All other fleet forecasts, other than containerships and RoRos, are the same as in the WRRDA 2014 Feasibility study.

4.3.2 Route Groups

For the analysis, the route for Panamax class containerships was assumed to be the same as current traffic with Sub-Panamax containerships (labeled Container Route in **Table 4-5**). All other traffic route miles were based on the data acquired for 2015 from Port Freeport, and the total sea distance was calculated using a weighted distance by each commodity based on total commodity tonnage by origin-destination.

The trade route forecast was applied to the commodity forecast. Mileages were weighted based on existing and anticipated percentage of tonnage by trade region. Trade regions were grouped based on general regions and similar vessel utilization patterns.

Table 4-5. Nautical Miles by Route Groups

Route Name	Commodity	Min Miles	Most Likely Miles	Max Miles
Container Route*	Container shipments	400	3,833	7,000
Crude Oil Route	Crude direct shipments	6,589	9,044	12,941
Crude Oil Route-Mother	Crude shipments for Mother Vessel	6,589	18,000	25,246
Crude Oil Route-Shuttle	Crude shipments for shuttle vessel	100	200	300
Petroleum Prod. Route	Petroleum product shipments	4,175	10,236	24,216
Liquid Bulk Route	LPG/ LNG	4,175	11,060	15,510
Dry Bulk Route	Dry bulk cargo, chemicals	1,400	10,312	24,216
General Cargo Route	General cargo	1,400	12,488	24,216
Domestic Route	Coastwise	1,300	1,500	1,700

Source: Port Freeport 2015, Waterborne Commerce 2015, SeaRates.com
**GRR Component*

4.3.3 Loading Patterns

Given the uncertainty surrounding the future conditions of Panamax vessels, and the similarities between the petrochemical industry services at Freeport and Houston, the analysis assumes the characteristics of Panamax vessels on similar Freeport trade lanes currently at Houston will be reflected at Freeport by the year 2040. These characteristics include vessel class distributions, tons per TEU, parcel size, sailing draft distributions, and load factors. Years prior to 2040 were interpolated between Freeport existing conditions and Houston existing conditions for vessel class distributions of Panamax vessels. The figures below show sailing drafts at Freeport and Houston for Sub-Panamax and Panamax containerships. The Sub-Panamax vessels were categorized by length of the vessel (LOA). SPX1 includes containership vessels less than 650 feet, while SPX2 includes containership vessels between 650 and 750 feet.

