Economic Appendix

1.0 Current Economic Conditions Overview

The Economic Reaches in the Freeport Economic Update are the same as those utilized for the Freeport WRRDA 2014 Project. The current channel is 46 feet MLLW and primarily serves the petrochemical industry. The reaches each serve different commodities. Freeport LNG (Liquefied Natural Gas), Seaway (crude oil, petroleum products), and Dow Chemical (chemicals) docks are in Reach 1. Phillips (crude petroleum, petroleum products, chemicals, LPG) has Berths 2 and 3. The Upper Turning Basin is also included in this reach. Berth 6 is tangent to the Upper Turning Basin. Brazos Harbor veers west of the Upper Turning Basin. It previously served the market of banana imports, but those shipments have moved to a newly constructed container facility (Velasco Terminal). The Velasco Container Terminal is located in Reach 3 and currently has Berth 7 dredged to 46-feet MLLW, although the channel is only 19 feet. Berth 7 connects to the Upper Turning Basin though, so vessels have access to the berth. Berth 8 is part of Port Freeport's future port expansions and will also be part of the Velasco Terminal located in Reach 3. Offshore supply vessels and other smaller vessels use Reach 4, which is also currently at 19 feet channel depth.

With growing demand in the hinterland due to population and economic growth, there may be a need for an additional container facility near Houston. Houston currently serves mostly Texas, including Dallas, Fort Worth, San Antonio, and Austin. This area alone has 20 million people and is growing at one of the fastest rates in the country. With the expansion of the Panama Canal, Post Panamax vessels are expected to call at Houston, which could open up the market to a much larger area. Instead of containers going to Los Angeles/Long Beach and transporting by rail to Dallas, it could be more cost effective for that traffic to go through Houston up to Dallas. Some of the increased traffic in the region could shift to Freeport. The Houston facilities have limited space and congestion within the channel. Freeport is expected to serve the same hinterland as Houston currently serves. As explained in Section 3, the distribution network will likely start shifting to Rosenberg as congestion increases. Therefore, to continue to provide for the region's needs, Port Freeport can help serve additional containers near Houston since Freeport is a logical alternative for the Rosenberg distribution network.

Port Freeport is developing the Velasco Terminal under several phases. Phase I is complete and containerships began calling in October 2014.

Figure 1-1 Economic Reaches

The Economic Reaches in the Freeport GRR include Reach 3, and additional features in Reach 2 detailed later in this report. The traffic associated with the Freeport GRR are containerships and RoRos. All other traffic mentioned in this report is tied to the economic update. This report addresses both the Economic Update as well as the GRR interspersed because the HarborSym model captures vessel interactions, so all relevant traffic was included in the model runs for both the GRR and Economic Update.

Vessel Traffic

The current channel configuration is limiting for future container growth. 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. The Aframax vessel utilizes the existing Berths 2 and 3 hauling petroleum and petroleum products. 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 that two containerships can dock simultaneously. Three additional cranes will be purchased. The port layout can be found in Figure 1-1 in the previous page.

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 accommodates rock ships (general cargo/aggregate). 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.

Berth 2 and Berth 3 are located across the channel from Dow Thumb. 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 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.

Pilot Rules

Freeport's existing traffic, particularly crude petroleum tankers and product tankers, are subject to vessel size limitations due to the existing channel width. 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 1-1. Vessel length limitations are enforced because crosswinds and crosscurrents force tankers to "crab" at an angle though the entranced Jetty Channel. Daylight-only operation (Table 1-2) 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. 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. Underkeel clearance is determined by the discretion of Pilots within the range recommended by the industry. Generally, underkeel clearance can range from one to four feet. Underkeel clearance for containerships are 1 to 3 feet, and tankers are 4 feet. Tide is one foot at Freeport so is not a consideration in daily operations at Freeport.

Table 1-1 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

Table 1-2 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

Vessel Traffic Distribution

The following Tables 1-3 through 1-8 show the distributions of historic traffic under existing conditions. Table 1-3 displays the distribution of tonnage by commodity type and year. Although total tonnage has been decreasing, container volumes are increasing. Table 1-4 displays the tonnage in terms of percent growth from 2010.

Table 1-3 Tonnage Distribution by Commodity Type

Commodity	2010	2011	2012	2013
Barge	42,339	36,182	43,301	46,478
Bulk	276,672	150,888	294,574	378,741
Container	249,366	180,762	219,908	386,421
Crude Petroleum	14,189,229	12,354,325	10,134,077	8,101,060
LNG	416,046	746,791	255,778	122,664
LPG	431,753	466,457	444,349	541,826
Petroleum Products	1,921,642	1,992,164	1,557,707	1,734,345
Vehicles	-	-	1,759	-
Grand Total	**17,527,047**	**15,927,570**	**12,951,454**	**11,311,536**

Source: Waterborne Commerce, 2010-2013

Table 1-4 Percent Change in Tonnage by Commodity Type (2010 base year)

Commodity	2010	2011	2012	2013
Barge	-	-15%	2%	10%
Bulk	-	-45%	6%	37%
Container	-	-28%	-12%	55%
Crude Petroleum	-	-13%	-29%	-43%
LNG	-	79%	-39%	-71%
LPG	-	8%	3%	25%
Petroleum Products	-	4%	-19%	-10%
Grand Total	**-**	**-9%**	**-26%**	**-35%**

Source: Waterborne Commerce, 2010-2013

Table 1-5 displays the number of transits and tonnage for commodities in the entire channel excluding containers.

Table 1-5 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
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

Table 1-6 shows the distribution of TEUs by route group. From October to December in 2014, 85 percent of the Freeport TEUs made short trips between the Caribbean and East Coast South America. According to the data received by Port Freeport, 100 percent of the TEUs were from South America in 2015.

Table 1-6 Container Distribution by Route Group Calling to Velasco Terminal

	2014		**2015**	
Region	**TEUs***	**% Share**	**TEUs**	**% Share**
Africa	3,124	6	0	0
Caribbean	32,050	61	0	0
East Coast South America	12,410	24	100,472	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**	**100,472**	**100**

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

Table 1-7 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 foot sailing draft was used. Exports were loaded heavier than imports.

Table 1-7 Containership 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 1-8 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

Table 1-8 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. Meanwhile, these vessels had a maximum sailing draft of 34 feet with 46 feet of available water depth. Therefore, in existing conditions, there does not appear to be a constraint for these sized vessels.

2.0 Future Without-Project Conditions

Under the future without-project conditions, the existing conditions will likely continue. The channel will not be able to accommodate vessels larger than the Aframax-sized vessel. Existing pilot rules will likely continue. As demand for container imports and exports grow, it will take additional vessels to meet this demand. Since larger vessels will not be able to utilize a deeper draft, the transportation costs will be higher. This higher cost could limit Port Freeport's ability to grow, and limit capitalizing on opportunities that contribute benefits to the Nation.

