FINAL

AECOM

Port of Corpus Christi Authority

Waterway Planning Study of the Corpus Christi Ship Channel System

FINAL REPORT

June 19, 2017

Quality information

Prepared by	Checked by	Approved by
Kylie Ford / Mark Sisson Economist / Associate VP Planning	Joseph Berlin / Rodrigo DeCastilho Senior Economist / Design and Simulation Engineer	Vijay Agrawal Project Manager

Revision History

Revision	Revision date	Details	Authorized	Name	Position
Rev 1	5/3/2017	Addresses comments on the DRAFT report	5/3/2017	Vijay Agrawal	Project Manager
Rev 2	6/5/2017	Addresses comments from Cheniere and Refiners group	6/5/2017	Vijay Agrawal	Project Manager
Rev 3	6/12/2017	Addresses comments from group June 12 group call	6/12/2017	Vijay Agrawal	Project Manager
Rev 4	6/19/20	Final	6/19/17	Vijay Agrawal	Project Manager

Distribution List

# Hard Copies	PDF Required	Association / Company Name

Prepared for:

Port of Corpus Christi Authority

Prepared by: AECOM

Executive Summary

AECOM was retained by the Port of Corpus Christi (POCC) to analyze the potential benefits of a Harbor wide dredging project. This project is expected to occur in two phases:

- **Phase 1: Dredge Cut A and Cut B.** Deepen and widen the channel across the Bay to virtually eliminate conflicts between vessels, and between vessels and coastal barges. This phase could be completed prior to 2021.

- **Phase 2: Dredge the Inner Harbor.** This phase would allow berths with adequate facilities to increase the cargo on large ships due to the ability to accommodate deeper drafts; which in turn result in efficiencies of transport, with fewer vessels moving the same amount of cargo. This phase would take longer to accomplish due to infrastructure constraints at each individual facility, but could be in place prior to 2036.

Market Forecsat – AECOM developed a market forecast for cargo at the Port based on a combination of tenant surveys for near term needs, and broad industry growth forecasts in longer term. Crude oil and petroleum products are the dominant commodities moved by POCC and these are in the midst of a radical increase in market demand due to a combination of new exploration technologies (fracking) and new US policy that permits the export of crude oil. LNG is also an important new commodity for the Port. Most of the increase in cargo forecast for the next 20 years is expected to take place within the next five years. As a result, there is a relatively minor difference between 2021 and 2036 forecasts for cargo volumes.

POCC recently commissioned a separate market forecast for petroleum products from Energy Analysts International Inc. (EAI). A comparison between the AECOM and EAI forecasts for the same commodities and years shows relatively few differences between the two forecasts.

AECOM's market forecast was unconstrained; it was not dependent on implementing any harbor upgrades. With the exception of new LNGC vessels , AECOM forecasts a relatively low amount of shift from Panamax vessels and below to larger size ships. This is largely based on the stakeholders' surveys, which did not predict a substantial shift in ship sizes. Enthusiasm for near term shifts to larger vessels seems to be tempered by the following: 1) Several berths are limited in what size ship can be handled; and 2) Some Port tenants also operate facilities at other ports that are subject to size restrictions.

The "With Project" case for 2036 will have fewer large ships, and fewer ships overall, than the "No Project" case, due to increased parcel sizes per ship as a result of deeper channels, including the Inner Harbor. This effect is not significant however as the overall difference in vessel calls is only 1%, between the 2036 With Project and No Project cases. For 2021, there is no difference in number of ships with or without the Phase 1 project. The loading depth at berth is unchanged between these two options because the Inner Harbor is assumed to have the same facilities with or without dredging in Cuts A and B (see Fig 10).

Simulation Model – In order to analyze the impact of these projects on the performance of the Port Corpus Christi, AECOM developed a detailed discrete event simulation model of the Port with our proprietary VNM software. This model allows the user to view every ship and berth and query the status of each as the model is running. The model is geometrically accurate and includes a graphic overlay of a Port map for validation. The model instructions mimic actual pilot operating rules to the greatest extent possible. When a ship is created in the model, it has a specific berth target. It then runs through a series of logical checks to see if it can proceed to a berth. These checks include:

- Is it daylight (for Suezmax and heavy Aframax)?
- Is the berth unoccupied and operating without backland constraints?
- Does the channel have capacity? (if a large vessel is departing the port, it may block some or all entries)
- Is the Port free from fog or high wind?

If all of these conditions are met, the vessel will proceed to berth. It will seize its share of channel capacity all the way to its destination before it begins to move. Once it is at berth, it will remain there for a specified time and then attempt to leave the Port. The model gives priority to outbound vessels, in order to prevent gridlock at berth. The model tracks the visit of each vessel in a detailed output file. AECOM analyzed each case for a total of 100 simulated weeks in order to ensure results were not influenced by random events in each model run.

The primary model outputs of interest were vessel wait time at anchorage, and the population of vessels at anchorage for each berth. In order to assign dollar values to different amounts of vessel wait time, AECOM assumed a range of demurrage values between US$20,000 to $40,000 per vessel day, depending on the size of the vessel.

Model results indicated that the project resulted in a demurrage saving of $26 Million in 2021, increasing to $52 Million in 2036. These are indicative costs based on simulation output and do not necessarily match specific customer agreements for demurrage.

Conclusion and Recommendation – The primary conclusion of this study is that the dredging of Cuts A and B will bring tremendous value to the Port in terms of reduction in demurrage, as well as expected increases in safety due to relocation of barges out of the main channel and into dedicated barge shelves. The project achieves three benefits that work in combination to radically reduce vessel queueing as listed below:

1. Elimination of beam restrictions for meeting vessels
2. Near elimination of draft restrictions in meeting
3. Increase in sailing speed
    a. Better hydrodynamics of a higher volume channel
    b. Elimination of conflict between vessels and coastal barges

A fourth potential long term advantage of the project may be the elimination of the prohibition on nighttime travel for Suezmax and heavily laden Aframax ships, or in relaxation in rules for meeting LNGC vessels. There is no guarantee that this will occur even with the project, but there is no possibility of it occurring without the project.

The value of dredging the Inner Harbor is minimal from a vessel wait reduction standpoint. The appeal of this project will be driven by system efficiencies for Port customers as opposed to reduction in vessel waiting time. It is worth noting that not all queueing will be eliminated even with the full Project. The primary remaining source of queuing will be high berth utilization for some facilities. AECOM recommends more detailed study of the busiest individual terminals at POCC to determine what measures may be employed to increase product transfer rate, and backland storage capacity, and as a result overall throughput capacity at these facilities. Other recommendations for future study are listed in Chapter 9.

Table of Contents

Figures

Tables

1. Introduction

The purpose of the Waterway Planning Study of the Corpus Christi Ship Channel (CCSC) System is to determine the impacts of future commodities and fleet distribution on existing and contemplated vessel traffic and customers with and without the CCSC Channel Improvement Project (CCSC-CIP) in the 5-, 10- and 20-year planning scope.

The Port of Corpus Christi is evaluating channel improvement measures to determine the most efficient methods and prioritize their implementation. In order to accomplish these goals, current and future vessel traffic scenarios have been modeled to estimate the potential congestion reduction within the Port, based upon vessel fleet forecasts, both with and without channel improvements. The commodity flow through the Port is not dependent upon channel improvements. However, the vessel fleet forecast changes with channel improvements due to the ability of larger vessels to increase their load and draft (load deeper) and more efficiently in the “with project” condition. The following describes the process taken to develop the commodity and vessel fleet forecasts, simulation modeling inputs, processes and the analysis output.

1.1 Interactive Communication

In addition to all of the data resources, calculations, and other inputs described in the subsequent chapters, the Project Team has participated in eight WebEx conference calls and Power Point presentations with the Port Authority staff, Waterway Planning Committee (WPC) members, and other stakeholders. The WebEx presentations proved to be a valuable resource for both the market forecast and simulation modeling efforts, allowing for input adjustments throughout the planning process and ongoing review by POCC and WPC to ensure accurate and up-to-date information is used in this study.

2. Stakeholder Surveys

The Port of Corpus Christi has undergone significant changes during the past several years and is poised for significant growth in the near future from major industrial developments in the area. For this reason, a confidential survey of key stakeholders was prepared to help determine their future use of Corpus Christi Harbor. The results of this survey were used to forecast future vessel traffic in the harbor and to model the impacts of increased traffic.

2.1 Survey Summary

AECOM contacted, surveyed, and received data from stakeholders as identified by the Port of Corpus Christi and WPC, including terminal operators, refineries, midstream companies, and beneficial cargo owners already in operation and those expected to be in operation by 2020. Interview data were used to estimate the inbound and outbound cargo volumes, vessel counts and fleet size distribution that are expected in the 5-, 10- and 20-year planning scope.

The project team coordinated with the Port Authority and the WPC to develop and confirm a detailed list of local industry stakeholders operating within the CCSC and LQC. To help expedite and standardize the information gathering task, a standardized questionnaire form was developed and used to collect the data. The use of this form provided a systematic method to collect the data and to ensure consistency.

The questionnaire focused on recent trends, current movements, and expected future throughput, in terms of both commodity tonnages and vessel fleets. Due to privacy concerns and the confidential nature of the information provided by the stakeholders, this report does not provide the specific responses of each stakeholder, but rather provides an overview of the majority of the responses received from the stakeholders.

At large, many stakeholders indicated that they are currently using the full channel depth. Others indicated that their vessel fleet would be unaffected by the changes; for example, if the stakeholder utilized only barges or small Handymax-sized vessels their design draft is not restricted by current conditions. Regarding changes upon the “with project” conditions taking place, some of the tenants indicated that they might use larger, more efficient vessels upon improvement of the CCSC; however, only a few of the stakeholders were able to quantify this.

There are several new facilities being constructed by a variety of stakeholders; including new facilities for production and shipment of crude oil, petroleum products, breakbulk, and dry bulk products. New facilities may lead to additional uncertainty in the forecast as there is no historic support for future movements; however, when involved in a new market, such as exporting crude oil, stakeholder input is largely the only available basis for the forecast, making it a critical component of this forecast. If a stakeholder indicated that they would be expanding or opening a new facility, the stakeholder was also asked about the amount of future cargo and the type and size of vessel it would be transported on.

2.2 Respondents

The Port of Corpus Christi and the WPC provided a list of current and future Port stakeholders. The Group announced the survey process to Port stakeholders and facilitated the survey process. The project team then attempted to contact stakeholders via email, phone call, and through scheduling a conference call, when possible.

Below is a list of respondents. Please note that some respondents elected not to complete a survey, or directed the project team to another stakeholder's responses, and as such there are more respondents than there are responses to some survey questions.

- Port of Corpus Christi Authority
- Aransas-Corpus Christi Pilots Association
- Bay Houston
- Plains Pipeline
- Statoil
- Suderman & Young Towing
- TPCO America
- U.S. Coast Guard
- ADM Elevator
- American Commercial Barge Lines/ACBL
- Bay Ltd.
- Buckeye Texas Hub & Field Svcs
- Castleton Commodities
- Celanese
- Cheniere LNG
- Citgo Refining
- EMAS
- Flint Hills Resources
- G&H Towing
- Gulf Marine Fabricators
- Koch
- Kiewit
- Lyondell Basell
- M&G Group U.S.
- Martin Midstream
- NuStar Energy
- Occidental Chemical (OxyChem)
- Oxy Energy Center
- Plains All American
- POCC Bulk Docks
- Signet Maritime
- Valero
- Voestalpine
- Windblades: BBC Chartering
- Accutrans Inc. (CGBM)

2.3 Responses

In addition to those respondents listed above, several stakeholders did not respond despite several attempts made to contact them, or responded that they did not wish to participate in the study. Of those that did not respond to the first survey, the majority were barge/tug companies, whose information, although important to understanding the operations of the Port, would likely not have a direct impact on the commodity forecast or vessel fleet forecast as barge movements are accounted for through other inputs in the model. Most of the barge companies participated in a second survey with questions targeted to barge and tug operations. Throughout the stakeholder surveying process, the project team identified several stakeholders as 'high priority'; these were stakeholders associated with a dock ranked by the Pilot's Association as 1 to 15 based on the total number of vessel calls handled at a given dock in year 2015. Of those that did not respond, none was considered 'high priority' by this definition.

The project team is not able to provide the detailed responses of each stakeholder due to non-disclosure agreements and confidentiality concerns. However, as requested by POCC and WPC, the responses are summarized and displayed in Table 1 without identifying the respondents.