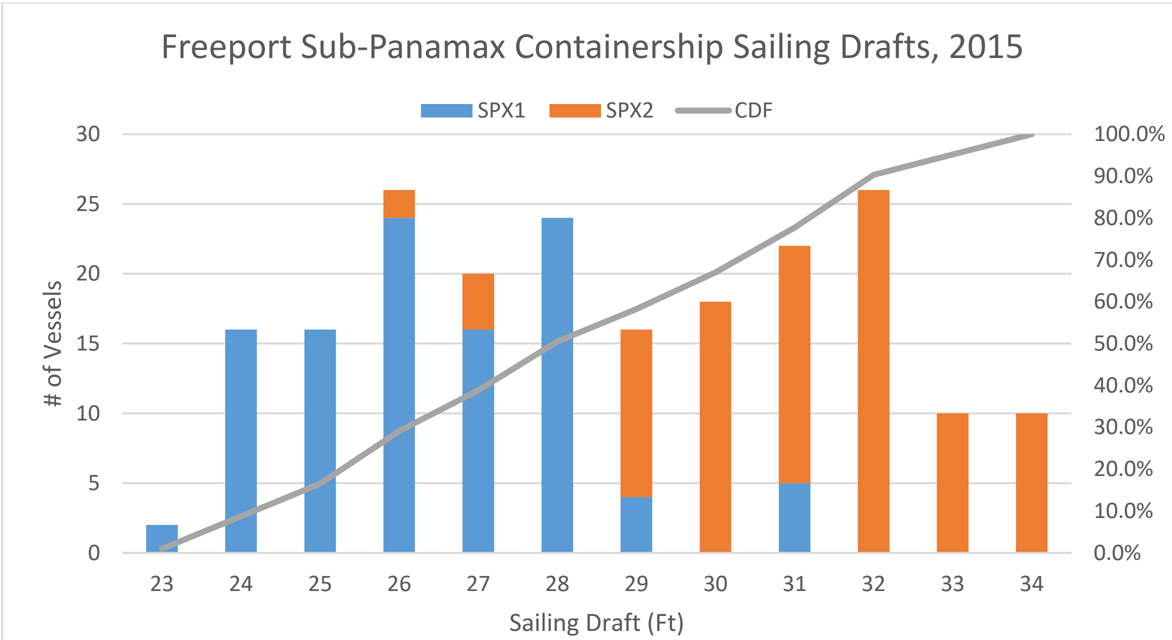


Figure 4-8. Freeport Sub-Panamax Containership Sailing Drafts

Source: Port Freeport, 2015

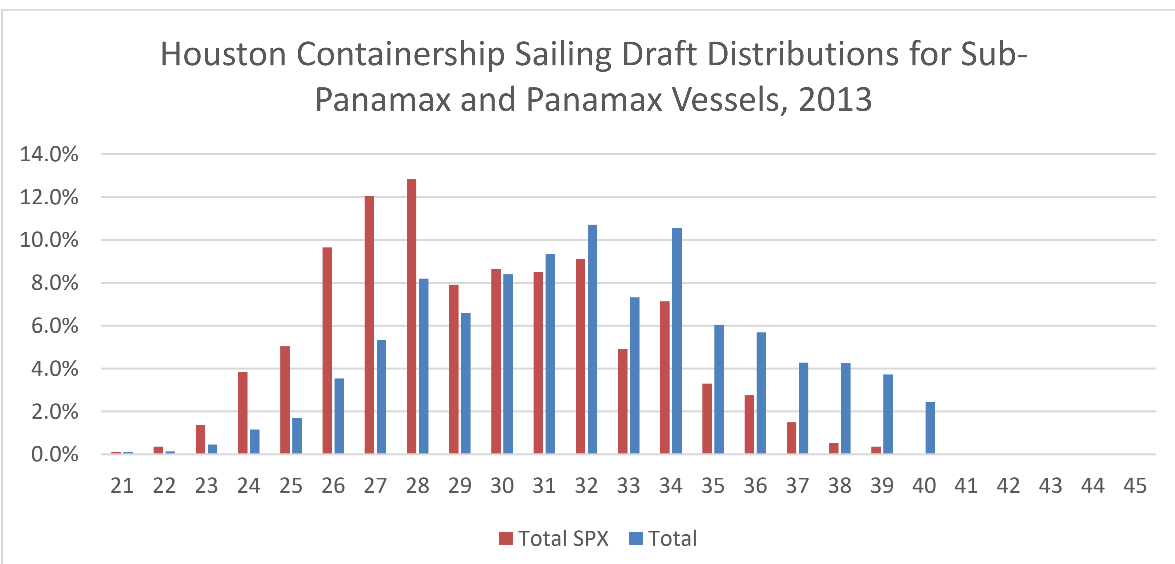


Figure 4-9. Houston Containership Sailing Draft Distributions

Source: Port of Houston Authority, 2013

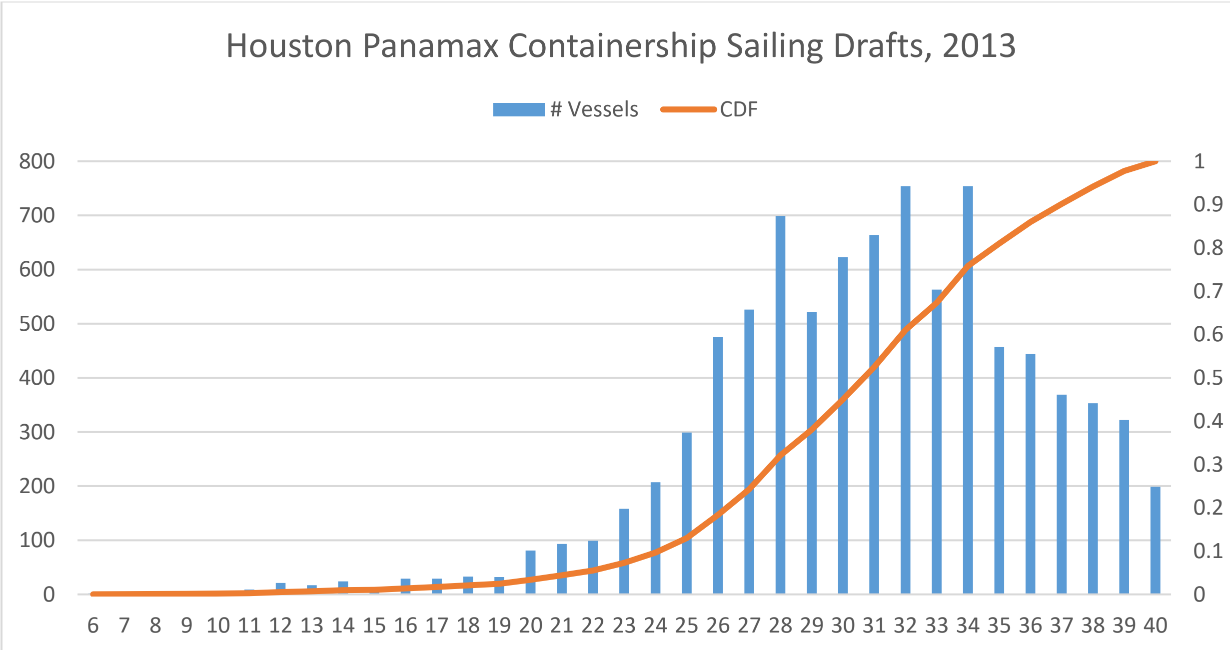


Figure 4-10. Houston Panamax Containership Sailing Drafts

Source: Port of Houston Authority, 2013

The following graphs compare Houston to Mobile Panamax sailing drafts. Houston had a 40 foot channel depth in 2013. Mobile had a 45 foot channel depth during 2012-2014. This was the most recent data that could be acquired for these channels on this project. Figure 4-11 shows the entire distribution while Figure 4-12 focuses on the upper drafts.