The without-project condition includes Berth 7 and the Velasco Terminal since they are both currently existing.

Commodity Forecast

The Velasco Terminal will have a total estimated throughput capacity of 500,000 TEUs. 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 2-1 indicates the compound annual growth rate (CAGR) for containers in the future without-project condition. Given these growth rates, the Velasco Terminal will reach throughput capacity in the year 2045.

Table 2-1 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 Houston AOM project, 2013

Fleet Forecast

Under current conditions, the channel has been designed for Aframax-sized vessels. Containerships have been limited to 721-feet LOA, and RoRo ships have been limited to approximately 700-feet LOA. Each vessel requires two tugs. These constraints will continue in the without-project condition.

Berth 2 currently has approximately 10 vessels per month, and Berth 3 has more than 10 vessels per month. It takes 2-24 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 analysis for benefits.

In the future without-project condition, 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. 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. With only a 20% chance of a containership being able to call when it arrives, it is questionable if the larger containerships will call in the future without-project condition. The vessels that do call will likely be small containerships that are making short trips from the Caribbean, and Central and South America. Therefore, it is expected that existing vessel fleet will continue in the future without-project condition. Table 2-2 shows the fleet forecast for containers in the future without-project condition.

Table 2-2 Fleet Forecast Without-Project Condition (Containers Calls)

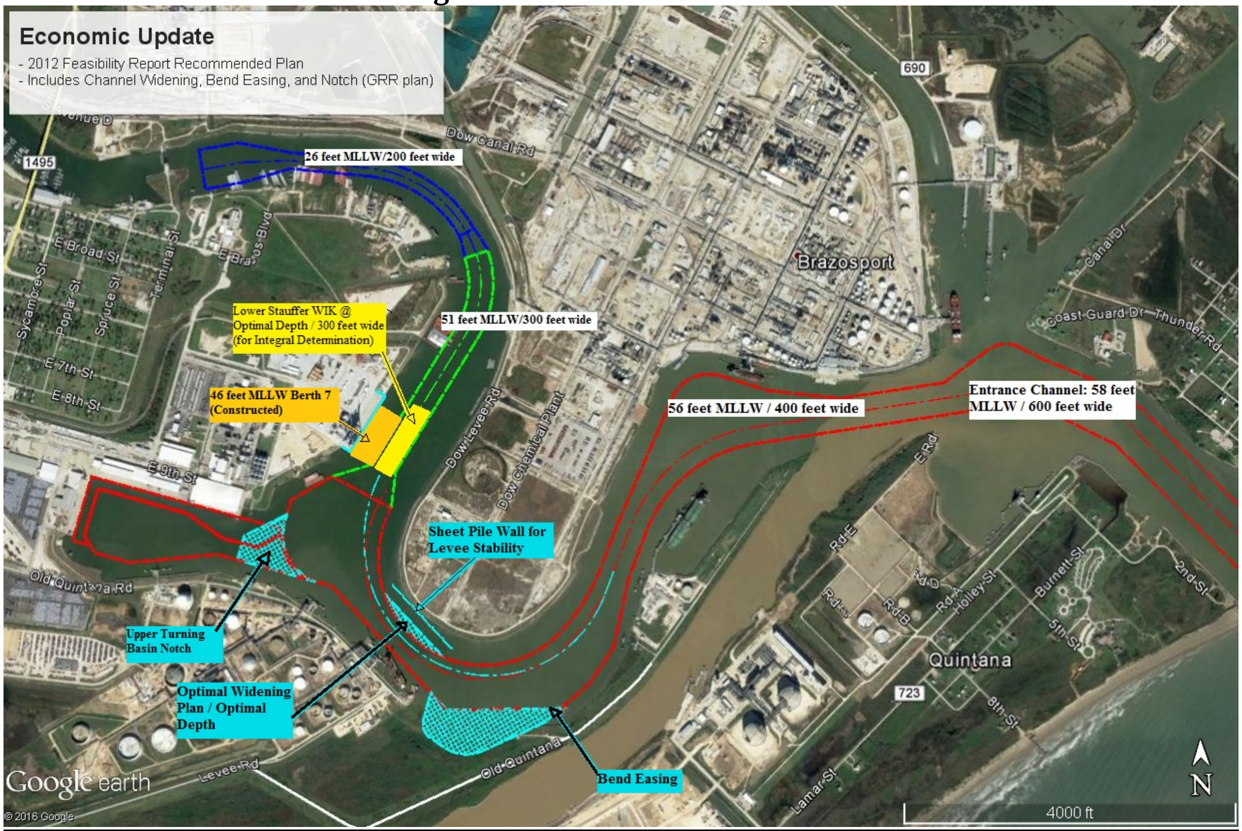
Vessel Type	2017	2025	2035	2045
Sub Panamax	268	290	328	366
Panamax	0	0	0	0

3.0 Future With-Project Conditions

In the future with-project condition, 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. Also, with larger vessels, trade routes could be longer such as Europe and Far East in addition to Caribbean and South America, offering more opportunity for trade. Tug costs per vessel are expected to not change between the without- and with-project conditions, although 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 3-1 Features in the GRR



Design Vessel

The design vessel is the largest sized vessel that is expected to regularly call at the port in the future with-project condition. Table 3-1 displays a summary of Houston Panamax containership data with an LOA of 965 feet and a beam of 106 feet. The table shows the majority of these vessels have a design draft of 44 feet, which is larger than a typical Panamax vessel in the world fleet with an average of 42 feet. It is also reasonable to assume Port Freeport could get a Panamax with design draft of 44 feet in the with-project condition since an underlying assumption with this project is that Freeport's traffic and loading patterns will closely reflect Houston's traffic because both Ports service the petrochemical industry. Therefore, the design vessel for the GRR is a Panamax containership with dimensions of 965 feet LOA, 106 feet beam, and 44 feet design draft.