Figure 1. Stakeholder Response Status

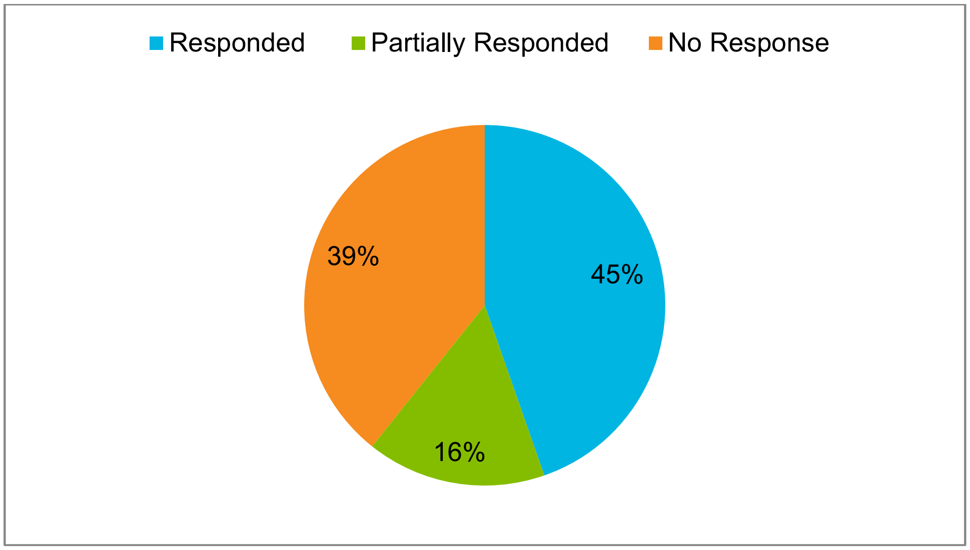


Table 1. Stakeholder Survey Responses

Stakeholder	Using full channel depth?	Port restrictions outside of POCC?	WITH Project, improve docks?	WITH Project, larger vessels?	Vessel / barge constraint?	Landside constraint?	Project Priorities?
A	N/A	N/A	N/A	N/A	N/A	N/A	Widening, Barge Shelf
B	N/A	N/A	Yes	N/A	N/A	N/A	Widening
C	N/A	N/A	No	No	No	No	Widening
D	N/A	N/A	No	No	No	No	N/A
E	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	No	N/A	N/A	N/A	N/A	N/A	Barge Shelf
H	No	No	No	No	N/A	N/A	Barge Shelf
I	No	No	No	No	No	No	Widening
J	No	N/A	N/A	N/A	N/A	N/A	N/A
K	No	Yes	Maybe	No	No	No	N/A
L	No	No	N/A	N/A	No	No	N/A
M	No	N/A	N/A	N/A	N/A	N/A	Barge Shelf
N	No	No	No	No	No	No	N/A
O	Sometimes	Sometimes	No	No	No	N/A	N/A
P	Yes	Yes	Maybe	Maybe	No	No	N/A
Q	Yes	No	Maybe	Maybe	No	No	N/A
R	Yes	No	Yes	Yes	N/A	N/A	Deepening
S	Yes	No	No	No	No	No	N/A
T	Yes	No	Maybe	Yes	No	N/A	Deepening
U	Yes	No	No	No	No	No	N/A
V	Yes	Yes	Maybe	Maybe	N/A	No	Deepening
W	Yes	No	No	No	N/A	N/A	N/A
X	Yes	Sometimes	Maybe	Maybe	No	Yes	Deepening
Y	Yes	Yes	Maybe	Maybe	N/A	No	Deepening

Table 2. Tug, Tow, Barge Stakeholder Survey Responses

Stakeholder	# Tugs per Month?	What % of your tows enter and depart:				What is the typical speed or range:		Do ships slow when overtaking or meeting tows in the channel?	Tows currently able to move out of channel?
		Lydia Ann	Aransas	Aransas-Corpus Christi Bay Cut off	Corpus Christi Baffin Bay	Loaded	Empty		
A	Varies	100%	0%	0%	0%	5	5	Yes	N/A
B	8	70%	30%	0%	0%	4	5	No	No
C	1	N/A	N/A	N/A	N/A	5.5	7	N/A	N/A
D	1	2%	2%	0%	<1%	5.5	5.5	Yes	No
E	2	100%	100%	0%	0%	5	6.5	No	No

The detailed information associated with the aforementioned responses, in conjunction with information on new and expanding facilities, were used to create the commodity forecast, and to place the commodity on vessel types and classes in future years.

Some of the most important information collected involves the responses for "Would you receive calls from larger vessels if the Harbor Channels are improved? Are there any specific vessels or vessel classes that would call at your facility with an improved channel?" For this question, if a stakeholder stated that they would use larger vessels in the "with project" conditions, commodity in the future years is assumed to go on the larger, specified vessels. Note that, of the two respondents that stated "yes", they would use larger vessels, only one was able to specify what size, and how much of their fleet would change.

3. Port Commodity Forecast

3.1 Data Sources

AECOM used the market forecast data currently being developed by the Port Authority to the extent possible. Other data sources included published forecasts, including:

- 2011 to 2016 Port of Corpus Christi Harbormaster Arrival and Departure Data
- 2011 to 2016 Port of Corpus Christi Commodity Throughput Data
- 2011 to 2014 Waterborne Commerce Statistics Center (WCSC) Manuscript Cargo Files
- 2016 Energy Information Administration (EIA) 2015-2040 Forecast
- American Chemistry Council (ACC) Forecast 2013 – 2030
- IHS Maritime Seaweb

3.2 Assumptions

The project team worked with the Port Authority and Waterway Planning Committee (WPC) to develop a current and projected forecast of vessel traffic within the Corpus Christi Ship Channel (CCSC) and La Quinta Channel (LQC) based on the expected future commodity imports and exports, and the future vessel fleet distribution.

AECOM also reviewed pilotage rules during various meetings held with the Pilots Association and POCC. Currently the Port operates with various limitations and restrictions that apply to all Vessels transiting the CCSC. These restrictions and limitations were verified by the Port Authority and WPC and included in the Base Simulation model.

While the Base Model was being developed and calibrated, AECOM prepared the future market projections based on the information gathered in the interviews conducted as well as other data sources, to create 5-, 10-, and 20-year commodity and vessel fleet forecasts.

AECOM used the IHS Sea-web database to evaluate the dimensions and capacity of the current vessel fleet calling upon Corpus Christi. AECOM also evaluated the capacity of the future vessel fleet calling on Corpus Christi in the "with project" condition, to determine the number of vessel calls.

When possible, historic data and stakeholder inputs were used to create the forecast. However, due to the volatility and uncertainty of the commodity markets and vessel use, several assumptions had to be made throughout the forecasting process. The following methodology and statements of assumptions outlines the necessary assumptions made in preparing the forecast.

The base data used in the forecast is the Port of Corpus Christi-provided historic commodity data. This data set expresses historic commodity totals from 2011 to 2016 by a broad commodity type. However, the data set does not express the commodities' direction or origin. This information is important as deep draft vessels, those primarily considered to be affected by the CCSC improvement project, are unlikely to be carrying commodities locally or internally, and therefore this commodity traffic should be separate within the forecast.

To assume direction and origin, the 2014[1] Waterborne Commerce Statistics Center (WCSC) Manuscript Cargo files were used to calculate what percent of total tonnage is local, internal outbound, internal inbound, coastwise outbound, coastwise inbound, exports, and imports. Local is defined as movements within the Port, internal is movements by barge on the Intracoastal Waterway, coastwise movement are to U.S. ports by U.S. flagged vessels, and imports and exports are by world fleet vessels. The following subsections outline the assumptions made for this portion of the forecast.

3.3 Growth of Existing Commodities

The commodity forecast is largely calculated in two broad segments – first, the growth of existing commodities, or the forecast for those commodities that were already calling at the Port in 2015, and new and expanding facilities, which is largely based on stakeholder-provided information. The growth rates described in the subsequent sections have been applied to the Port of Corpus Christi-provided historic commodity data to account for the slow growth of existing facilities. Note that the historic growth rates encompass both the slow growth of existing facilities, as well as the rapid growth of new facilities and expansions that have taken place from 2011 to 2016. Thus, the historic growth rates are often much higher than the growth rates applied to existing tonnage. In sections 3.4 and 3.5, the forecast will discuss the addition of new and expanded facilities, as well as present the results of the combined forecast, and the corresponding growth rates. Upon adjustment for new and expanded facilities, the future growth rates align more closely with the historic growth rates.

3.3.1 Breakbulk

Local

Historically, there is no breakbulk cargo moving locally from 2011 to 2016. Tonnage is assumed to remain at zero.

Internal Outbound

Some tonnage, approximately 2,000 to 12,000 tons, was moved from 2011 to 2013. From 2014 to 2016, no breakbulk cargo was moved internal outbound. Tonnage is assumed to remain at zero.

Internal Inbound

Some tonnage, approximately 1,000 to 7,500 tons, was moved in 2011 and 2013. In 2013 and from 2014-2016, no breakbulk cargo was moved internal inbound. Tonnage is assumed to remain at zero.

Coastwise Outbound

Some tonnage, approximately 24,000 tons, was moved in 2013. From 2011-2012 and from 2014-2016, no breakbulk cargo was moved coastwise outbound. Tonnage is assumed to remain at zero.

[1] At the time of the analysis, the 2015 and 2016 WCSC Manuscript Cargo Files were unavailable. It was assumed that although cargo may have grown or decline, the percentage of cargo traveling in each direction stayed relatively the same and thus 2014 data was utilized.

Coastwise Inbound

Historically, there is no breakbulk cargo moving coastwise inbound from 2011 to 2016. Tonnage is assumed to remain at zero.

Exports

From 2011 to 2016, breakbulk tonnage was variable, with throughput varying from approximately 62,000 tons to a maximum of 130,000 tons. Overall, breakbulk tonnage declined at an annual rate of 7.07% from 2011 to 2016. For the next six years, until 2022, this rate of decline is assumed to continue. After 2022, the tonnage is held constant to account for future uncertainty.

Imports

From 2011 to 2016, breakbulk import tonnage was also variable, with throughput varying from approximately 169,000 tons to a maximum of 277,000 tons. Overall, breakbulk tonnage increased at an annual rate of 1.7% from 2011 to 2016. For the next six years, until 2022, this rate of growth is assumed to continue. After 2022, the tonnage is held constant to account for future uncertainty.

3.3.2 Bulk Grain

Local

Historically, there is no bulk grain cargo moving locally from 2011 to 2016. Tonnage is assumed to remain at zero.

Internal Outbound

Historically, there is no bulk grain cargo moving internal outbound from 2011 to 2016. Tonnage is assumed to remain at zero.

Internal Inbound

In 2012, there was approximately 2,000 tons of internal inbound bulk grain cargo. In 2011 and from 2013 to 2016, no bulk grain cargo was moved internal inbound. Tonnage is assumed to remain at zero.

Coastwise Outbound

Historically, there is no bulk grain cargo moving coastwise outbound from 2011 to 2016. Tonnage is assumed to remain at zero.

Coastwise Inbound

Historically, there is no bulk grain cargo moving coastwise inbound from 2011 to 2016. Tonnage is assumed to remain at zero.

Exports

From 2011 t o2016, bulk grain export tonnage is largely unpredictable with throughput varying from approximately 2,338,000 to a maximum of 3,824,000. Overall, bulk grain tonnage decreased at an annual rate of 2.16% from 2011 to 2016. Due to the extremely volatile nature of the grain industry, 2016 tonnage was held constant.

Imports

Historically, there is no bulk grain cargo being imported from 2011 to 2016. Tonnage is assumed to remain at zero.

3.3.3 Chemicals

Local

From 2011 to 2013, local chemical tonnage was variable; however, tonnage stabilized from 2014 to 2016. Overall, chemical tonnage increased at an annual rate of 10.20% from 2011 to 2016. For the next six years, until 2022, this rate of growth is assumed to continue. After 2022, the tonnage is held constant.

Internal Outbound

From 2011 to 2016, internal outbound chemical tonnage was slowly but steadily increasing. Overall, chemical tonnage increased at an annual rate of 1.44%. For the next six years, until 2022, this rate of growth is assumed to continue. After 2022, the tonnage is held constant.

Internal Inbound
Historically, there is no internal inbound chemical cargo from 2011 to 2016. Tonnage is assumed to remain at zero.