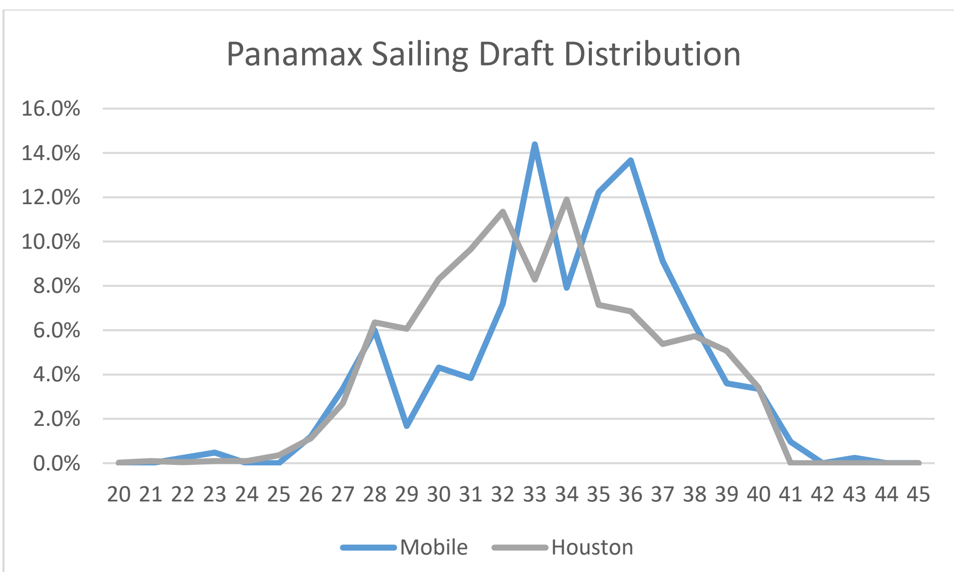


Figure 4-11. Panamax Sailing Draft Distribution

Source: Port of Houston Authority, 2013; Waterborne Commerce for Mobile, 2012-2014

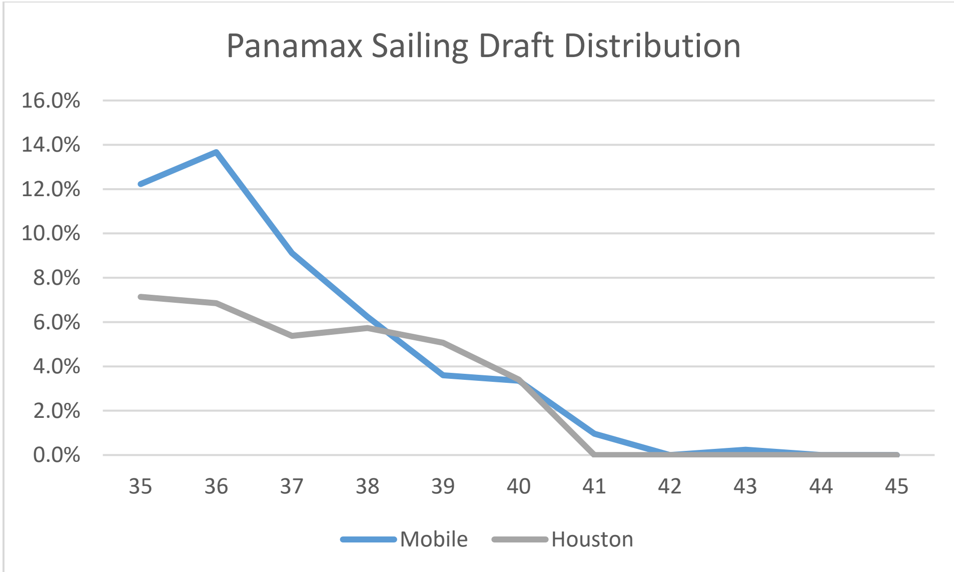


Figure 4-12. Panamax Sailing Draft Distribution

Source: Port of Houston Authority, 2013; Waterborne Commerce for Mobile, 2012-2014

Based on the data presented above, Mobile and Houston share similar sailing draft distributions for Panamax vessels. Therefore, these distributions were applied to Freeport's future with-project condition for Panamax vessels.

The following tables show the model assumptions for the FWOP and FWP for the GRR. Table 4-6 provides a summary of vessel class specifications used in the load factor analysis. Mean DWT is used in the load factor analysis to determine the vessel's loading capacity by vessel sailing draft. Parcel size is based on the average metric tons of cargo to be loaded/unloaded at Freeport. The load factor percentage provides the parcel size as an average percentage of total vessel capacity by sailing draft.

Table 4-6. Loading Characteristics for Containerships

Vessel Class	Mean DWT**	Max Sailing Draft		Parcel Size (TEUs)		Load Factor	
		FWOP	FWP	FWOP	FWP	FWOP	FWP
Sub-Panamax 1	19,712	37.7	37.7	356	356	20%	20%
Sub-Panamax 2	34,375	41.0	41.0	444	444	13%	13%
Panamax*	38,631	---	43.0	---	882	---	17%

**Based on Houston Historical data*
***Based on Historical data*

Table 4-7 shows the distribution of TEUs by year for the FWOP and FWP conditions. In the FWOP conditions, it is anticipated that the distribution of existing TEUs will not change, although the number of TEUs grows. In the FWP conditions, it is anticipated that the distribution of TEUs at Freeport will resemble the existing distribution at Houston for the Sub-Panamax and Panamax vessels by the year 2040. In the forecast, the 2040 FWP TEU distribution was derived from Houston 2013 data. The years from 2015-2040 were interpolated.