Table 3-1 Houston Trips for Panamax Vessels by Design Draft and Sailing Draft

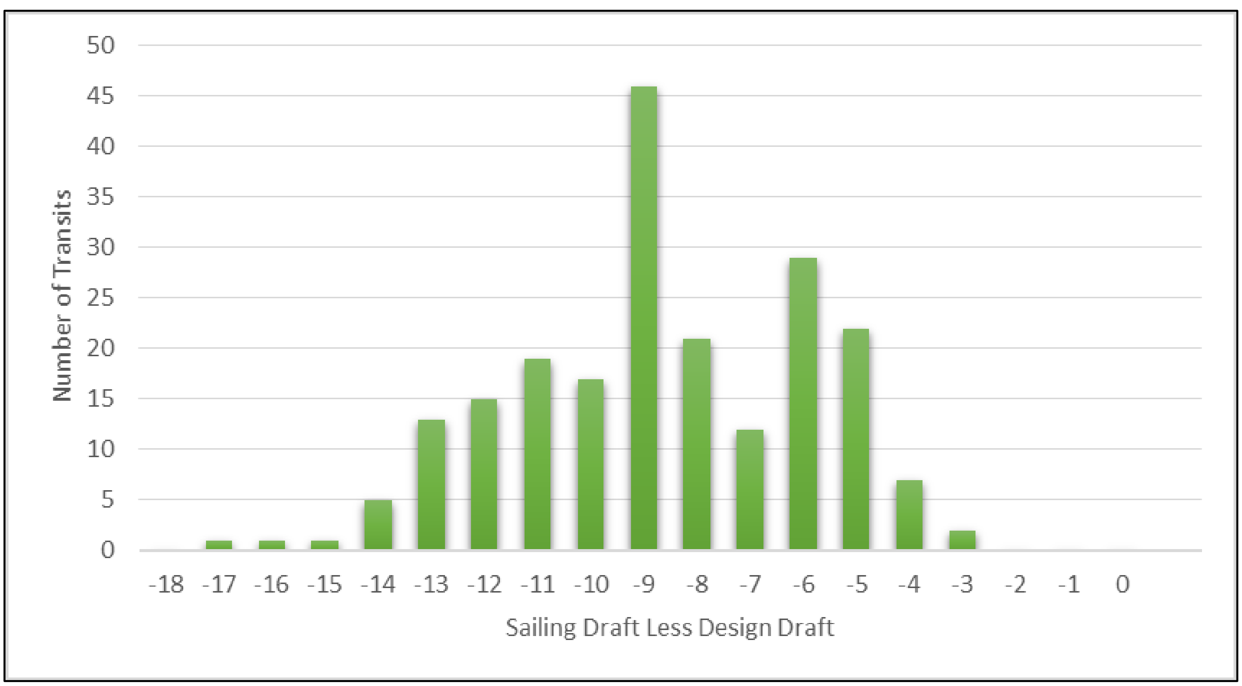
		Sailing Draft														
		27	28	29	30	31	32	33	34	35	36	37	38	39	40	Total Trips
Design Draft	40						1				1					2
	43			1					7						2	10
	44	1	1	1	3	12	12	19	16	39	20	12	27	22	6	191
	45					1	1	3		1				2		8

Source: Port of Houston, 2010

Fleet Forecast

The future container traffic composition at Freeport is largely uncertain. Presently, the main commodity being transported in containers is bananas. However, 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, it is assumed that the fleet composition at Freeport will reflect Houston current traffic by the year 2040. 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 doesn't have any Panamax vessels calling Freeport.

Figure 3-2 Histogram of Available Remaining Draft for Houston Panamax Vessels

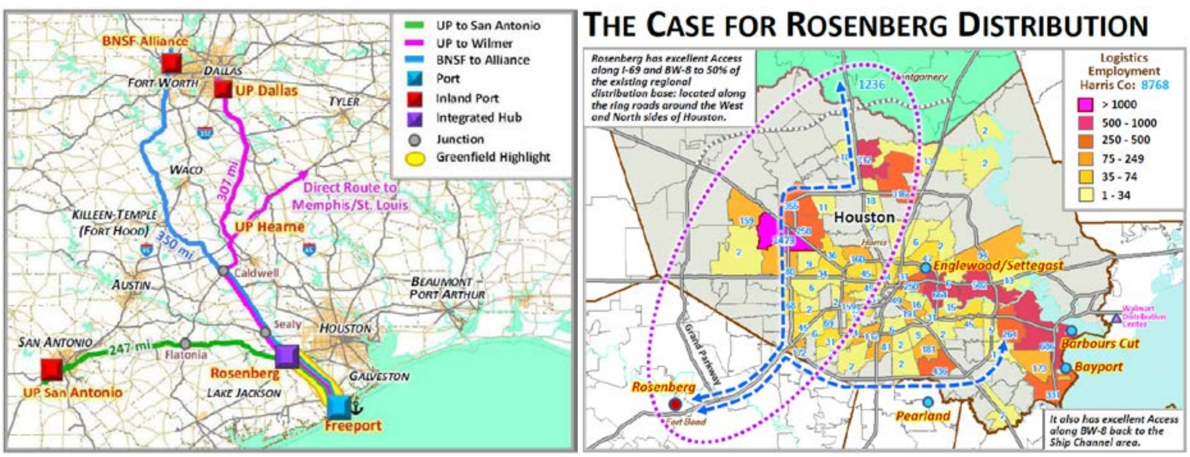


Source: Port of Houston, 2010

Figure 3-2 shows a histogram of remaining available draft for Panamax containership vessels at the Port of Houston. Since both Port Freeport and Port of Houston serve the petrochemical industry and hinterland, they will likely carry similar products in the containers in the future. The graph shows that the majority of Houston's Panamax vessels generally have a sailing draft five to 13 feet less than the vessel's design draft.

Recent Changes of Conditions and Economic Assumptions in Freeport Model

Some general assumptions that are included in the Freeport model are detailed in this section. In the previous analysis, it was assumed Freeport will service some overflow of Houston traffic since the two ports are less than 60 miles apart. This assumption was established on the basis that Houston will reach containership throughput capacity by the year 2025. However, Houston deepened their channels that service containers in 2014 from 40 feet to 45 feet, and are expanding their facilities. As a result, it is now expected that Houston will reach capacity after 2040. Therefore, Port Freeport is now anticipated to largely compete for container traffic.



Source: Impact of the Panama Canal and Market Opportunity for Texas, Transportation Economics & Management Systems, Inc.

The figures show the distribution network from Freeport that can serve the hinterland. The distribution centers currently are concentrated near the Port of Houston and in Northwest Houston. West Houston and Southwest Houston are rapidly expanding though, and are closer to Port Freeport than Port of Houston. For these markets, a distribution hub at Rosenberg is logical. Shifting intermodal activity from the Union Pacific Englewood and Burlington Northern Santa Fe Pearland to Rosenberg would reduce rail congestion in downtown Houston.

With the expansion of the Panama Canal, it is anticipated that some traffic will be diverted from the Port of Los Angeles/Long Beach to Houston because the deepening of the Panama Canal will allow cheaper transport to Dallas. This shift is subject to pricing of rail service and Panama Canal crossings, which is an unknown at this point. There is a population of 20 million currently within this hinterland, and both ports are expected to service this hinterland. The expected traffic at Freeport is approximately 5 percent of Houston traffic. One possibility regarding market share in future conditions is that Freeport could service more niche markets that are more time sensitive for imports while Houston accommodates the "box store" distribution that is more price conscious, and both service the petrochemical industry for exports.

Another change of condition is the discovery of Eagle Ford Shale oil and natural gas in 2012. The oil market has shifted in the region in recent years. Coupling that, Seaway reversed the direction of its pipeline in 2013. Therefore, petroleum and petroleum product exports are increasing, and petroleum imports and lightering operations have decreased dramatically. Loading patterns and vessel sizes have not changed, just the growth rates of these commodities for imports and exports.