Coastwise Outbound
From 2011 to 2016, coastwise outbound chemical tonnage was slowly but steadily decreasing. Overall, chemical tonnage decreased at an annual rate of 2.8%. For the next six years, until 2022, this rate of decline is assumed to continue. After 2022, the tonnage is held constant.

Coastwise Inbound
In 2011, coastwise inbound chemical tonnage was zero. From 2012 to 2016, coastwise inbound chemical tonnage throughout was approximately 26,000 tons. Due to the apparent steady nature of 2012 to 2016 tonnage, 2016 tonnage was held constant.

Exports
There was some chemical export throughput in 2011 and 2013, approximately 6 to 8,500 tons. However, there was no chemical throughput in 2012 and from 2014 to 2016. Although the American Chemical Council predicts that chemical exports will grow at an annual rate of 2.99% from 2013 to 2030, there is no historic tonnage present to apply this growth to. Tonnage is assumed to remain at zero.

Imports
Chemical import throughput from 2011 to 2016 remained steady between 235,000 and 289,000 tons. However, the American Chemical Council predicts that chemical imports will decline at an annual rate of 4.92% from 2013 to 2030. This rate of decline was applied to chemical imports from 2017 to 2030. After 2030, the tonnage is held constant.

3.3.4 Dry Bulk

Local
From 2011-2013 there was no dry bulk local throughput. From 2014 to 2016, there were small amounts of local throughput ranging from approximately 1,500 to 2,000 tons. 2016 tonnage was held constant.

Internal Outbound
There were approximately 36,000 tons of dry bulk internal outbound throughputs in 2011. From 2012 to 2016, there was no dry bulk cargo moving internal outbound. Tonnage is assumed to remain at zero.

Internal Inbound
From 2011 to 2016, dry bulk internal inbound cargo was somewhat unpredictable, ranging from approximately 169,000 to a maximum of 731,000 tons. Overall, dry bulk throughput increased at an annual rate of 17%. For the next six years, until 2022, this rate of growth is assumed to continue. After 2022, the tonnage is held constant.

Coastwise Outbound
From 2011 to 2016, dry bulk coastwise outbound cargo throughput ranged from approximately 326,000 to 513,000. However, this tonnage was entirely or almost entirely the throughput from Sherwin Alumina. This facility permanently closed at the end of the 2016 and thus throughput has ceased. Tonnage is assumed to remain at zero until 2030.

Coastwise Inbound
Historically, there is no dry bulk cargo moving coastwise inbound from 2011 to 2016. Tonnage is assumed to remain at zero.

Exports
From 2011 to 2016, dry bulk export cargo throughput ranged from approximately 728,000 to a maximum of 1,409,000 tons. However, the vast majority of this tonnage was throughput from Sherwin Alumina. This facility permanently closed at the end of 2016 and thus their throughput has ceased. Tonnage is assumed to be 2015 tonnage (950,000) less the tonnage of Sherwin Alumina (850,000), which is equal to approximately 100,000 tons until 2030. 2016 tonnage was not used as a base as the total tonnage was less than the capacity of Sherwin Alumina. It is possible that Sherwin Alumina began to decrease throughput prior to closure, and thus 2015 throughput is a more accurate estimate.

Imports

From 2011 to 2016, dry bulk import cargo throughput ranged from approximately 4,169,000 to 6,096,000 tons. However, the vast majority of this tonnage was throughput to Sherwin Alumina. The facility permanently closed at the end of 2016 and thus their throughput has ceased. Tonnage is assumed to be 2015 tonnage (5,441,000) less the tonnage of Sherwin Alumina (4,316,000), which is equal to approximately 1,125,000 tons until 2030. 2016 tonnage was not used as a base as the total tonnage was significantly less than prior years. It is possible that Sherwin Alumina began to decrease throughput prior to closure, and thus 2015 throughput is a more accurate estimate.

3.3.5 Crude Oil

Local

From 2011 to 2016, local crude oil movements have, for the most part, steadily increased. Overall, crude oil throughput increased at an annual rate of 21.22%. The crude oil market is volatile and it is unlikely that a 20%+ growth rate is sustainable. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil production will grow at a rate of 0.70%. This rate is applied to the 2016 tonnage until 2036.

Internal Outbound

From 2011 to 2016, internal outbound crude oil movements have increased substantially. Overall, internal outbound crude oil throughput increased at an annual rate of 57.79%. The crude oil market is volatile and it is unlikely that this growth rate is sustainable. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil production will grow at a rate of 0.70%. Additionally, there are several new pipelines opening that will transport crude oil to places like Beaumont and Houston, Texas, reinforcing that the historic growth rates will likely be disturbed. The forecast predicts that upon the opening of the pipelines, internal outbound crude oil tonnage will begin to decline, and by 2019, will return to 2011 levels. The tonnage will be held constant after 2019.

Internal Inbound

From 2011 to 2016, internal inbound movements have increased substantially. Overall, crude oil throughput increased at an annual rate of 34. %. The crude oil market is volatile and it is unlikely that this growth rate is sustainable. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil production will grow at a rate of 0.70%. This rate is applied to the 2016 tonnage until 2036.

Coastwise Outbound

In 2011, coastwise outbound shipments of crude oil were minimal at approximately 91,000 tons. Since that time, throughput has grown exponentially. However, the crude oil market is rapidly changing. With restrictions on crude oil exports lifted, coastwise outbound shipments are expected to continue, but not increase. Instead, future growth is anticipated to be seen in crude oil exports. Thus, the 2016 tonnage was held constant through to 2036.

Coastwise Inbound

From 2011 to 2014, crude oil coastwise inbound movements were highly volatile ranging from 0 to 423,000 tons. In 2015 and 2016, tonnage appeared to stabilize. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil production will grow at a rate of 0.70%. This rate is applied to the 2016 tonnage until 2036.

Exports

Exports of crude oil were previously prohibited. In recent years, the 40 year ban on crude oil exports has been gradually lifted, and as such, exports at the Port of Corpus Christi have gone from 0 tons in 2011 to approximately 1,594,000 tons in 2015. In 2016, exports declined slightly by 1,148,000 tons due to market conditions but are expected to recover. The EIA does not forecast crude oil exports as the market is too new to predict at this time. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil production will grow at a rate of 0.70%. This rate is applied to the 2016 tonnage until 2036.

Imports

From 2011 to 2016, crude oil imports have declined at the Port of Corpus Christi. This is largely due to the ability of local facilities to now use domestic crude oil from the Eagle Ford fields. However, U.S. crude oil is often light crude oil as opposed to heavy crude oil. Facilities are designed to operate on a blend of both light and heavy crude oil. Thus, despite overall crude oil imports declining at an annual rate of 11.8% from 2011 to 2016, at some point, a tipping point will occur where decline can no longer take place or will be a far less severe decline. It is unlikely that the local refineries could ever be sustained on only light crude oil; thus, there will likely always be some crude oil imports. The

2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that crude oil imports will decline at a rate of 0.10%. This rate is applied to the 2016 tonnage until 2036.

3.3.6 Petroleum Products

Local

From 2011 to 2016, petroleum product local movements have remained steady near 3,000,000 tons. Overall, petroleum products declined at an annual growth rate of 0.28% from 2011 to 2016; however, there were fluctuations both up and down. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products consumption will grow at a rate of 0.10%. This rate is applied to the 2016 tonnage until 2036. At this minimal rate of growth, the 20-year forecast is nearly equal to the 2011 throughput.

Internal Outbound

From 2011 to 2016, petroleum product internal outbound movements have remained steady near 5,500,000 tons. Overall, petroleum products increased at an annual growth rate of 1.16% from 2011 to 2016; however, there were fluctuations both up and down. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products consumption will grow at a rate of 0.10%. This rate is applied to the 2016 tonnage until 2036. At this minimal rate of growth, the 20-year forecast is nearly equal to the 2012 throughput.

Internal Inbound

From 2011 to 2016, petroleum product internal inbound movements have remained steady near 4,000,000 tons. Overall, petroleum products increased at an annual growth rate of 2.10% from 2011 to 2016; however, there were fluctuations both up and down. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products consumption will grow at a rate of 0.10%. This rate is applied to the 2016 tonnage until 2036. At this minimal rate of growth, the 20-year forecast is nearly equal to the 2015 throughput.

Coastwise Outbound

From 2011 to 2016, petroleum product coastwise outbound movements have remained steady near 2,500,000 tons. Overall, petroleum products increased at an annual growth rate of 2.13% from 2011 to 2016; however, there were fluctuations both up and down. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products consumption will grow at an annual rate of 0.10%. This rate is applied to the 2016 tonnage until 2036. At this minimal rate of growth, the 20-year forecast is nearly equal to the 2013 throughput.

Coastwise Inbound

From 2011 to 2016, petroleum products coastwise inbound movements were somewhat volatile. Overall, petroleum products increased by an annual rate of 11.5%, nearly doubling tonnage over the 6-year period. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products consumption will grow at an annual rate of 0.10%. This rate is applied to the 2016 tonnage until 2036.

Exports

From 2011 to 2016, petroleum product exports were somewhat volatile. Overall, petroleum product exports increased by an annual rate of 1.16%. The 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products exports will grow more aggressively, at an annual rate of 2.10%. This rate is applied to the 2016 tonnage until 2036.

Imports

From 2011 to 2016, petroleum product imports were somewhat volatile. Overall, petroleum product imports declined by an annual rate of 3.8%. However, the 2016 EIA American Energy Outlook (AEO) 2015-2040 forecast predicts that petroleum products imports will grow at an annual rate of 0.40%. This rate is applied to the 2016 tonnage until 2036.

3.4 New and Expanded Facilities

There is also commodity growth due to the openings of new facilities and the expansion of existing tenants. This information was collected during the stakeholder surveys or taken from news articles describing the developments. Several stakeholders have expressed their concerns for confidentiality issues, and thus, these assumptions cannot be provided independently. Overall, the forecast assumes 13 new facilities and expansion developments that will increase total tonnage by 71.3 million tons by 2021, 78.2 million tons by 2026, and 90.5 million tons by 2036. These developments will include new breakbulk, chemical, dry bulk, crude oil, and petroleum product tonnage.

3.5 Port-wide Commodity Forecast Results

The growth of existing facilities and the addition of new and expanded facilities are combined to complete the Port-wide commodity forecast. The 2021, 2026, and 2036 Port-wide commodity forecasts drives the number of vessels expected to call at the Port of Corpus Christi in these future years. As shown below in Table 3, the 2017 to 2021 annual growth rate is expected to be 4.46%, which is significantly more aggressive than the 1.89% growth rate experienced from 2011 to 2016.

The forecast uses stakeholder information for new and expanding facilities from 2017 to 2019, which can be seen through the steep slope shown at the beginning of the forecast in Table 3 and Figure 2. After 2019, most stakeholders are not able or willing to provide insight on long-term expansions or new facilities; thus, at that point, the forecast relies only on moderate growth based on reliable forecasts, such as the EIA or ACC. This portion of the forecast is portrayed by a nearly flat line after 2020. This is not to say that continued growth through new and expanded facilities will not happen beyond 2019, but instead that there is not sufficient evidence at this time to forecast that it will. Forecasting exponential growth of volatile markets, such as crude oil and petroleum products, without stakeholder input or more advanced forecasts would be inappropriate.