Table 4-7. TEUs by Containership Vessel Class

Vessel Class	Existing	FWOP			FWP		
	2015	2022	2030	2040	2022	2030	2040
SPX1	38,083	50,682	68,273	94,609	40,947	49,031	33,972
SPX2	43,966	58,511	78,819	109,224	40,947	49,031	33,972
PX1	-	-	-	-	27,298	49,031	135,888

Table 4-8. Number of Calls

Route and Vessel Class	Existing	FWOP			FWP		
	2015	2022	2030	2040	2022	2030	2040
Container Route- Sub-Panamax 1	107	142	192	266	115	138	95
Container Route- Sub-Panamax 2	99	132	177	246	92	110	76
Container Route- Panamax	-	-	-	-	31	56	154
General Cargo Route-RoRo 1	28	38	52	74	38	52	74
General Cargo Route-RoRo 2	18	25	34	47	25	34	47
Crude Oil Route-OIL1	28	27	29	33	26	28	33
Crude Oil Route-OIL3	1	1	1	1	1	1	1
Crude Oil Route-OIL4	71	67	73	84	58	63	72
Crude Oil Route-OIL5	36	34	37	42	28	30	34
Petroleum Product Route-OIL1	17	23	25	27	23	25	26
Petroleum Product Route-OIL3	5	7	7	8	6	7	7
Dry Bulk Route-CHEM1	125	154	195	262	154	195	262
Dry Bulk Route-CHEM2	143	176	223	299	173	219	295
Liquid Bulk Route-LPG2	20	55	67	72	55	67	72
Dry Bulk Route-BLKC3	27	27	27	27	25	25	25
Dry Bulk Route-GC2	4	5	6	8	5	6	8
General Cargo Route-GC1	36	18	18	18	18	18	18

5.0 Calculation of Costs

The main report and engineering appendix should be referenced for specific details and assumptions regarding construction and O&M costs. Interest during construction (IDC) was calculated based on the Project First Cost and construction schedule.

Table 5-1. Project Cost Summary ($000)

Project	Project Costs	IDC[2]	Total Investment	AAEQ Total Investment	AAEQ OMRR&R	Total AAEQ Costs
GRR	$52,500	$1,450	$53,950	$1,998	$2,157	$4,155
2012 Feasibility	$272,584	$11,400	$283,984	$10,519	$11,181	$21,700
Total	**$325,084**	**$12,850**	**$337,934**	**$12,517**	**$13,337**	**$25,855**

[2] Assumed 2-year construction period for GRR and 3-year construction period for 2012 Feasibility

6.0 Transportation Cost Savings Benefit 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 Port Freeport. 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 deepening benefits, mooring alternatives, widening alternatives, and bend easing improvements for the container design vessel.

Within this section, the HMST and its application in the study are described in detail. The resulting benefits are described in Section 6.2 through Section 7.3.

6.1 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 Port Freeport 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 Freeport route services.

There are three primary effects from channel deepening that lead to changes in the future fleet at the Port of the Freeport. The first is an increase in a vessel’s maximum practicable loading capacity. Channel restrictions limit vessel capacity by limiting 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 required vessel trips 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 Freeport. The third effect is a consequence of the second. The increase in Panamax vessels displaces the less economically efficient Sub-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 HMST was used to generate a vessel call list based on the commodity forecast at Port Freeport for a given year, Freeport'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.

6.1.1 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.

6.1.2 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 exits 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

At-Sea cost allocations were applied to transportation cost savings estimates by applying historical loading practices to the forecasted fleet. All benefit results presented in the economics appendix have been adjusted by the at-sea cost allocation fraction.

6.1.3 HarborSym Data Inputs

Data requirements for running HarborSym are separated into six categories, as described below. Key data for Port Freeport 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 violations when a vessel experiences a delay. The base year for the model was 2022. Model runs at 100 iterations were performed for the following years: 2022, 2030, and 2040. Model runs of forecast year 2022 showed a standard deviation of total vessel time in system of 131 hours through 100 iterations (Figure 6-1).