In response to the shifting market, the petrochemical facilities have made significant investments to accommodate the increasing export market. Phillips is converting Berth 2 to an LPG dock. This adds increased safety concerns expressed by the Pilots as they traverse the channel around the Dow Thumb, prompting the need for the bend easing feature of the GRR.

The period of analysis is 2022-2071. The industry standard for underkeel clearance along the Texas Coast is 10 percent of the channel depth minus 1 foot. Therefore, for a 46 foot channel, underkeel clearance is generally suggested to be 3.6 feet. Panamax vessels are assumed to have 3 feet underkeel clearance.

Data sources include Port Freeport data whenever available. Waterborne Commerce data was also used for trend analysis. Data from Freeport, Houston, and Mobile was analyzed for comparison to derive many of the assumptions.

Summary of Assumptions

The figure below summarizes some key assumptions used in the analysis.

Figure 3-3 Summary of Assumptions

Velasco Terminal

Current Conditions	Future WOP Conditions	Future WP Conditions
7,000 undeveloped acres	Some development but not much past the DOW thumb/ Velasco Terminal	7,000 developed acres
2 cranes (handles 70 boxes/hour)	2 cranes (handles 70 boxes/hour)	5 cranes (handles 175 boxes/hour)
Berth 7 dredged to -46 feet	Berth 7 dredged to -46 feet	Berth 7 and 8 dredged to -46 feet (or optimal depth)
Largest container Vessel 706 feet LOA	Largest container Vessel limited to 820 feet LOA	Largest Vessel 965 feet LOA (Panamax)
About 200,000 TEUs per year (First call in October 2014)	Forecasting similar to existing 200,000 TEU per year	Throughput capacity of 500,000 TEUs per year
Dock 2 & 3 used for petroleum products (some restriction)	*Dock 2 & 3 used for Liquefied Petroleum Gas (more restrictions)	*Dock 2 & 3 used for Liquefied Petroleum Gas (more restrictions)

4.0 Forecasts

Commodity Forecast

The commodity forecasts were derived using the Department of Energy's Annual Energy Outlook forecasts for crude oil and petroleum products. Chemicals were derived from trend analysis. Containers and cars forecasts were acquired from Port Freeport projections as well as forecasts used in the Houston AOM project. The growth rates and tonnages are shown below.

Table 4-1 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 Products	316,123	435,474	472,367	497,534	1.83%
Liquid Bulk-Chemicals	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

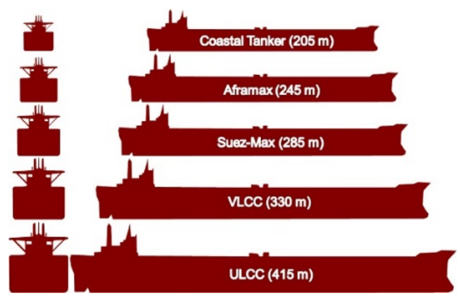
The commodity forecast included the following (beginning in 2022):

- Baseline tonnage starts from 2015
- Crude Petroleum (DOE)
  - Imports 0.74% CAGR (2015-2040), (0% 2040-2071)
  - Exports 0.00% (50% growth from 2015-2020), (0% 2020-2071)
- Petroleum Products (DOE)
  - Imports 0.20% (63% growth from 2015-2020)
  - Exports 1.01% (26% growth from 2015-2020)
- Chemicals (Trend)
  - Imports 3.0% (2015-2040), 0% (2040-2071)
  - Exports 3.0% (2015-2040), 0% (2040-2071)
- Containers (Houston 204)

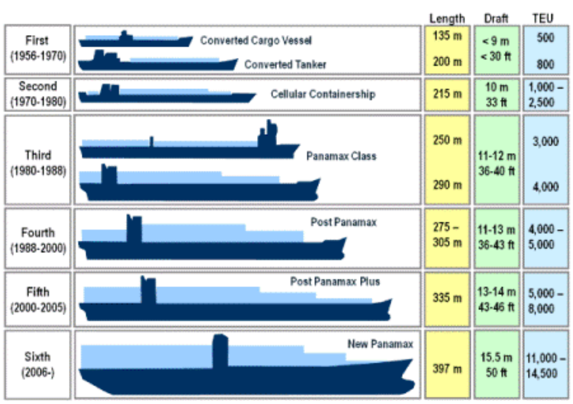
- o Imports 3.33% (2015-2025), 3.02% (2025-2035), 2.50% (2035-2045), 0% (2045-2071)
- o Exports 4.94% (2015-2025), 3.83% (2025-2035), 3.5% (2035-2045), 0% (2045-2071)
- o Empties and Vacants same as 2012 Houston analysis
- o Metric Tons per TEU same as 2012 Houston analysis (10.0 for Caribbean, ECSA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

- RoRos
  - o Imports Same as containers
  - o Exports Same as containers
- Upper Stauffer Vessels
  - o 0% (2015-2071)

Fleet Forecast



The fleet forecast distributions were derived from a combination of 2015 Port data and previous analysis. For Reach 1, the Aframax fleet for Crude Oil is projected to grow to a 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 grow 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.