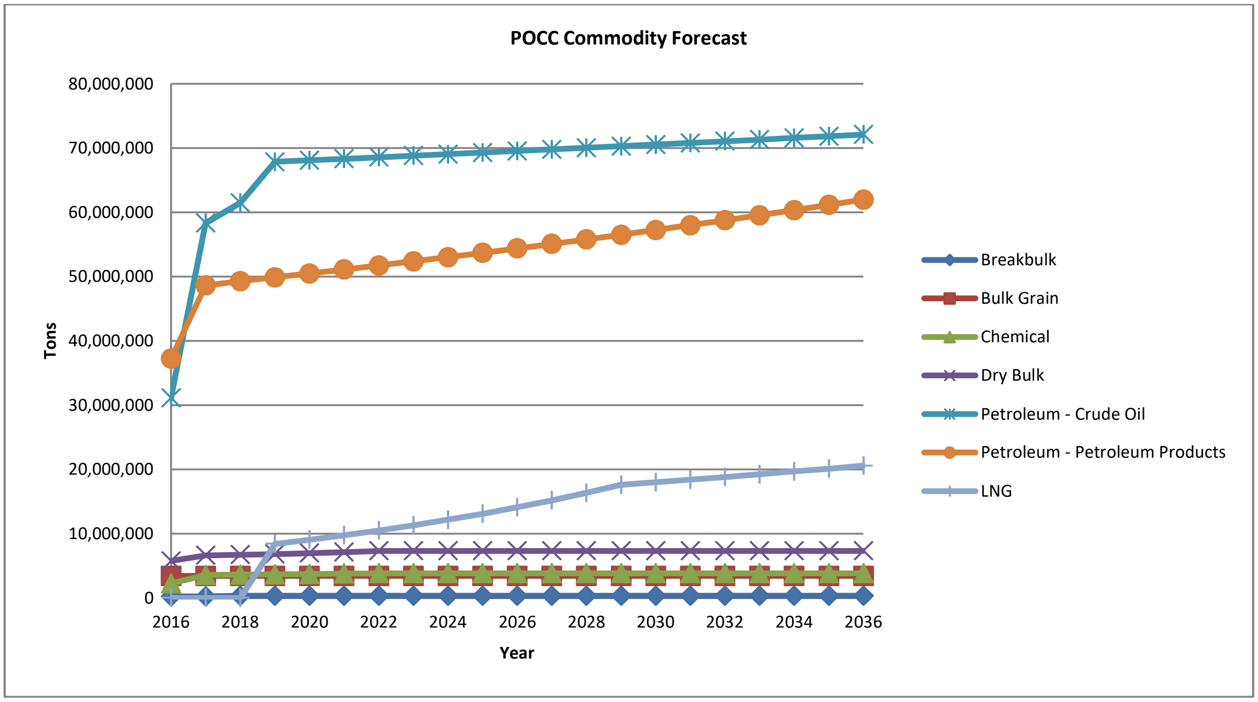
As with all forecasts, there is no guarantee that markets will react as expected, and even the conservative forecast provided based upon stakeholder input, historic movements, and internationally recognized forecasts may prove to be incorrect. Further market dynamics such as, a) domestic shale light crude supply replacing light crude imports, b) crude oil commodity price volatility risk, c) impacts due to possible changes in OPEC policies and increased oil supplies into the global market; can change the market forecast, which have not been accounted in this report.

Table 3. Port-wide Commodity Tonnage Forecast

Year	Project Year	Breakbulk	Bulk Grain	Chemical	Dry Bulk	Crude Oil	Petroleum Products	LNG	Total
		Metric Tons (x 1,000)							
2011	**-5**	278	3,824	2,066	7,886	22,044	36,759	0	72,856
2012	**-4**	355	2,339	2,286	7,203	21,296	38,013	0	71,492
2013	**-3**	298	2,707	2,202	8,066	30,837	36,530	0	80,641
2014	**-2**	246	3,693	2,449	8,313	40,075	36,464	0	91,238
2015	**-1**	370	3,082	2,302	7,517	43,203	37,399	0	93,874
2016	**0**	247	3,428	2,247	5,759	31,104	37,215	0	79,999
2021	**5**	324	3,428	3,781	7,137	68,329	51,108	9,758	143,864
2026	**10**	324	3,428	3,853	7,325	69,541	54,384	14,108	152,962
2036	**20**	324	3,428	3,853	7,325	72,100	61,985	20,575	169,590
11-16 Annual Growth Rate		-2.39%	-2.16%	1.70%	-6.09%	7.13%	0.25%	N/A	*1.89%*
17-21 Annual Growth Rate		7.19%	0.00%	1.38%	1.89%	4.04%	1.26%	N/A	4.46%
17-26 Annual Growth Rate		3.15%	0.00%	0.82%	1.13%	1.97%	1.25%	N/A	2.66%
17-36 Annual Growth Rate		1.48%	0.00%	0.39%	0.53%	1.12%	1.29%	N/A	1.80%

Source: Port-wide Commodity Forecast

Figure 2. Port-wide Commodity Forecast



3.5.1 Port-wide Commodity Forecast Results – Coastwise, Imports, and Exports only

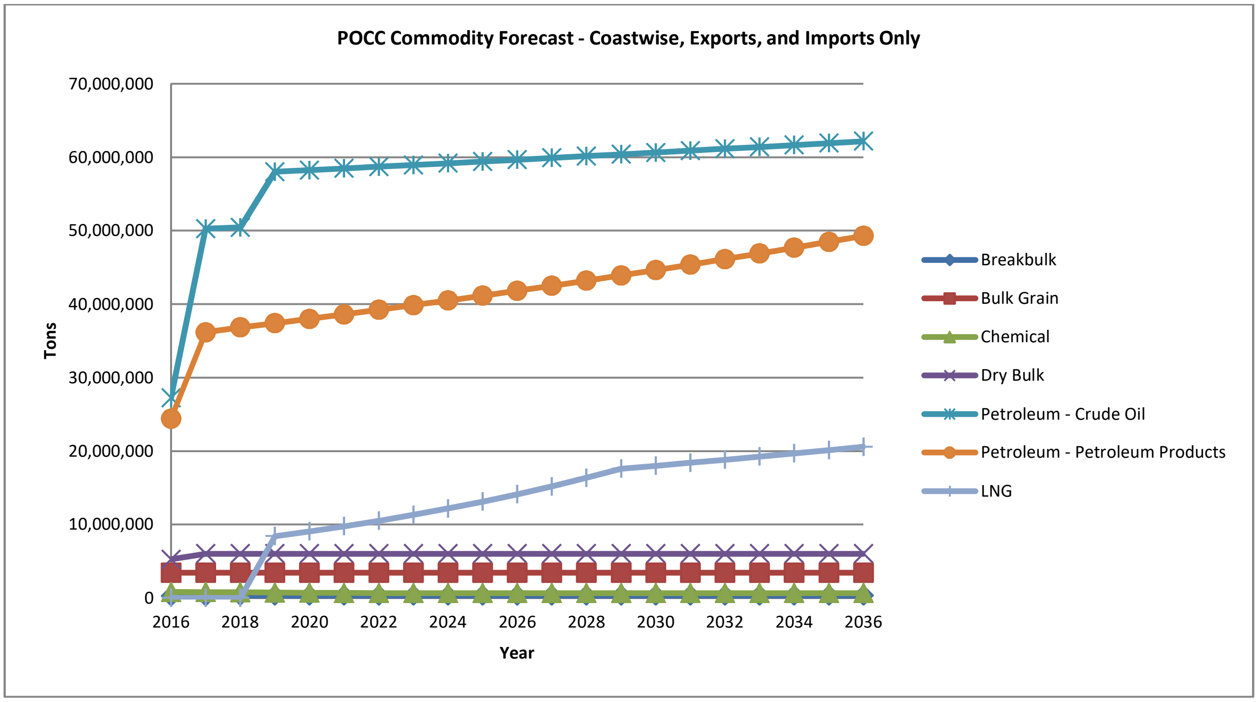
Specifically, the commodity forecast for coastwise, import, and export movements are imperative for this study as these types of cargos travel on deep draft vessels and ocean going barges. Table 4 displays the Port-wide commodity forecast for only the cargo likely traveling on these vessels.

Table 4. Port-wide Commodity Forecast – Coastwise, Imports, and Exports only

Year	Project Year	Breakbulk	Bulk Grain	Chemical	Dry Bulk	Crude Oil	Petroleum Products	LNG	Total
		Metric Tons (x1,000)							
2011	**-5**	259	3,824	871	7,618	21,428	24,607	0	58,607
2012	**-4**	353	2,338	910	7,034	19,094	25,381	0	55,109
2013	**-3**	289	2,707	863	7,831	26,585	24,344	0	62,619
2014	**-2**	246	3,693	891	7,580	35,092	23,891	0	71,391
2015	**-1**	370	3,082	837	6,854	37,831	24,504	0	73,479
2016	**0**	247	3,428	817	5,252	27,236	24,383	0	61,363
2021	**5**	324	3,428	689	6,028	58,473	38,056	9,758	116,755
2026	**10**	324	3,428	666	6,028	59,661	41,209	14,108	125,422
2036	**20**	324	3,428	666	6,028	62,168	48,541	20,575	141,731
11-16 Annual Growth Rate		*-0.99%*	*-2.16%*	*-1.27%*	*-7.17%*	*N/A*	*4.91%*	*-0.18%*	*N/A*
17-21 Annual Growth Rate		*7.19%*	*0.00%*	*-3.36%*	*0.00%*	*N/A*	*3.85%*	*1.64%*	*N/A*
17-26 Annual Growth Rate		*3.15%*	*0.00%*	*-1.88%*	*0.00%*	*N/A*	*1.92%*	*1.62%*	*N/A*
17-36 Annual Growth Rate		*1.48%*	*0.00%*	*-0.89%*	*0.00%*	*N/A*	*1.12%*	*1.64%*	*N/A*

Source: Port-wide Commodity Forecast

Figure 3. Port Wide Commodity Forecast - Coastwise, Exports, and Imports Only



3.6 Dock Commodity Forecast

The 2015 vessel class and type makeup, or the percent of vessel calls that are Handymax, Panamax, Aframax, or Suezmax-size for each ship type, is held constant relative to the type of commodity typically carried by that vessel and the percent utilized for each vessel type and class is applied to future years, unless stakeholders have stated an intention to use larger vessels. This information was calculated using the Port of Corpus Christi Harbormaster data paired with vessel dimensions from IHS Maritime Seaweb. The number of vessels then grows or decreases to match the commodity growth or decline of existing commodities. New facilities and their commodities grow the number of vessels based on the stated vessel class and the size new development's plan to use. When a stakeholder did not specify a vessel class and size, it was assumed that the vessel class and size would be similar those being used by other new or existing facilities of the same commodity type. In the "without project", vessels are assumed to be loaded consistent with 2015 levels determined by comparing total vessel deadweight tonnage of 2015 vessel calls to 2015 Port of Corpus Christi commodity tonnage. The growth of existing commodity was then dispersed to the docks based on the 2015 vessel calls and the 2015 commodity tonnage. Each vessel type was assumed to be carrying a specific commodity type, listed below.

Table 5. Commodity Type by Vessel Type

Vessel Type	Commodity Type
Asphalt/Bitumen Tanker	Petroleum Products
Bulk Carrier	Dry Bulk or Bulk Grain
Bulk/Caustic Soda Carrier (CABU)	Petroleum Products
Bulk/Oil Carrier (OBO)	Crude Oil
Chemical Tanker	Chemicals
Chemical/Products Tanker	Petroleum Products
Crude Oil Tanker	Crude Oil
Crude/Oil Products Tanker	Petroleum Products
General Cargo Ship	Breakbulk Cargo
Heavy Load Carrier	Breakbulk Cargo

Vessel Type	Commodity Type
LNGC	LNG
Logistics Vessel	Breakbulk Cargo
LPG Tanker	Petroleum Products
Ocean Going Barge	Assortment; Assumed on a dock-by-dock basis
Open Hatch Cargo Ship	Dry Bulk
Ore Carrier	Dry Bulk
Pipe Layer	Breakbulk Cargo
Platform Supply Ship	Breakbulk Cargo
Products Tanker	Petroleum Products

For companies with new or expanded facilities and multiple docks, assumptions were made as to which dock the commodity was dispersed to. When the stakeholder specified which dock the new tonnage would transit to or from, that dock was used in the forecast. For their privacy, assumptions and information from individual stakeholders cannot be described in this report.

4. Vessel Fleet Forecast - Base

4.1 Without Project

In the “without project” condition, vessels are forecasted to be loaded at the same percentage of deadweight tonnage (capacity) as in 2015. Larger vessels, such as Suezmax, Aframax, and some Panamax vessels, cannot be loaded to their full capacity at Corpus Christi due to channel depth restrictions. These vessels have design drafts of 45 feet or greater, requiring them to be ‘light loaded’ in order to transit the channels. For the “without project” condition, all of these vessels must be light loaded to a depth of 45 feet or less. Growth in the number of vessel calls is driven by the growth of commodity flows at an existing dock or by the development of new or expanded facilities. The number of inland barges was determined by taking the total amount of commodity forecasted to travel on inland barges (local, internal inbound, and internal outbound), and dividing it by the average barge capacity utilized at POCC in 2015. The number of inland barges does not change in any of the “with project” or alternate forecasts as the commodity forecast does not change. Instead, the model simulation inputs are used to control for changes in barge movements, which will be further described in subsequent sections.