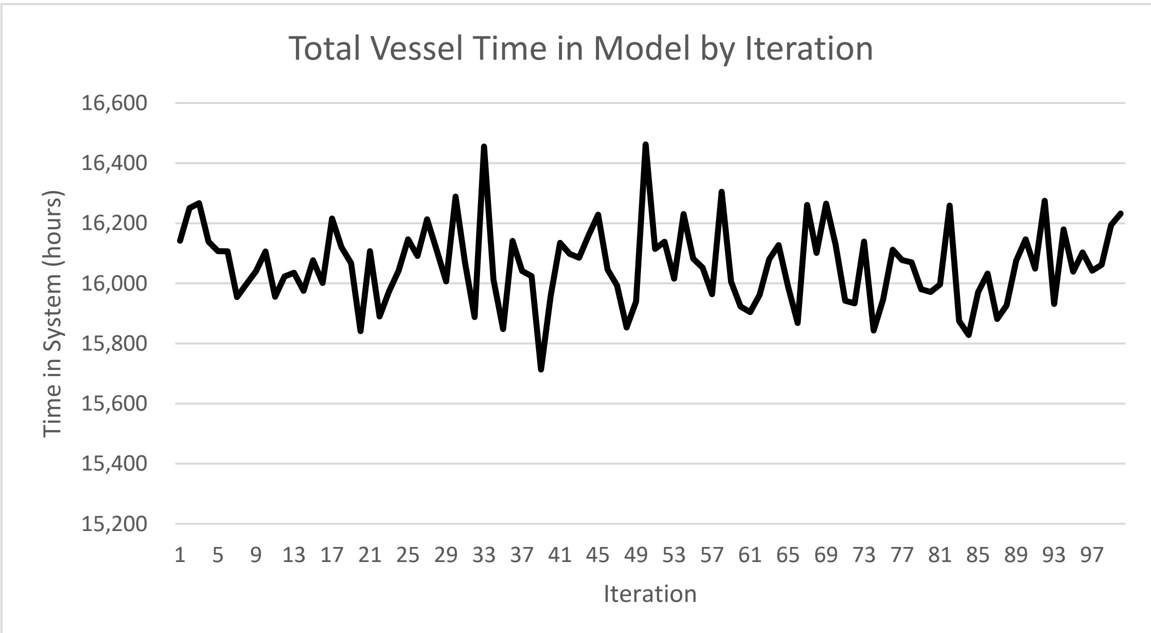


Figure 6-1. Total Vessel Time in Model by Iteration

Physical and Descriptive Harbor Characteristics. These data inputs include the specific network of Port Freeport 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. Figure 6-2 provides an overview of the reach-node network developed for this study.

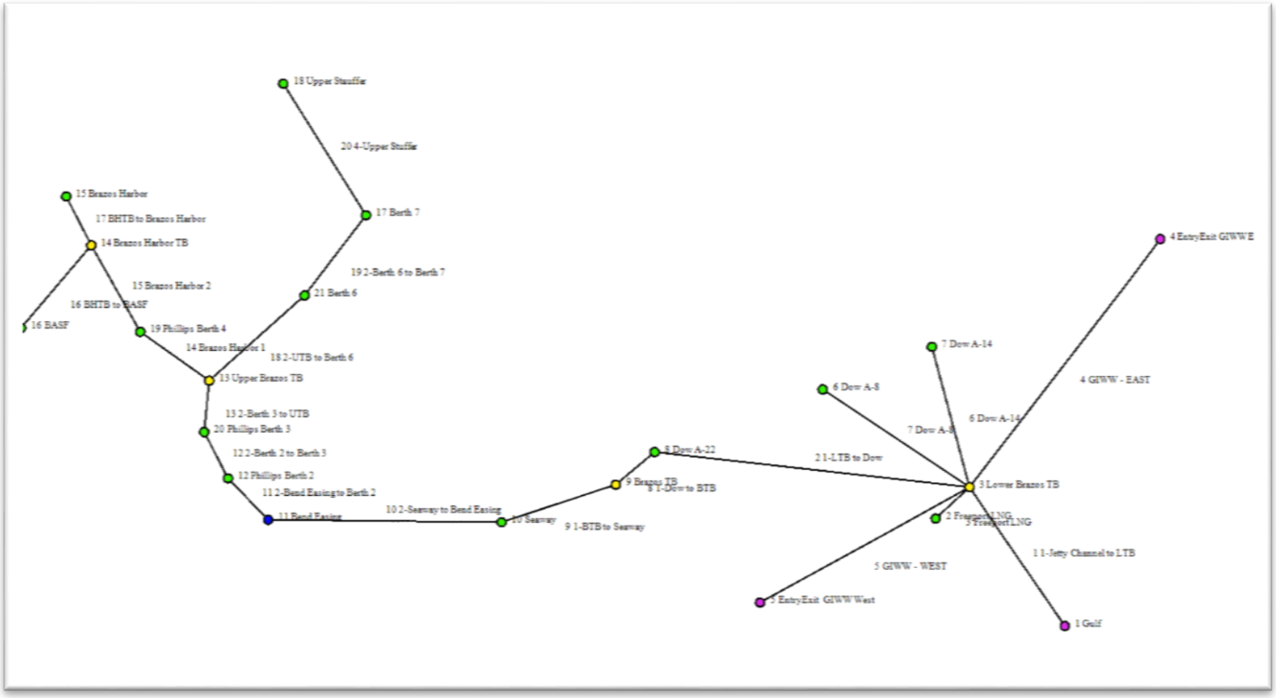


Figure 6-2. HarborSym Node Network

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 Port Freeport. 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 6-1.

Table 6-1. Nautical Miles by Route Group

Route Name	Commodity	Min.	Most Likely	Max.
Container*	Container Shipments	400	3,833	7,000
Crude Oil	Crude Direct shipments	6,589	9,044	12,941
Crude Oil-Mother	Crude shipments for Mother Vessel	6,589	18,000	25,246
Crude Oil-Shuttle	Crude shipments for shuttle vessel	100	200	300
Petroleum Products	Petroleum Product shipments	4,175	10,236	24,216
Liquid Bulk	LPG/ LNG	4,175	11,060	15,510
Dry Bulk	Dry Bulk Cargo, Chemicals	1,400	10,312	24,216
General Cargo	General Cargo	1,400	12,488	24,216
Domestic	Coastwise	1,300	1,500	1,700

Source: Port Freeport 2015, Waterborne Commerce 2015, SeaRates.com
**GRR Component*

Vessel Speeds. Table 6-2 presents the average vessel speed by reach group for all vessels. These speeds in reach are an average of all vessel classes when light and loaded based on actual practice.