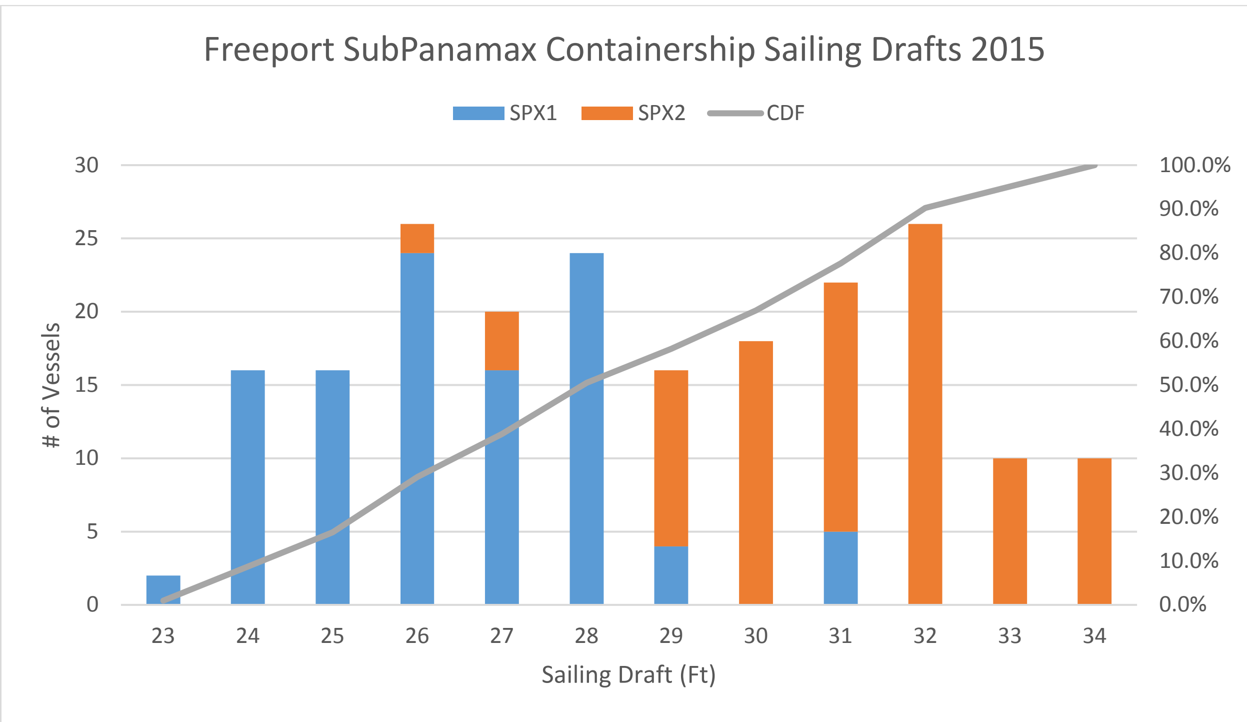
In Reach 3, the recent ship simulation results detailed in the main report show Panamax containerships with dimensions of 965 feet LOA x 106 feet beam x 44 feet draft with 65,890 DWT and 5,095 TEU Capacity. This sized vessel was determined to be the design vessel for the GRR. In Reach 4, the same vessels that were used in the 2012 analysis is assumed for future conditions.

Loading Patterns

The loading patterns in the future conditions are largely uncertain. In the past, Freeport has utilized only sub-Panamax vessels. The loading patterns on those vessels have been relatively consistent across years. With the introduction of Panamax vessels, new markets could potentially be availed. These new markets could introduce new commodities, but the densities of those potential commodities are uncertain. Also, the load factor, that is, the share of cargo loaded/unloaded at Freeport as proportion to total vessel capacity, is largely uncertain, thereby adding uncertainty to the loading drafts of Panamax vessels. Also, the routes of the Panamax vessels are uncertain. A larger vessel may use longer routes than sub-Panamax vessels. Finally, the share of overall tonnage at Freeport being transported on sub-Panamax versus Panamax vessels is unknown.

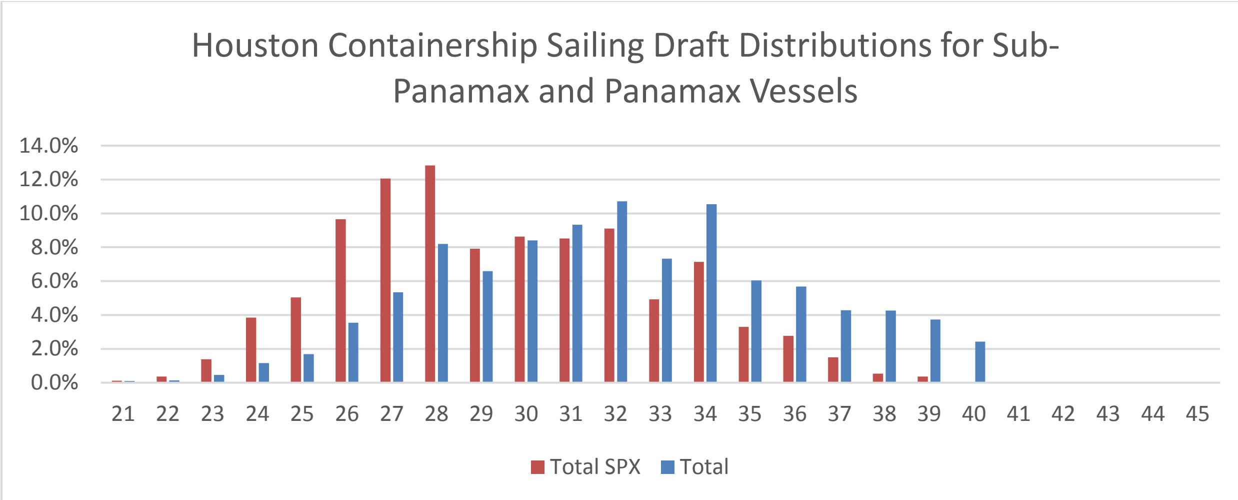
Given the uncertainty surrounding the future conditions of Panamax vessels, the analysis assumes the Panamax traffic currently at Houston will be adapted at Freeport by the year 2040. Years prior to 2040 were interpolated between Freeport existing conditions and Houston existing conditions for Panamax vessels. The figures below show sailing drafts at Freeport and Houston for sub-Panamax and Panamax containerships.