4.1.1 Without Project Forecast Results

Table 6 displays the Port-wide vessel fleet forecast results for the “without project” condition at the 5-, 10-, and 20-year intervals.

Table 6. Without Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	23.15%	23.83%	24.32%	670	730	820
Panamax	46.20%	45.91%	46.09%	1,330	1,400	1,550
Handymax	12.89%	12.72%	12.43%	370	390	420
Ocean Barge	17.75%	17.55%	17.17%	510	530	580
Deep Draft Total	100.00%	100.00%	100.00%	2,890	3,040	3,370
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

4.2 With Project

In the “with project” condition, those vessels whose average design draft is greater than 45 feet are assumed to load to a 52 foot depth, or to their design draft, whichever is less. In addition, if a stakeholder stated that they would shift their vessel fleet from using primarily Handymax or Panamax vessels to using primarily Aframax or Suezmax vessels, this shift was also accounted for. Overall, this process reduces the number of vessel calls, partially due to increasing the efficiency of the existing vessel fleet by allowing heavier loading, and also due to some stakeholders using fewer larger vessels instead of many smaller vessels.

4.2.1 With Project Forecast Results

Table 7 displays the Port-wide vessel fleet forecast results for the “with project” condition at the 5-, 10-, and 20-year intervals.

Table 7. With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	22.3%	23.0%	23.5%	640	690	790
Panamax	46.7%	46.4%	46.6%	1,330	1,400	1,550
Handymax	13.0%	12.9%	12.6%	370	390	420
Ocean Barge	17.9%	17.7%	17.4%	510	530	580
Deep Draft Total	100.0%	100.0%	100.0%	2,850	3,010	3,340
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5. Dock Vessel Fleet Forecast – Alternate Scenarios

5.1 EAI Inc. Data and Low / High Commodity Forecast

5.1.1 EAI Inc. Data

The Port of Corpus Christi provided AECOM several documents from EAI Inc. documents describe the state of oil and gas markets throughout the United States and at the Port of Corpus Christi. The executive summary of these documents provides a forecast from 2012 to 2025 for outbound crude oil and condensate, inbound crude oil and condensate, and outbound light petroleum products. For each of these categories, EAI Inc. forecasts a low, base (mid), and high forecast. It was requested that AECOM review this data and utilize it to create a low and high alternative for the AECOM stakeholder-based forecast. The following sections compare the stakeholder-based forecast to the EAI Inc. forecast.

The EAI Inc. forecast is primarily published in thousands of barrels per day (MBPD). To convert this such that it can be utilized to build a new low and high vessel fleet forecast, the EAI Inc. forecast numbers were multiplied by 365 days per year, and 1,000 barrels to determine a total number of barrels per year. Then, this number was converted into metric tons per year based on expected product density. As the exact weight of the crude oil and petroleum products is unknown, this conversion may add to the variability between forecasts.

Comparing AECOM’s stakeholder-based forecast to the EAI Inc. forecasts is not easily done. It is unclear what EAI Inc. includes within the “light petroleum product” category, which makes it difficult to compare or adjust either party’s petroleum product forecast. Additionally, within several categories, the historic data from 2012 to 2015 in the EAI Inc. forecast does not match or appear to be close to matching the data used by AECOM. AECOM’s forecast uses the Port of Corpus Christi-provided total tonnage data paired with the Waterborne Commerce Statistics Center (WCSC) data to determine what direction (outbound/inbound) and origin/destination pairs (foreign/domestic). The historic outbound crude oil and condensate estimates are off by between 2 million and 9 million tons, shown in Table 4. This is again seen for the historic outbound petroleum products forecast; however, this may be due to the unknown definition of "light petroleum products". Within the Port of Corpus Christi-provided commodity data, there were some commodities considered petroleum products that sometimes would be classified as a chemical by other sources, such as WCSC or possibly EAI Inc. There are also large differences between the inbound historic crude oil tonnages. In some years, AECOM's forecast is higher and in others, the EAI Inc. forecast is higher.

In the future years, the EAI Inc. forecast has steady but diminishing growth, whereas the AECOM forecast has several years where rapid growth occurs due to the opening of new facilities. Because of this difference, it would be inaccurate to complete a year-by-year comparison, and would be more appropriate to compare the last available year, 2025. For outbound crude oil and condensate, the EAI Inc. low forecast is similar, but higher than AECOM's forecast. Thus, a high forecast could be created for outbound crude oil using the EIA Inc. forecast; however, a low forecast could not be.

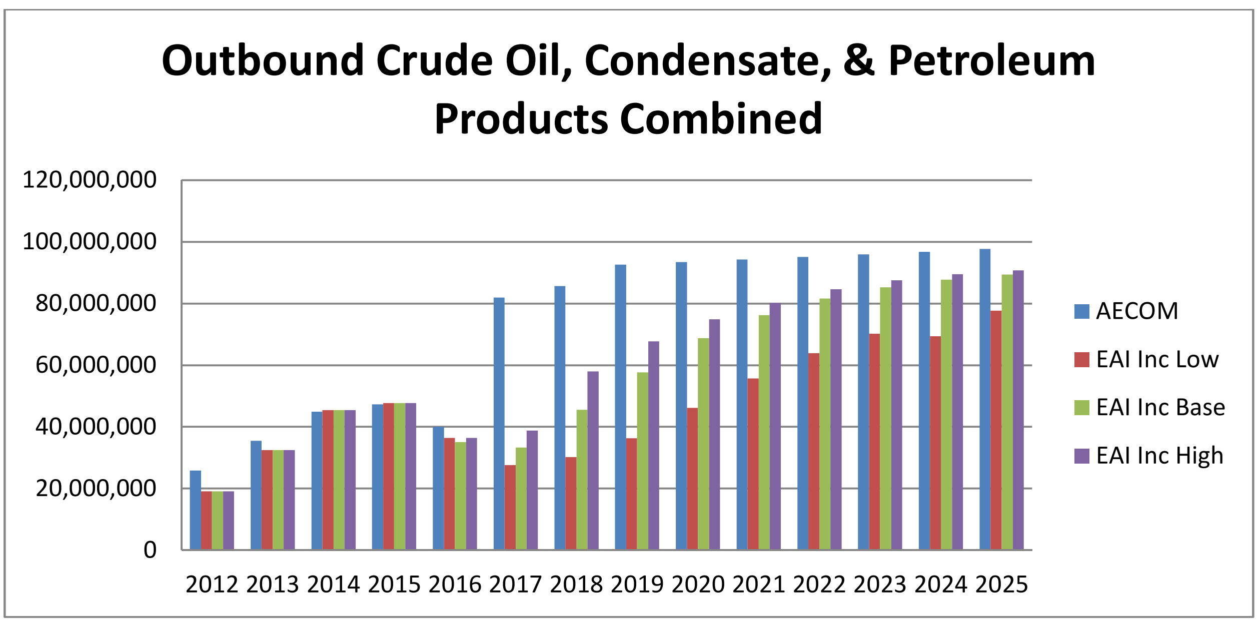
In this same year, AECOM's outbound petroleum product forecast is substantially higher than each EAI Inc. forecast. The majority of the AECOM forecast's rapid growth in petroleum products is due to the development or expansion of new facilities. This was determined primarily due to stakeholder interviews and was likely unknown to EAI Inc. forecasters. Because AECOM had access to immediate stakeholder input, it would likely be less accurate to utilize the EAI Inc. forecast.

The inbound crude oil forecasts are within 733,000 tons of each other in 2025; however, the EAI Inc. low, base, and high forecasts are all the same for this category, and thus it is not useful when developing a new low and high forecast.

Despite the above challenges in comparing the forecasts, when the outbound crude oil and outbound petroleum product forecasts are combined, the forecasts are very similar. The following Figure 4 displays the difference between the EAI Inc. forecasts and the stakeholder-based forecast.

Although individually the difference in the outbound crude oil EAI Inc. high forecast to the stakeholder-based forecast is nearly 25% in 2025, and the difference in the outbound petroleum product EAI Inc. high forecast to the stakeholder-based forecast is approximately -55%, the difference between the combined outbound crude oil, condensate, and petroleum product high forecast from EAI Inc. to AECOM's stakeholder-based forecast is only -7%. Additionally, the inbound crude oil and condensate forecast is within 7.5%. Considering the major changes and developments occurring at the Port of Corpus Christi, such as the ability to export crude oil, a difference of 7% in 2025 is reasonable.

Figure 4. Combined: Outbound Crude Oil, Condensate, & Petroleum Products



5.1.2 Low Forecast

Due to the previously outlined issues with the EAI Inc. data, it was not possible to create a low and high commodity forecast based on these forecasts. Instead, each commodity type was reduced by 10% in all years for the low forecast.

5.1.2.1 Low Without Project Forecast Results

Table 8 displays the Port-wide vessel fleet forecast results for the “without project” condition at the 5-, 10-, and 20-year intervals when the commodity forecast is reduced by 10%.

Table 8. Low Without Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	23.19%	23.85%	24.31%	600	660	740
Panamax	45.84%	45.87%	45.97%	1,190	1,260	1,400
Handymax	13.02%	12.72%	12.58%	340	350	380
Ocean Barge	17.95%	17.56%	17.14%	470	480	520
Deep Draft Total	100.00%	100.00%	100.00%	2,600	2,750	3,050
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.1.2.2 Low With Project Forecast Results

Table 9 displays the Port-wide vessel fleet forecast results for the “with project” condition at the 5-, 10-, and 20-year intervals when the commodity forecast is decreased by 10%.

Table 9. With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	21.6%	22.3%	22.9%	550	600	690
Panamax	46.8%	46.8%	46.8%	1,190	1,260	1,400
Handymax	13.3%	13.0%	12.8%	340	350	380
Ocean Barge	18.3%	17.9%	17.5%	470	480	520
Deep Draft Total	100.0%	100.0%	100.0%	2,540	2,700	3,000
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.1.3 High Forecast

Likewise, a high forecast was created by adding 10% to each commodity type.

5.1.3.1 High Without Project Forecast Results

Table 10 displays the Port-wide vessel fleet forecast results for the "without project" condition at the 5-, 10-, and 20-year intervals when the commodity forecast is increased by 10%.

Table 10. Without Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	23.18%	23.80%	24.40%	740	800	920
Panamax	45.92%	45.74%	45.79%	1,460	1,530	1,730
Handymax	13.09%	12.90%	12.89%	420	430	490
Ocean Barge	17.82%	17.56%	16.91%	570	590	640
Deep Draft Total	100.00%	100.00%	100.00%	3,170	3,350	3,780
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.1.3.2 High With Project Forecast Results

Table 11 displays the Port-wide vessel fleet forecast results for the "with project" condition at the 5-, 10-, and 20-year intervals when the commodity forecast is increased by 10%.

Table 11. With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	22.3%	23.0%	23.3%	700	770	870
Panamax	46.6%	46.3%	46.6%	1,460	1,540	1,740
Handymax	13.2%	13.0%	13.0%	420	430	490
Ocean Barge	18.0%	17.7%	17.1%	570	590	640
Deep Draft Total	100.0%	100.0%	100.0%	3,150	3,330	3,740
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.2 Panamax Shift

Another uncertainty with the base forecast is that several stakeholders either stated that "maybe" they would utilize larger vessels with the improved channel, or that "yes" they would utilize larger vessels, but they were unable to quantify this shift. Some stakeholders may have birth restrictions, or restrictions at their origin/destinations preventing the use of larger vessels; however, others will likely shift over time, even if this shift was not quantifiable. To account for this, AECOM created several alternative forecasts where 25%, 50%, and 75% of the commodity that was predicted to travel on Panamax-sized vessels in the base forecast, for any given year, are 'shifted' to travel on Aframax-sized vessels, when appropriate.

5.2.1 Panamax Shift Without Project

In the “without project” condition, vessel shift does not take place as the channel has not been deepened or widened; thus, a 25%, 50%, and 75% panama shift forecast was not created for the without project. The base “without project” conditions still apply.

5.2.2 Panamax Shift With Project

In the “with project” condition, 25%, 50%, or 75% of the commodity previously assigned to Panamax-sized vessels is re-assigned to Aframax-sized vessels. In doing this, the forecast predicts less Panamax vessels, and less overall vessels as it takes less Aframax vessels to transport the same amount of commodity as more Panamax vessels. Although this shift may never occur, many stakeholders stated that it ‘maybe’ would. Conjoined with the fact that vessel size intends to increase over time, this alternative scenario could give insight into the future at POCC.