Table 6-2. Vessel Speed by Reach

Reach	Speed in Reach, Light (knots)	Speed in Reach, Loaded (knots)
1-BTB to Seaway	6.5	5.0
1-Dow to BTB	6.5	5.0
1-Jetty Channel to LTB	13.0	13.0
1-LTB to Dow	6.5	5.0
2-Bend Easing to Berth 2	6.5	5.0
2-Berth 2 to Berth 3	6.5	5.0
2-Berth 3 to UTB	6.5	5.0
2-Berth 6 to Berth 7	6.5	5.0
2-Seaway to Bend Easing	6.5	5.0
2-UTB to Berth 6	6.5	5.0
4-Upper Stuffer	6.5	5.0
BHTB to BASF	6.5	5.0
BHTB to Brazos Harbor	6.5	5.0
Brazos Harbor 1	6.5	5.0
Brazos Harbor 2	6.5	5.0
Dow A-14	6.5	5.0
Dow A-8	6.5	5.0
Freeport LNG	6.5	5.0
GIWW - EAST	6.5	5.0
GIWW - WEST	6.5	5.0

Vessel Operations. Hourly operating costs while in-port and at-sea were determined for all vessel classes. These are based on FY18 operating costs provided by EGM 18-01 and 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 6-3.

Table 6-3. Vessel Speed at Sea

Description	Vessel Speed at Sea, Min (knots)	Vessel Speed at Sea, Most Likely (knots)	Vessel Speed at Sea, Max (knots)
BLKC1	11	12	13
BLKC2	12	13	14
BLKC3	12	13	14
CHEM1	12	13	14
CHEM2	12	13	14
CHEM3	12	13	14
CHEM4	13	14	15
CONT1	18	19	20

Description	Vessel Speed at Sea, Min (knots)	Vessel Speed at Sea, Most Likely (knots)	Vessel Speed at Sea, Max (knots)
CONT2	18	19	20
CONT3	20	21	22
GC1	13	14	15
GC2	12	13	14
GC3	12	13	14
GC4	12	13	14
LNG1	17	18	19
LNG2	16	17	18
LPG1	13	14	15
LPG2	13	14	15
LPG3	17	18	19
LPG4	16	17	18
MISC1	11	12	13
MISC2	11	12	13
OIL1	12	13	14
OIL2	12	13	14
OIL3	13	14	15
OIL4	13	14	15
OIL5	13	14	15
RR1	17	18	19
RR2	17	18	19
TUG1	12	13	14
TUG2	13	14	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 Port Freeport are used to simulate actual conditions in the port. The most significant changes to transit rules for this study are related to the increase in allowable vessel size between the without-project and with-project conditions and allowance for deeper loading for all vessels.

Vessels Calls. The vessel call lists are made up of forecasted vessel calls for a given year as generated by the HMST. 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.

The forecasted commodities for Port Freeport were allocated to the future vessel fleet using the HMST. Historical loading data was used to inform a Load Factor Analysis which was used in determining the future vessel fleet's total number of calls, total cargo onboard, import and export totals, arrival and departure drafts, as well as at-sea cost allocations. A separate vessel fleet forecast was completed for each alternative plan. Vessel calls by vessel class for the Future Without-Project and recommended plan are shown in Table 6-4. These are the results of the HMST loading algorithm, the commodity forecast for Port Freeport, and the Load Factor Analysis data inputs.

Table 6-4. Vessel Calls by Class

Vessel Class	FWOP	FWP
2022		
OIL1	50	49
OIL3	8	7
OIL4	67	58
CONT1	141	115
CONT2	133	92
CONT3	0	31
LPG2	55	55
BLKC3	27	25
RR1	38	38
OIL5	34	28
RR2	25	25
GC1	18	18
GC2	5	5
CHEM1	154	154
CHEM2	176	173
Total	***931***	***873***
2030		
OIL1	54	53
OIL3	8	8
OIL4	73	63
CONT1	191	137
CONT2	178	111
CONT3	0	56
LPG2	67	67
BLKC3	25	23
RR1	52	52
OIL5	37	30
RR2	34	34
GC1	18	18
GC2	6	6
CHEM1	195	195

Vessel Class	FWOP	FWP
CHEM2	223	219
Total	***1,161***	***1,072***
2040		
OIL1	60	59
OIL3	9	8
OIL4	84	72
CONT1	265	95
CONT2	247	76
CONT3	0	154
LPG2	71	72
BLKC3	26	22
RR1	74	74
OIL5	42	34
RR2	47	47
GC1	18	18
GC2	7	7
CHEM1	262	262
CHEM2	298	293
Total	***1,510***	***1,293***

6.2 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). Results and calculations were verified using spreadsheet models used in previous deep draft navigation analyses as well.

Transportation costs were estimated for a 50-year period of analysis for the years 2022 through 2071. Transportation costs were estimated using HarborSym for the years 2022, 2030, and 2040. 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.

Table 6-5 provides the annual transportation costs for the GRR and Authorized Project. The transportation cost saving benefit summary for the GRR and Authorized Project is provided in Table 6-6. The AAEQ transportation cost saving benefits for the GRR and Authorized Project are provided in Table 6-7.