Figure 4-1



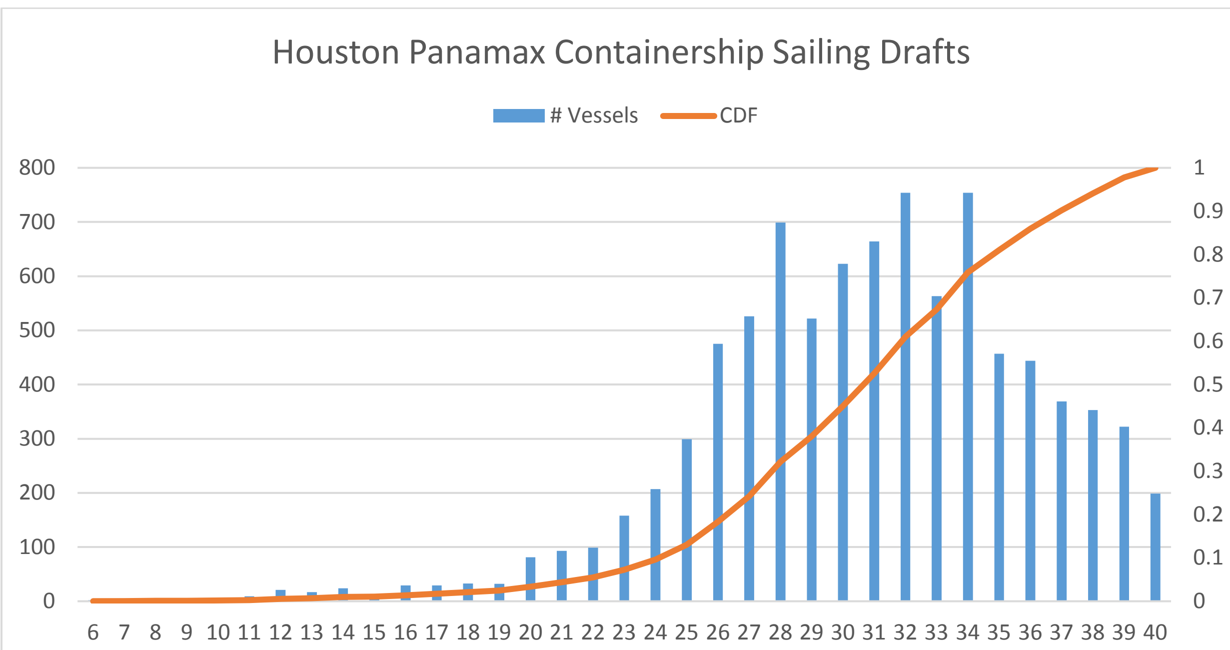
Source: Port Freeport, 2015

Figure 4-2



Source: Port of Houston Authority, 2013

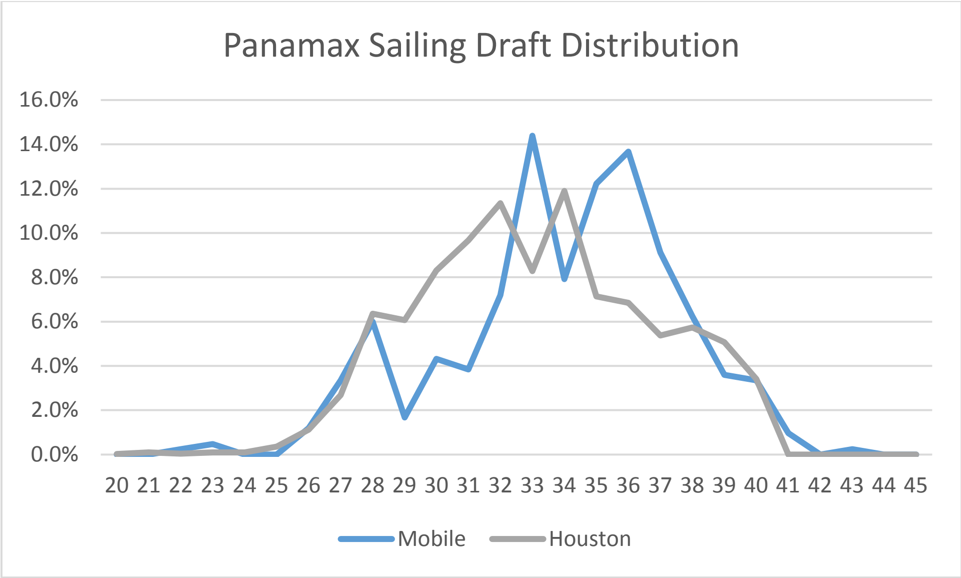
Figure 4-3



Source: Port of Houston Authority, 2013

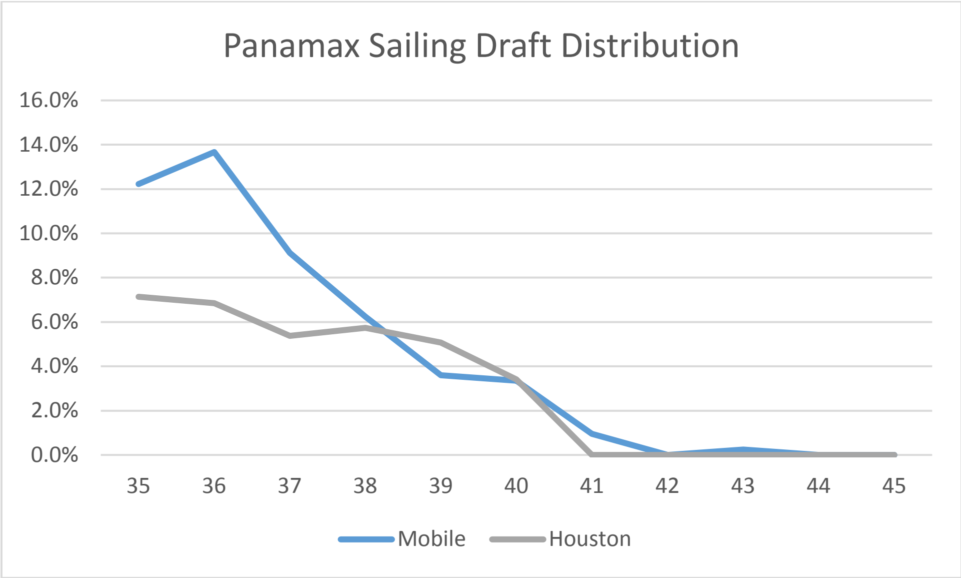
The following graphs compare Houston to Mobile Panamax sailing drafts. Houston had a 40 foot channel depth with 7 feet advanced maintenance and 2 feet allowable overdepth in 2013. Mobile had a 45 foot channel depth during 2012-2014. This was the most recent data that could be acquired for these channels on this project.

Figure 4-4



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

Figure 4-5



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

The following tables show the model assumptions for the FWOP and FWP for the GRR.

Table 4-2 Loading Characteristics for Containerships

Vessel Class	Mean DWT**	Mean TEU Capacity**	Max Sailing Draft		Parcel Size (TEUs)		Load Factor	
			FWOP	FWP	FWOP	FWP	FWOP	FWP
Sub-Panamax 1	19,712	1,780	37.7	37.7	356	356	20%	20%
Sub-Panamax 2	34,375	3,410	41.0	41.0	444	444	13%	13%
Panamax*	51,421	5,190	---	43.0	---	882	---	17%

*Based on Houston Historical data

**Based on Historical data

Table 4-3 Loading Patterns for Containerships (TEUs)

	Existing	FWOP			FWP		
Vessel Class	**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 4-4 Number of Calls

	Existing	FWOP			FWP		
Route and Vessel Class	**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
Container Route-RoRo 1	28	38	52	74	38	52	74
Container 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

Route Groups

As stated above, the route groups for Panamax vessels in the future area largely uncertain. For the analysis, the route for Panamax vessesls were assumed to be the same as current traffic with sub-Panamax vessels. All other traffic route miles were based on the data acquired for 2015 from Port Freeport, and each country's mileage was researched to calculate a weighted miles by each commodity.

Table 4-5 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 Products 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

*GRR Component

Vessel Operating Costs

The hourly operating costs for tankers include fuel, labor, and maintenance. The costs used were obtained from deep-draft vessel operating cost EGM 2015. The tanker costs were used for the crude petroleum, petroleum product, chemical product, LPG and LNG transportation cost calculations. Containership costs were used for container movements. RoRo costs were used for car movements.

The vessel classes grouped in the HarborSym model did not exactly match the groupings in the EGM. The closest grouping was chosen to represent the most likely operating cost for that particular vessel size. To determine the minimum and maximum operating costs, the smaller vessel class and larger vessel class in each grouping was used.