5.2.2.1 25% Shift With Project Forecast Results

Table 12 displays the Port-wide vessel fleet forecast results for the “with project” condition at the 5-, 10-, and 20-year intervals when 25% of the commodity previously transported on Panamax-sized vessels is reassigned to Aframax-sized vessels.

Table 12. 25% Shift With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	21.6%	23.0%	23.5%	800	870	980
Panamax	47.1%	46.4%	46.6%	1,030	1,080	1,210
Handymax	13.1%	12.9%	12.6%	370	380	410
Ocean Barge	18.1%	17.7%	17.4%	510	530	580
Deep Draft Total	100.0%	100.0%	100.0%	2,720	2,860	3,180
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.2.2.2 50% Shift With Project Forecast Results

Table 13 displays the Port-wide vessel fleet forecast results for the “with project” condition at the 5-, 10-, and 20-year intervals when 50% of the commodity previously transported on Panamax-sized vessels is reassigned to Aframax-sized vessels.

Table 13. 50% Shift With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	21.6%	23.0%	23.5%	940	1020	1160
Panamax	47.1%	46.4%	46.6%	750	780	860
Handymax	13.1%	12.9%	12.6%	370	380	410
Ocean Barge	18.1%	17.7%	17.4%	510	530	580
Deep Draft Total	100.0%	100.0%	100.0%	2,580	2,710	3,010
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

5.2.2.3 75% Shift With Project Forecast Results

Table 14 displays the Port-wide vessel fleet forecast results for the “with project” condition at the 5-, 10-, and 20-year intervals when 75% of the commodity previously transported on Panamax-sized vessels is reassigned to Aframax-sized vessels.

Table 14. 75% Shift With Project Forecast

Vessel Type	2021	2026	2036	2021	2026	2036
	Percent of Vessel Fleet			*Number of Vessel Calls*		
Aframax & Larger	21.6%	23.0%	23.5%	1,090	1,190	1,350
Panamax	47.1%	46.4%	46.6%	460	470	510
Handymax	13.1%	12.9%	12.6%	370	380	410
Ocean Barge	18.1%	17.7%	17.4%	510	530	580
Deep Draft Total	100.0%	100.0%	100.0%	2,430	2,570	2,850
Inland Barges				26,000	26,000	27,000

Source: Port-wide Vessel Fleet Forecast

6. Vessel Fleet Forecast Summary

The commodity forecast shows that the Port of Corpus Christi will nearly double their commodity throughput from 2016 to 2036. However, the number of vessel calls is not expected to double, even in the “without project” condition. This can be accounted for as some of the stakeholders that have recently reduced or are forecasted to reduce tonnage had used smaller vessels, such as Handymax vessels, while some of the added tonnage from new and expanded facilities is anticipated to be carried on larger, more efficient vessels, such as Aframax or Suezmax vessels.

This trend is experienced to an even greater extent during the “with project” forecast as some vessels will be able to be loaded deeper than 45 feet, further improving efficiency. In addition, some stakeholders specifically stated that they would shift to larger vessel classes in the “with project” so that they may take advantage of these efficiencies.

Note that Panamax vessels are growing in the “with” and “without project” forecasts, both as the number of vessels and as a percentage of the Port’s fleet. This is not a result of stakeholders shifting their fleet to utilize more Panamax vessels, but instead the result of aggressive growth amongst petroleum products. Petroleum products typically travel in Panamax-sized vessels due to transportation logistics outside of the Port’s boundaries. Thus, an increase in Panamax vessels is expected when this commodity type experiences significant growth.

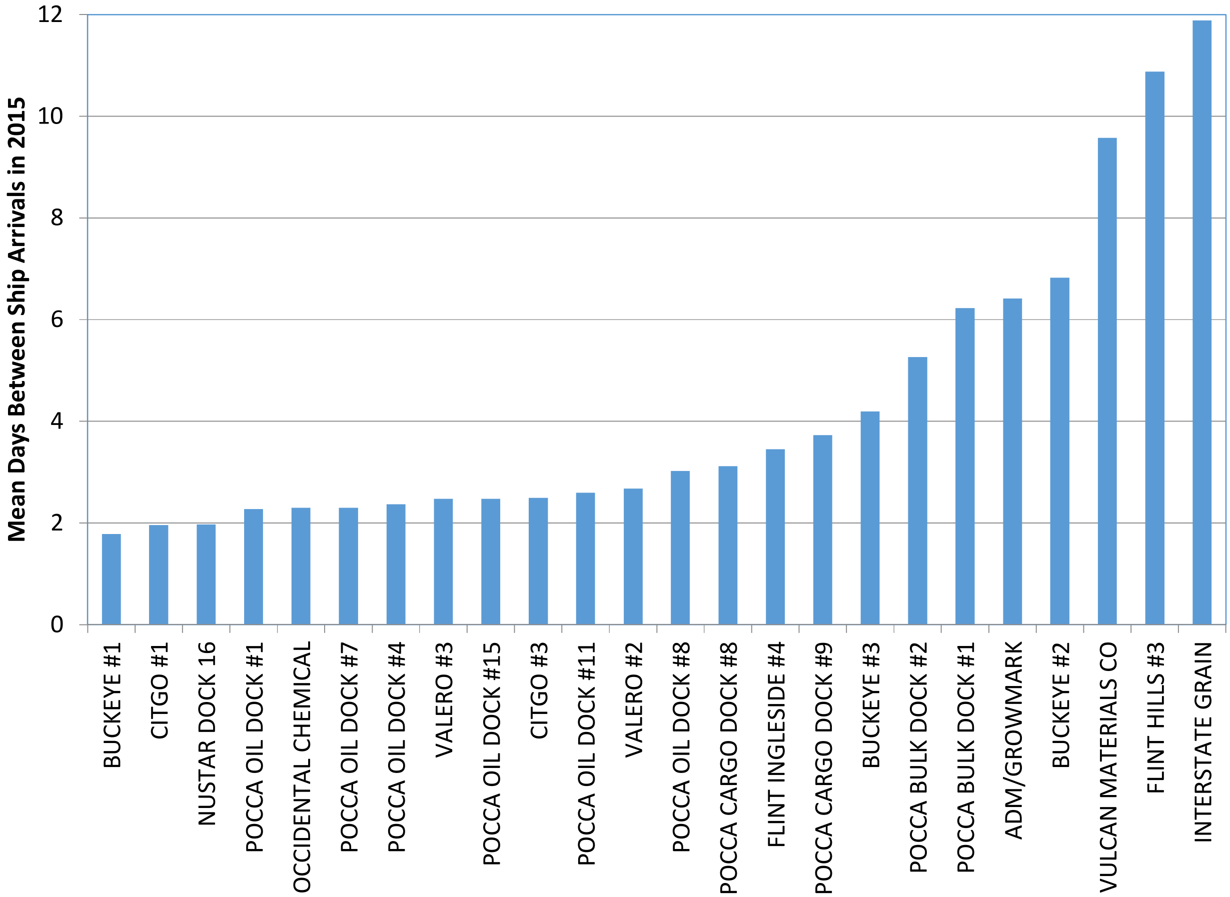
7. Simulation Modeling

7.1 2015 Data Summary

The POCC and the Aransas Pilots provided AECOM with a large quantity of data on vessel operating at the Port in 2015. Approximately 2,500 vessels (including ocean barges but not coastal barges) arrived at the Port in 2015.

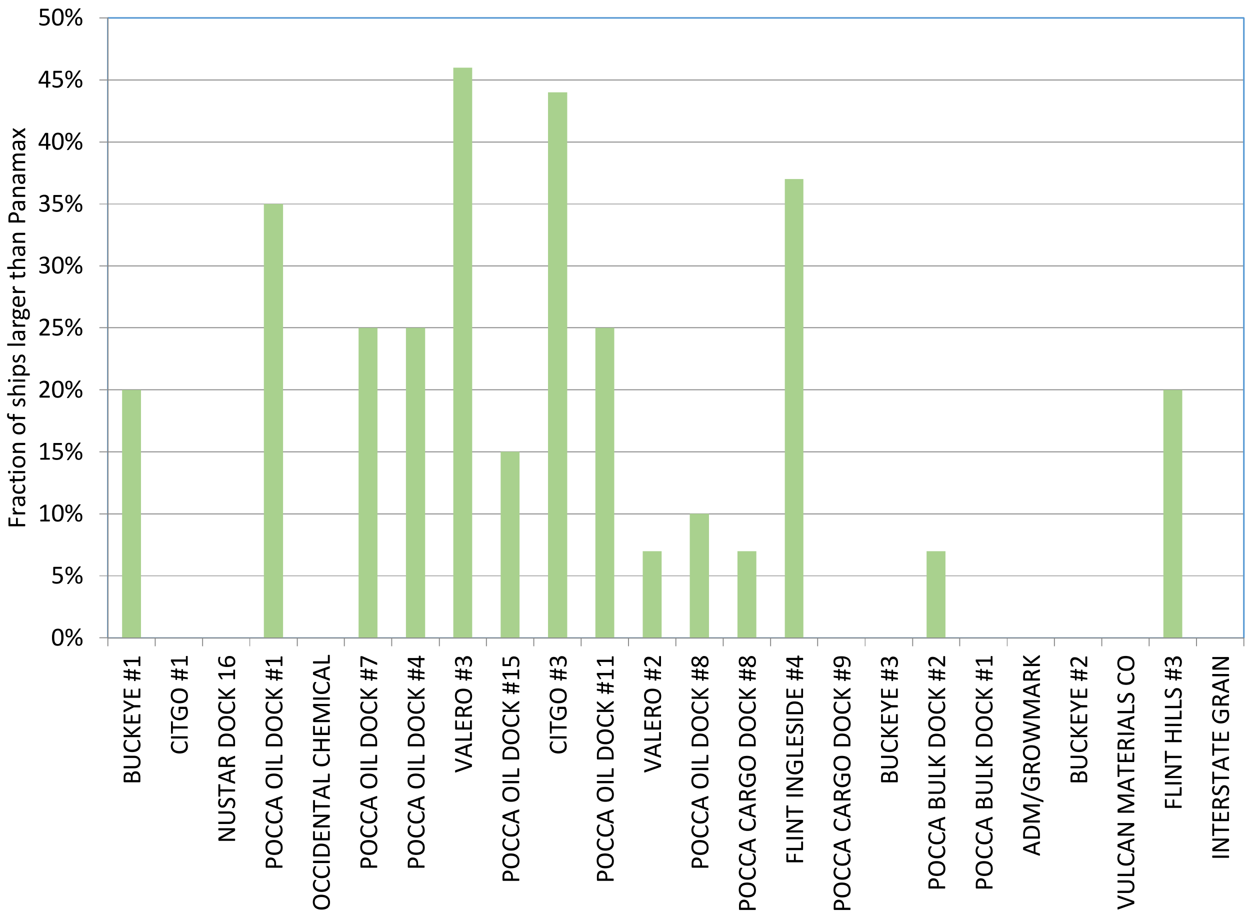
Figure 5 shows the mean inter-arrival time of vessels at each terminal at the Port. The busiest terminals received a new vessel approximately every two days.