Table 6-5. Annual O-D Transportation Cost Allocated to Port (Million $)

Year	FWOP	FWP
2022	$276.4	$251.5
2023	$281.3	$256.1
2024	$286.2	$260.7
2025	$291.2	$265.3
2026	$296.1	$269.9
2027	$301.1	$274.5
2028	$306.0	$279.1
2029	$311.0	$283.7
2030	$315.9	$288.2
2031	$323.1	$293.9
2032	$330.3	$299.5
2033	$337.5	$305.2
2034	$344.6	$310.8
2035	$351.8	$316.5
2036	$359.0	$322.1
2037	$366.2	$327.7
2038	$373.4	$333.4
2039	$380.5	$339.0
2040-2071	$387.7	$344.7

Table 6-6. Annual O-D Transportation Cost Saving Benefit (Million $)

Year	FWP
2022	$24.90
2023	$25.20
2024	$25.50
2025	$25.90
2026	$26.20
2027	$26.60
2028	$26.90
2029	$27.30
2030	$27.70
2031	$29.20
2032	$30.80
2033	$32.30
2034	$33.80
2035	$35.30
2036	$36.90
2037	$38.50

Year	FWP
2038	$40.00
2039	$41.50
2040-2071	$43.00

Table 6-7. O-D AAEQ Transportation Cost and Cost Savings (Million $)

Alternative	OD AAEQ Transportation Cost	OD AAEQ Transportation Cost Savings
FWOP	$361.9	$-
FWP	$324.6	$37.3

To evaluate the GRR and Authorized Project separately, all benefits of the GRR project were considered independent of the Authorized Project. Table 6-8 summarizes the transportation cost savings of the GRR and Authorized project.

Table 6-8. AAEQ Transportation Cost and Cost Savings by Project (Million $)

Alternative	OD AAEQ Transportation Cost	OD AAEQ Transportation Cost Savings
GRR		
FWOP	$36.09	$-
FWP	$28.85	$7.24
Authorized Project		
FWOP	$325.83	$-
FWP	$295.75	$30.08

7.0 Economic Summary

7.1 Previous Analysis

Table 7-1 presents a summary of the WRRDA 2014 authorized project analysis in October 2013 dollars. The channel depths presented in the table are in MLT. The Federal discount rate at the time of the analysis was 4.0%.

Table 7-1. Economic Summary

Economic Summary of NED and LPP for Freeport Channel and Stauffer Modification
Average Annual Values (4.0% and $1,000)

	NED Plan			
		Stauffer Modification		
	Freeport Channel 60/50 feet	Lower Reach 50 feet	Upper Reach 25 feet	Totals
First Cost of Construction	374,522	12,664	4,090	391,276
Interest During Construction	28,477	149	6	28,632
Total Investment	402,999	12,813	4,096	419,909
Average Annual Cost	18,760	596	191	19,547
Average Annual O&M	11,258	1,024	42	12,324
Total Annual Cost	30,018	1,620	233	31,871
Average Annual Benefits	65,270	7,784	1,419	74,474
Net Excess Benefits	35,253	6,164	1,186	42,603
B/C Ratios	2.2	4.8	6.1	2.3
	LPP			
		Stauffer Modification		
	Freeport Channel 55/50 feet	Lower Reach 50 feet	Upper Reach 25 feet	Totals
First Cost of Construction	274,988	11,840	3,823	290,651
Interest During Construction	19,156	139	6	19,301
Total Investment	294,144	11,979	3,829	309,952
Average Annual Cost	13,692	558	178	14,428
Average Annual O&M	9,569	1,024	42	10,635
Total Annual Cost	23,261	1,581	221	25,063
Average Annual Benefits	38,442	7,784	1,419	47,646
Net Excess Benefits	15,181	6,203	1,199	22,583
B/C Ratios	1.7	4.9	6.4	1.9

7.2 Current Update

The table below shows the summary for this economic analysis in October 2017 dollars. For the 2012 Authorized Project Economic Update, the total average annual benefits of $30,085,000 for the project exceeds the total average annual costs of $22,587,000, yielding net benefits of $7,498,000 and a continued justified project with a benefit cost ratio of 1.3. For the GRR portion, the total average annual benefits of $7,237,000 exceed the total average annual cost of $4,200,000, yielding net benefits of $3,037,000 and return a benefit cost ratio around 1.7 at the FY18 discount rate.

Table 7-2. Summary of Benefits and Costs with GRR Features at -46 Feet MLLW

(October 2017 dollars, 2.75% interest rate, $000)

	2012 Feasibility	GRR	Total
Project Costs*	$272,584	$52,500	$325,084
IDC	$11,400	$1,450	$12,850
Total Investment	$283,984	$53,950	$337,934
AAEQ Total Investment	$10,519	$1,998	$12,517
AAEQ OMRR&R	$11,181	$2,157	$13,337
Total AAEQ Costs	$21,700	$4,155	$25,855
Total AAEQ Benefits	$30,085	$7,237	$37,322
AAEQ Net Benefits	$8,385	$3,082	$11,467
BCR	**1.39**	**1.74**	**1.44**

*Includes Project First Costs and Associated Costs
Note: There may be slight difference due to rounding

7.3 Preliminary Incremental Analysis

A preliminary incremental analysis was conducted to determine the optimal depth for the GRR features. Costs were calculated at -46 feet MLLW and -40 feet MLLW, and interpolated for intermediate depths based on a linear trend. HarborSym was used to calculate benefits, and individual model runs were conducted for the channel depths 42 feet, 43 feet, 44 feet, 45 feet, and 46 feet. Benefits for 41 feet and 40 feet were extrapolated. The assumptions used at 46 feet were also used for each of the other depths. The only changing factor was the vessel's ability to load to its draft-constrained depth. The results showed that a channel depth for Reach 3 and the GRR features maximized net national economic benefits at 46 feet based on transportation cost savings.