5.0 BENEFITS

The benefits were calculated for a 2022–2071 period of analysis using Fiscal Year (FY) 2017 Federal Discount rate of 2.875 percent. The benefits were calculated using the HarborSym model Version 1.5.5.2. The analyses and computations presented in this report are based on data and statistics obtained from personal interviews with industry officials and from analyses of historical data and published trends.

The methodology used for calculating benefits includes the following (note: if the subscript “j” is absent in the equation, it is constant across time):

$TC_{ij} = S_i + D_{ij} + H_{ij} + B_{ij}$

¥ i = 1 to n; j = 1 to m
Where:
TC = Transportation Cost
S = At-Sea Cost
D = Delay Cost
H = In-Harbor Cost
B = Docking/Berthing Cost (including Load/Unload)
i = individual vessel
j = year in period of analysis

$S_i = f(V_i, M_i, C_i)$

¥ i = 1 to n
Where:
S = At-Sea Cost
V = Velocity (speed of vessel)
M = Miles
C = Vessel Operating Cost

i = individual vessel

$D_{ij} = f(T_{ij}, C_i)$
¥ i = 1 to n; j = 1 to m
Where:
D = Delay Cost
T = Time
C = Vessel Operating Cost
i = individual vessel
j = year in period of analysis

$H_{ij} = f(V_i, M_i, D_{ij}, TB_{ij}, C_i)$
¥ i = 1 to n; j = 1 to m
Where:
H = In-Harbor Cost
V = Velocity (speed of vessel)
M = Miles
D = Delay Cost
TB = Time in Turning Basin/Anchorage
C = Vessel Operating Cost
i = individual vessel
j = year in period of analysis

$B_{ij} = f(LU_{ij}, A_{ij}, D_{ij}, C_i)$
¥ i = 1 to n; j = 1 to m
Where:
B = Docking/Berthing Costs
LU = Load/Unload Rate
A = Amount of Commodity
D = Delay Cost
C = Vessel Operating Cost
i = individual vessel
j = year in period of analysis

The without-project and with-project costs are the sum of the transportation costs for each vessel, expressed as:

$WOPC_j$ ₳ $WPC_j = \sum TC_{ij}$
¥ i = 1 to n; j = 1 to m
Where:
WOPC = Without-Project Condition
WPC = With-Project Condition
TC = Transportation Cost
i = individual vessel
j = year in period of analysis

The benefits are the difference between the without-project and with-project transportation costs.

$BF_j = WOPC_j – WPC_j$

¥ j = 1 to m

Where:

BF = Benefits

WOP = Without-Project Condition

WP = With-Project Condition

j = year in period of analysis

The present value of the benefits are found by applying the present worth factor.

$PV_j = BF_j * PWF_j$

¥ j = 1 to m

Where:

PV = Present Value of Benefits

BF = Benefits

PWF = Present Worth Factor = $(1/((1+r)^m)$

j = year in period of analysis

r = Federal Discount Rate

The average annual benefits are calculated by applying the capital recovery factor.

$AAB = \sum (PV_{jk} * CRF)/k$

¥ j = 1 to m

Where:

AAB = Average Annual Benefits

PV = Present Value of Benefits

CRF = Capital Recovery Factor = $(r*(1+r)^m)/(((1+r)^m)-1)$

j = year in period of analysis

k = number of iterations

r = Federal Discount Rate

Using the methodology above, average annual benefits were calculated at the associated Federal Discount Rate.

6.0 Construction and O&M Costs

The main report and engineering appendix should be referenced for specific details and assumptions regarding construction and O&M costs. From the Project First Cost provided by engineering, and construction schedule provided by engineering, the interest during construction (IDC) was calculated. IDC was calculated based on the contract duration, assuming that all costs are distributed evenly monthly during the contract period. Once the contract period is complete, the full contract cost accrued interest until the first year of the project (January 2022). The sum of the IDC and Project First Cost was applied to the Federal Discount Rate to determine average annual costs.

Table 6-1 Construction Costs
($1,000s, October 2016 dollars, 2.875% interest rate)

Contract #	Reach	Duration (Months)	Mid-Point (Year)	Months to Year 1 of Project	Project First Cost	Total IDC	Total Cost with IDC	Average Annual Cost
1	1	16	2019	30	$51,635	$2,697	$54,332	**$2,026**
2	1	25	2021	9	75,861	2,222	78,083	**2,963**
3	1	13	2019	26	23,453	1,081	24,534	**915**
4	1	6	2019	36	963	77	1,040	**39**
5	1	8.5	2021	7	56,041	506	56,547	**2,146**
6	2	2	2020	13	45,156	1,259	46,415	**1,746**
7a	3	6	2020	16	23,147	700	23,846	**897**
7b	4	6	2020	16	6,671	202	6,873	**259**
8	1	3	2019	31	1,297	93	1,390	**52**
9	GRR	6	2017	53	5,326	666	5,992	**220**
10	GRR	12	2019	33	15,342	994	16,336	**609**
11	GRR	12	2019	33	36,338	2,355	38,693	**1,443**
12	Expended as of 5/1/15				942		942	**27**
Total					**342,172**	**12,852**	**355,024**	**13,341**

Notes: Economic Update includes all costs above. GRR costs include Contracts 9, 10, 11. Contract 7 includes costs to deepen to authorized depth of 51 feet.

O&M dredging costs were analyzed on a per year basis to determine average annual costs. For Reach 1, the dredging cycle is on an annual basis and estimated cost each cycle is $8,011,138. Reach 2, and the GRR features (bend easing, notch, widening) have a projected dredging cycle every 3 years. Reach 3, Reach 4, and the WIK portion of Reach 3 have a dredging cycle every 12 years throughout the period of analaysis.

Table 6-2 O&M Dredging Costs
(October 2016 dollars, 2.875% interest rate)

	Reach 1*	Reach 2**	Reach 3***	Reach 4***	GRR**	WIK***
FWOP						
2024	$8,011,138	$5,221,113				
2027	$8,011,138	$5,221,113				
2030	$8,011,138	$5,221,113				
…	$8,011,138	$5,221,113				
2069	$8,011,138	$5,221,113				
FWP						
2024	$18,075,905	$6,428,425			$6,225,950	
2027	$18,075,905	$6,428,425			$6,225,950	
2030	$18,075,905	$6,428,425			$6,225,950	
2033	$18,075,905	$6,428,425	$1,088,314	$536,680	$6,225,950	$257,625
…	$18,075,905	$6,428,425			$6,225,950	
2069	$18,075,905	$6,428,425			$6,225,950	
Project Costs						
	$10,064,767	**$1,207,312**	**$1,088,314**	**$536,680**	**$6,225,950**	**$257,625**
Average Annual Costs						
	$10,208,423	**$389,266**	**$76,872**	**$37,908**	**$2,007,393**	**$18,197**

Notes: Economic Update includes all costs above. GRR costs include Reach 3, GRR, and WIK.
*Annual dredging cycle 2022-2071
**Dredging cycle every 3 years beginning in 2024
***Dredging cycle every 12 years beginning in 2033

7.0 Economic Summary

Previous Analysis

Table 7-1 presents a summary of the WRRDA 2014 authorized project analysis. 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 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

Current Update

The table below shows the summary for this economic analysis in October 2016 dollars. The total average annual benefits of $40,019,000 for the project exceeds the total average annual costs of $26,155,000, yielding net benefits of $13,863,000 and a continued justified project. For the GRR portion, net benefits yield $2,078,000 and return a benefit cost ratio of 1.47 at current interest rates.