Figure 5. Mean Inter-arrival Time per Berth



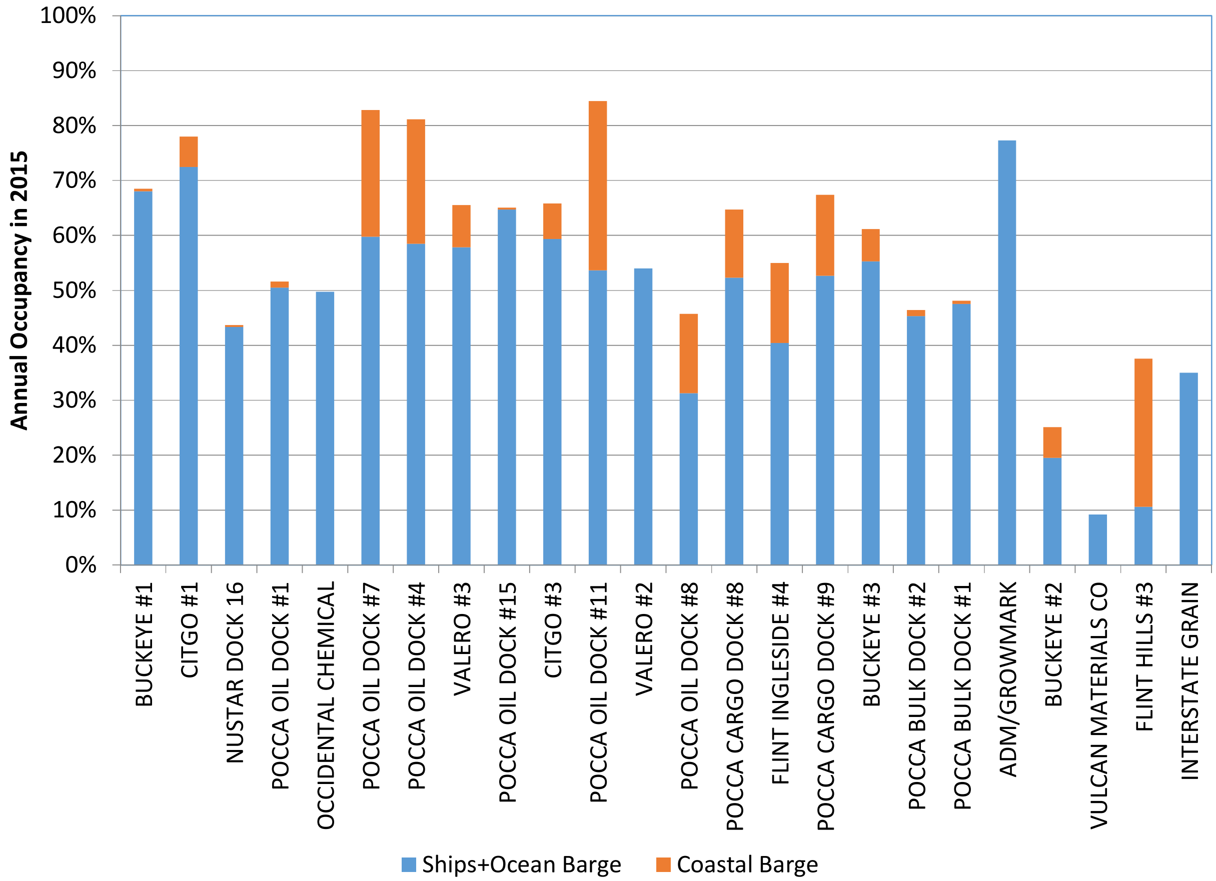
Not all berths handled the same type and size of ships. Only some of the berths at POCC can handle very large ships. Port-wide, approximately 16% of vessels are larger than Panamax in size, but the calls from these large vessels are not uniformly distributed. Figure 6 shows the fraction of calls at each terminal that are greater than Panamax in size.

Figure 6. Fraction of Large Vessels by Terminal



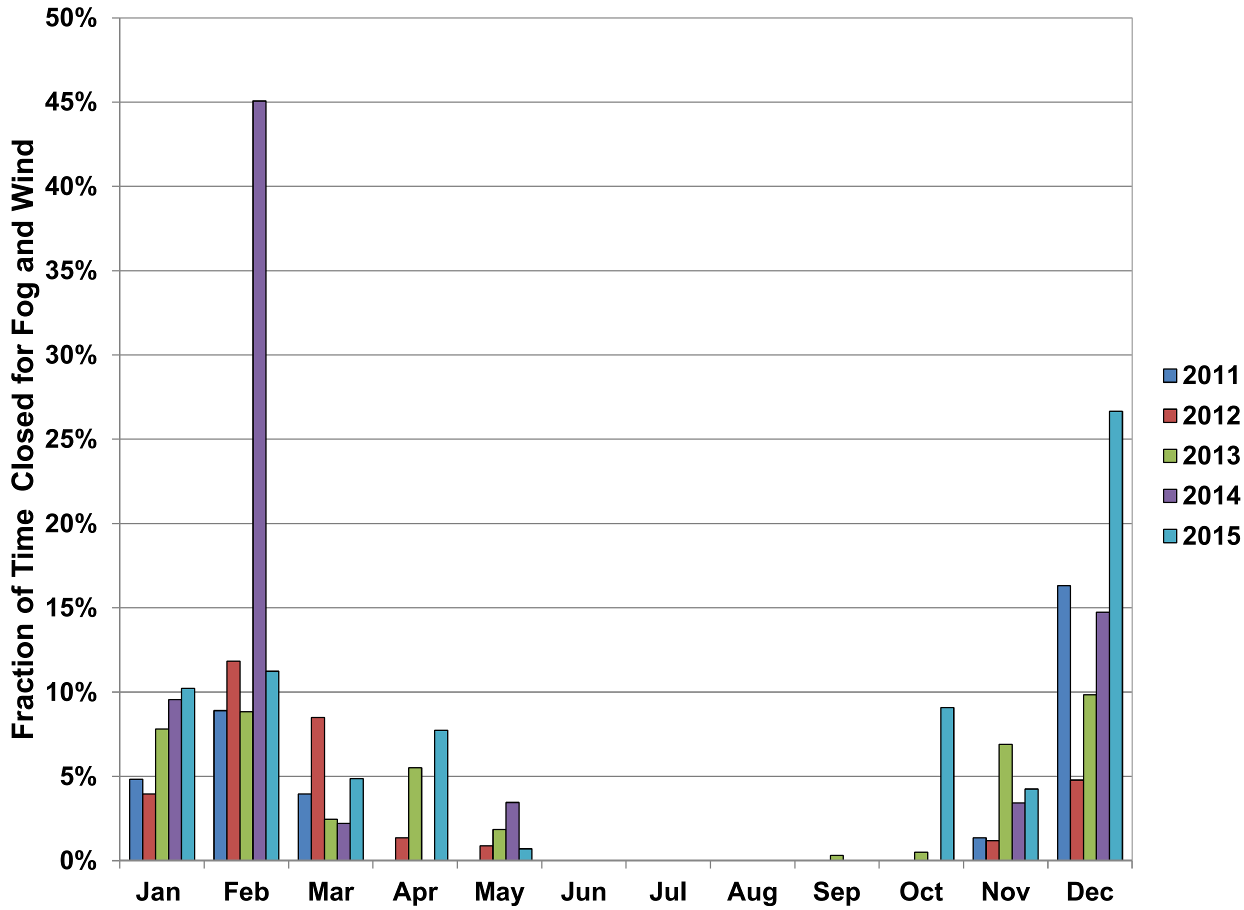
Many of the berths at the Port are currently heavily utilized. In addition to handling ocean-going vessels, many terminals also serve coastal barges on the same berths. This can lead to occasional interference between vessel and coastal barge operations. This interference is not uniformly distributed across the Port, however. Figure 7 shows the berth occupancy for each berth at the Port, including both ocean vessels (including ocean barges) and coastal barges.

Figure 7. Berth Occupancy in 2015



The POCC is sometimes closed to due weather events, which generally occur in the winter. Figure 8 shows five years' worth of Port closures for wind and weather delay. Based on this plot, AECOM determined that 10% outage during a winter month is typical and has built this into our model.

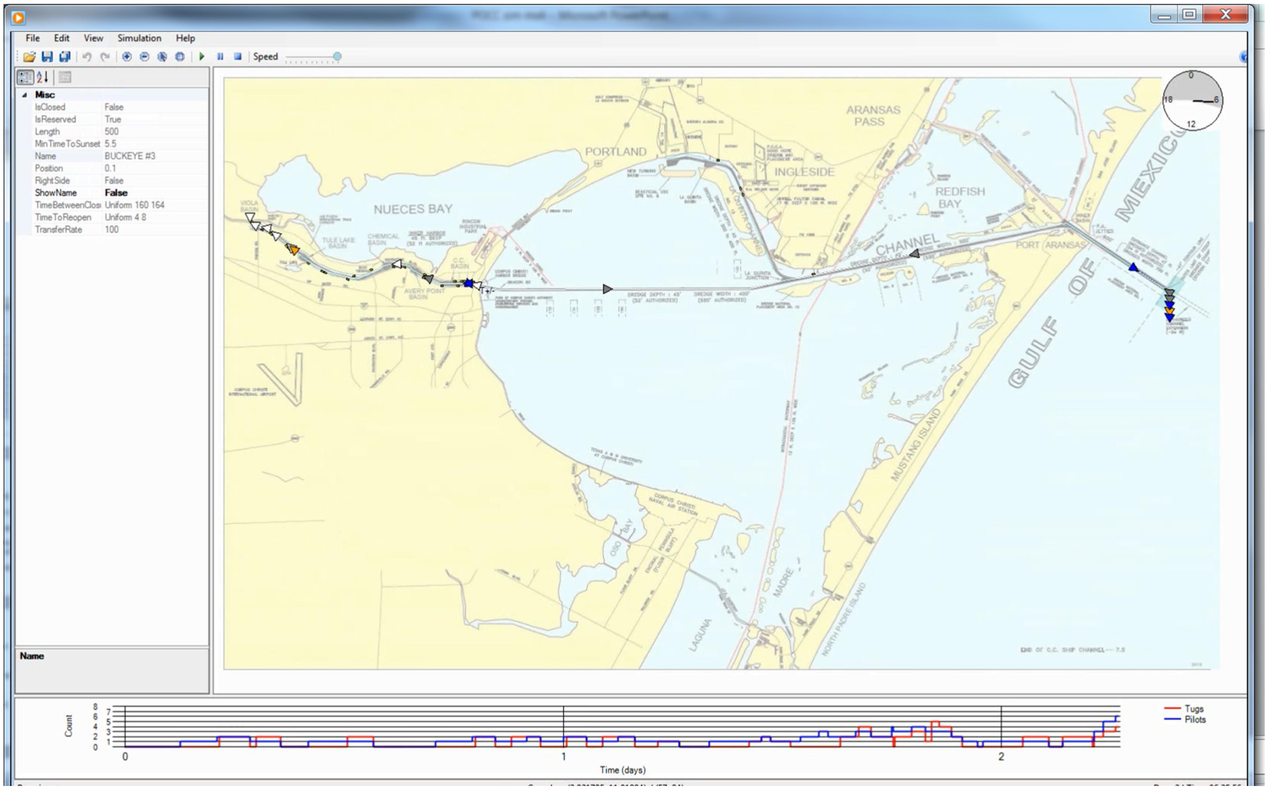
Figure 8. Port Weather Closure Rates by Month 2011-2015



7.2 AECOM Channel Model

AECOM used our Vessel Network Model (VNM) to analyze vessel movement at the POCC. VNM is a proprietary discrete event simulation model developed specifically for channel capacity analysis. Every vessel and berth is visible, and the overall port is modelled to-scale over a reference background map. Figure 9 shows an example screen capture from VNM running.

Figure 9. Example VNM Animation Graphic



The user can click on a ship or berth while VNM is running to get a status update as to what it is trying to do, where it wants to go, how much time it has left, and if it's queuing, what is preventing it from getting to its desired berth. The model has a 24-hour clock (see upper right in Figure 9) that shows whether it is daylight or darkness. The model keeps track of each individual ship's visit to the port and reports all statistics in a detailed Excel output file.

AECOM ran each simulated case for 20 weeks, and then averaged five runs to generate a single set of output for a given scenario. This technique ensures that the influence of random events (fog for example) will have a negligible impact on the overall reported mean results.

AECOM's input files list the number of ships expected to call at each terminal, and the mix of sizes of those ships, which are also specific by terminal. When a ship is created by the model, it pops up at the anchorage point outside of the harbor and runs through a series of checks:

- Is the Port open? (Is the Port closed due to adverse weather condition?)
- Is it daytime? (for large vessels limited to daylight moves)
- Is the target berth free?
- Are there adequate pilots and tugs available?
- Does the channel have sufficient capacity for this vessel to move?

If these conditions are all met, the vessel proceeds to its target berth. If not, it waits at anchorage until all of the conditions are met. The model gives preference for outgoing vessels in order to prevent gridlock in the harbor. Once an incoming vessel gets permission to move, it proceeds all the way to its target berth. There are no intermediate queuing positions in the harbor. Similarly, outbound vessels reserve channel capacity all the way to the open sea as soon as they move away from berth. Note that although the model tracks the usage of pilots and tugs, AECOM assumed that these would not be a constraint to vessel movement over the long term. In other words, although there may be occasional temporary shortages of pilots or tugs, over the long run they will be expanded as needed to serve the Port without any chronic shortages.

Vessels are able to “jump the queue” if the criteria allows. For example, a Panamax vessel that arrives at midnight can proceed even if there is a Suezmax vessel waiting at anchorage. The model operating rhythm often creates de facto platooning of vessels (several consecutive vessels travelling in the same direction) but the model does not have any specific platooning rules in place. Vessels move according to their ability and priority regardless of direction of travel.