Table 7-3. Incremental Analysis Summary for GRR

(October 2016 dollars, 2.875% interest rate, $000)

Channel Depth	40	41	42	43	44	45	46
Average Annual Benefits	$3,123	$3,789	$4,455	$5,111	$5,598	$6,010	$6,452
Average Annual Costs	4,270	4,287	4,305	4,322	4,340	4,357	4,374
Net Excess Benefits	(1,147)	(499)	150	788	1,259	1,653	2,078
BCR	0.73	0.88	1.03	1.18	1.29	1.38	1.47

7.4 Risk and Uncertainty

There are several key uncertainties that could potentially affect the BCR. First, data from a number of Gulf ports (Freeport, Houston, and Mobile) was used to derive study assumptions and complete the economic analysis. Given the proximity to Houston, the growing congestion at Houston both in the channel and landside, and given that both ports serve the petrochemical industry, the analysis assumes the characteristics of Panamax vessels on Caribbean routes currently at Houston will be reflected at Freeport by the year 2040. These characteristics include vessel class distributions, tons per TEU, parcel size, sailing draft distributions, and load factors.

Commodity growth rates are uncertain. The projected growth rates published by the Department of Energy varies each year based on the policies of the current administration coming to fruition. It is possible that the current administration will have more favorable views toward the production and consumption of petroleum and petroleum products. Also, the projections for containerships are varied. The analysis used growth rates that were developed in the Houston AOM study. However, a new terminal such as Velasco may experience higher growth rates in the immediate future than a "regional average".

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 includes 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 commodity and fleet 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 Port Freeport.

7.5.1 No Growth Sensitivity Analysis

The "No Growth" sensitivity analysis assumes that there is no growth in throughput tonnage or vessel fleet size. This is intended to represent the most extreme growth scenario at Port Freeport. Overall growth trends at Port Freeport and in the region show this to be the least likely scenario. The results of this sensitivity analysis are presented in Table 7-4. The analysis shows that while the improvements associated with the Economic Update are still justified even with no commodity or fleet growth, the improvements associated with the GRR would not be economically justified.

Table 7-4. No Growth Sensitivity Analysis

Project	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
GRR	$ 4,155,000	$ 1,980,000	$ (2,175,000)	0.48
2012 Feasibility	$ 21,700,000	$ 25,543,000	$ 3,843,000	1.18
Total	$ 25,855,000	$ 27,523,000	$ 1,668,000	1.06

7.5.2 Low Growth Sensitivity Analysis

To simulate a low growth scenario, commodity and fleet growth were capped at study year 2030. This sensitivity replicates a low growth scenario for all commodities and all vessel types. As summarized in Table 7-5, the improvements associated with the economic update remain justified while those included in the GRR would not be justified.

Table 7-5. Low Growth Sensitivity Analysis

Project	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
GRR	$ 4,155,000	$ 3,457,000	$ (698,000)	0.83
2012 Feasibility	$ 21,700,000	$ 27,997,000	$ 6,297,000	1.29
Total	$ 25,855,000	$ 31,454,000	$ 5,599,000	1.22

The outcomes of these sensitivity analyses point to a high level of confidence that the economic benefits of the improvements associated with the economic update outweigh their costs. The economic benefits associated with the improvements in the GRR are justified given the most likely growth scenarios (as included in the main analysis); however, there is some risk that these measures would not be justified given less optimistic commodity growth and fleet shift scenarios.

7.6 Regional Economic Development

According to a feasibility study conducted by Transportation Economics & Management Systems, Inc. on the impact of the Panama Canal for Texas Ports:

- Texas GDP has been growing at 7 percent per year. The Texas Comptroller of Public Accounts predict the average Texas GDP will grow at 5.4 percent annually through the year 2035. Container imports are closely correlated to GDP growth.
- Population in Texas is expected to grow from 26 million today to 40 million by the year 2050.
- Shifting intermodal activity to Rosenberg has the potential of adding 15,000-30,000 jobs in the State Highway 36A corridor consisting of distribution and industrial jobs. Approximately 2/3 of those will be in Freeport, and 1/3 will be in Rosenberg. This shift will also increase income and sales tax revenues a total of $800 million per year. Direct jobs created will contribute $449 million annually, and indirect jobs will contribute $363 million annually.

An Economic Impact Analysis was conducted by Texas A&M Transportation Institute in February 2016. The report states that Port Freeport provides

- 16,400 local direct jobs with $1.5 billion in income ($91,000 average)
- 69,500 local indirect and induced jobs with $3.8 billion in income ($55,000 average)
- 40,100 jobs elsewhere in Texas with $2.3 billion in income ($57,000 average)
- $46.2 billion in economic activity supported economy wide
- $522 million in annual tax impacts economy wide