Table 7-2 Summary of Benefits and Costs at 46 Feet Channel Depth
(October 2016 dollars, 2.875% interest rate)

	Economic Update	**GRR**
Project First Cost	$342,172,000	$57,006,000
Interest During Construction	12,852,000	4,016,000
Total Construction Cost with IDC	355,024,000	61,022,000
Total O&M Cost (50 years)	529,055,000	100,646,000
Average Annual Cost	26,155,000	4,374,000
Average Annual Benefit	40,019,000	6,451,000
BCR	1.53	1.47
Net Excess Benefits	13,863,000	2,078,000

Incremental Analysis

Incremental analysis was conducted to determine the optimal depth for the GRR features. Costs were calculated at 46 feet and 40 feet, 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 and 40 feet were interpolated. 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 was economically optimal at 46 feet based on transportation cost savings. Hence, the PDT proposes 46 feet as the NED depth.

Table 7-3 Incremental Analysis Summary

							NED
Channel Depth	**40**	**41**	**42**	**43**	**44**	**45**	**46**
Average Annual Benefits	$3,123,000	$3,789,000	$4,455,000	$5,111,000	$5,598,000	$6,010,000	$6,452,000
Average Annual Costs	4,270,000	4,287,000	4,305,000	4,322,000	4,340,000	4,357,000	4,374,000
Net Excess Benefits	(1,147,000)	(499,000)	150,000	788,000	1,259,000	1,653,000	2,078,000
BCR	0.73	0.88	1.03	1.18	1.29	1.38	1.47

Sensitivity Analysis, Risk and Uncertainty

There are several key uncertainties that could potentially affect the BCR. First, average parcel size of Panamax containerships could affect the results. Historical data shows the sub-Panamax vessels do not load similarly between Freeport and Houston, probably as a result of transporting different commodities. Freeport has an average parcel size for sub-Panamax vessels of 3,990 tons. Houston's average parcel size on sub-Panamax vessels are 1,073 tons. It is unknown what the parcel size for Panamax vessels at Freeport will be, but in the Houston AOM, the projected parcel size was 2,146 tons. The average parcel size is a key variable that indicates whether it is more economical to use sub-Panamax vessels or Panamax vessels for a given route, when studying a Port in isolation. It is possible that another Port on the route offers a distinct advantage to using Panamax vessels, even if the calculations at another Port show sub-Panamax to be more favorable. Therefore, the cost comparisons may not explain actual practice entirely if the vessels are not analyzed as a system, but that is beyond the scope of this analysis and the HarborSym model is not equipped to conduct this type of analysis.

Second, commodity growth rates are uncertain. The projected growth rates published by the Department of Energy varies each year. Also, the projections for containerships are varied. The analysis used growth rates that were used in the Houston AOM study. However, a new terminal such as Velasco may experience higher growth rates than a "regional average". On the contrary, with a lower growth rate, Berth 8 may not be needed in the next 25 years.

A third key uncertainty pertains to routes. The future routes for Panamax vessels are completely unknown to date. Panamax vessels have not called at Freeport yet, and any potential contract discussions are not public information yet. It is also uncertain what share the tonnage distribution will be from each region for Panamax vessels. Also potentially affecting shipping drafts, it is unknown what the partnering Ports depths will be. If the previous or next Port calling on the route has a shallower channel, the vessel may not load as fully as anticipated. Also, the miles on a route may be vastly different than anticipated in the analysis. A change in the mileage has a proportional effect on the benefits.

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

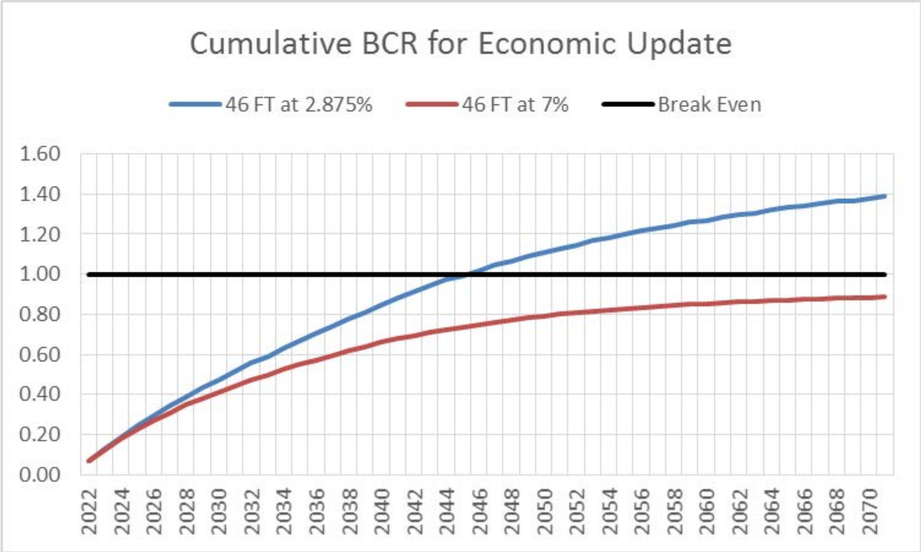
Summary

The economic analysis shows a benefit cost ratio of 1.47 at a channel depth of 46 feet for the GRR, and 1.53 for the economic update.

Table 7-4 Summary of Benefits and Costs at 46 Feet

	Economic Update	GRR
Project First Cost	$342,172,000	$57,006,000
Total O&M Cost (50 years)	529,055,000	100,646,000
Average Annual Cost	26,155,000	4,374,000
Average Annual Benefit	40,019,000	6,452,000
BCR	1.53	1.47
Net Excess Benefits	13,863,000	2,077,000

Figure 7-1



The channel depth proposed to be the NED is 46 feet for the GRR. At this depth, the benefit cost ratio is 1.47 with net excess benefits of $2,078,000. As shown in the figures below, the break-even point on the GRR investment, using only transportation cost savings as the source of benefits, is the year 2049 for the 46 foot channel depth given current interest rates. Generally, a longer duration to the break-even year has a greater level of risk associated with the investment because of the uncertainty surrounding the assumptions. Simply stated, statistically it is easier to predict what will happen next year versus 30 years from now.

Figure 7-2