It seems unlikely that strict mandates of convoys by direction would improve the overall port performance. In order to execute a convoy system, some ships would actually incur more delay until a designated number of ships were ready to go, or a designated time passed for the channel restriction to flip direction. This could be a valuable sensitivity case for further simulation studies.

Table 15 summarizes the rules for tug and pilot assignment as described by the Aransas Pilots. These rules were incorporated into the simulation model. Suezmax and Aframax ships of 40.9’ or more in draft are currently restricted to daylight operations only. The demurrage costs shown are AECOM estimates based on example data provided by the Port.

Table 15. Vessel Size vs Pilot and Tug Assignment

Rule	LNGC	Suezmax	Aframax	Panamax	Handy	Sub-handy	ATB (Ocean Barge)
Tugs inbound	3	3	2.5	2	2	2	1
Tugs outbound	3	3	2.5	2	1.5	1	1
Pilots @ day	2	2	1.5	1.5	1	1	1
Pilots @ night	NA	NA	2	1.5	1	1	1
Typical beam (ft.)	154	158	138	106	90	75	75
Daylight only Y/N	Y	Y	Y for 40.9'+	N	N	N	N
Demurrage ($000/day)	40	40	30	25	20	20	20

The current harbor configuration allows for a maximum beam for vessels meeting in Cuts A and B at 265’ and 215’ respectively. Vessel draft may also limit meeting maneuvers due to the hydrological behavior of the channel. The pilots currently limit meeting events to a combined draft (regardless of beam) of 80’ in both Cuts A and B. The outer harbor dredging project involves widening and deepening both Cuts to allow a combined beam of 316’ and a combined draft of 90’.

The current configuration of the Inner Harbor includes a pinch point at ADM/Citgo where the total width of ships on berth and meeting vessels cannot exceed 357’. For example, if a Panamax ship is berthed on either side, only 145’ of space remains, and a Suezmax ship therefore cannot pass through the gap. The Port is exploring options to change navigation rules to effectively widen this constraint to 377’. AECOM modelled all of the “no project” scenarios at the existing 357’ and all of the future project cases at 377’ of width at this point.

At the present time, Coast Guard rules generally do not permit any vessels to meet an LNGC vessel. The base cases for AECOM’s modelling assume that this is the case, and we have run sensitivity cases that treat LNGC ships as normal ships in terms of beam restrictions.

AECOM’s simulation model takes into account the width of each channel section, and the meeting rules allowed within each segment. Table 16 shows the types of moves that will be blocked before or after the project (excluding LNGC ships which are treated as a special case). The following nomenclature is used:

- “b” indicates beam criteria, and “d or D” indicates draft criteria.

- Upper case letters indicate blockage with the project, and lower case letters indicate blockage with the current channel configuration.

Note that in the "With Project" case, all beam related blockage is eliminated so that there are no upper case "B"s in Table 16. The beam dimensions for each vessel class are noted at the edges of the table for reference.

The "heavy" ships in each case are loaded to the maximum allowable for the channel individually. The current maximum restriction is approximately 45' vessel draft. Two vessels loaded to at least 40' draft each cannot meet as they would have a combined draft of more than the 80' draft limit.

- After Phase 1 is completed, Cuts A and B will be 52' deep, with a combined meeting limit of 90'. Because the Inner Harbor will still be at today's depth, no vessels deeper than 45' will be transiting, and therefore Phase 1 will not have any meeting restrictions due to draft.

- After Phase 2 is complete and the inner Harbor is also deepened to 52', the heaviest vessels will likely be in the range of 50'+. These heavy vessels in Phase 2 will not be able to pass because they would have a combined draft of at least 96', which is above the 90' combined limit. As a result, the Phase 2 project will actually increase the potential for navigational conflict between vessels.

Table 16. Channel Meeting Prohibition Rules

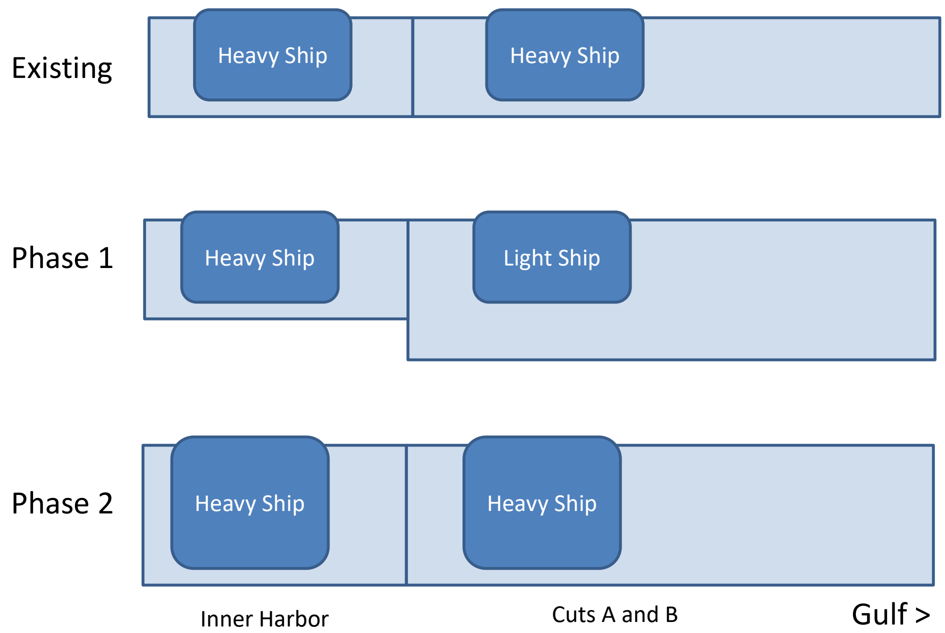
		75	75	90	106	106	138	138	158	158
Beam	**Vessel**	**Ocean Barge**	**Sub Handy**	**Handy**	**Panamax light**	**Panamax heavy**	**Aframax light**	**Aframax heavy**	**Suezmax light**	**Suezmax heavy**
75	**Ocean Barge**								b	b
75	**Sub Handy**								b	b
90	**Handy**						b	b	b	b
106	**Panamax light**						b	b	b	b
106	**Panamax heavy**					d,D	b	b,d,D	b	b,d,D
138	**Aframax light**			b	b	b	b	b	b	b
138	**Aframax heavy**			b	b	b,d,D	b	b,d,D	b	b,d,D
158	**Suezmax light**	b	b	b	b	b	b	b	b	b
158	**Suezmax heavy**	b	b	b	b	b,d,D	b	b,d,D	b	b,d,D

Table 16 indicates for example that, before the project, two Panamax ships can always meet due to beam (106'+106' = 212' < 215' meeting limit) but two heavily loaded Panamax ships cannot meet because they will exceed 80' of combined draft. Another key issue highlighted by Table 16 is that no vessel can meet a Suezmax ship in Cut B at present because even the 158' typical beam only leaves 215'-158' = 57' for a meeting vessel and even ocean barges are wider than this.

As previously mentioned, once the Inner Harbor channel is deepened, large vessels can be more heavily loaded, so in some cases, meeting restrictions will remain even after the project, but these will be relatively rare. AECOM has assumed that only 25% of Panamax or larger ships will be "heavy" and unable to meet in Phase 2. This is due to limitations at the loading berth in POCC, or to limitations at other Ports visited by this ship. If two large ships are sampled at random in the "Project" case, they will only be blocked from meeting 25% * 25% = 6.25% of the time.

Figure 10 shows a conceptual section view of the harbor channels, with the Inner Harbor on the left and Cuts A and B on the right. In the existing configuration these are all the same depth. After the Phase 1 Project when Cuts A and B are now deeper than the Inner Harbor, any vessel that is heavily laden within the Inner Harbor is still considered a light vessel in the deeper channels of Cuts A and B and therefore faces no restrictions in meeting due to combined draft. After Phase 2 is complete, the situation is now similar to the existing where the entire harbor is the same depth, and vessels can be loaded to a heavy draft in the Inner Harbor that will cause a meeting restriction in Cuts A and B.

Figure 10. POCC Vessel Forecast Summary



7.3 Simulation Results and Conclusions

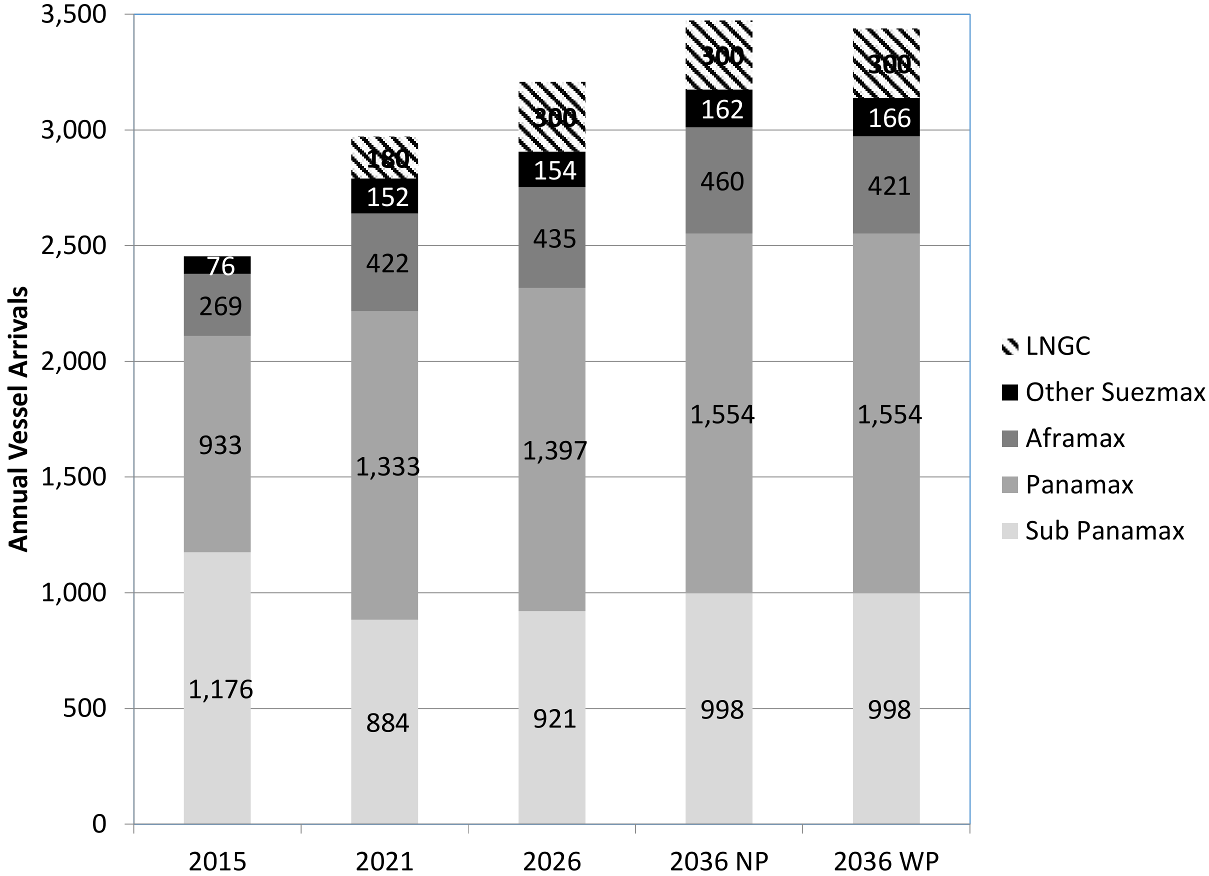
7.3.1 Model Input

AECOM simulated a base case using 2015 data, and future cases based on vessel projections and new terminal developments for 2021, 2026, and 2036. Two options are presented for 2036, with and without project. The project in this case refers to both Phase 1 and Phase 2 dredging. In 2021 and 2026, only Phase 1 is possible and there will be no difference in ship calls with or without the Phase 1 project.

Figure 11 summarizes the expected ship volume by size and year. Other than the new addition of LNGC ships, AECOM expects little organic growth or shift to very large ships beyond the year 2021. This is due to limitations of individual loading docks in POCC or at other ports used by customers at POCC.

Most of the specifically identified new facilities to be built in the future at POCC come on line between 2015 and 2021. These operations of these new facilities will result in a dramatic increase in the Aframax and Suezmax vessels at the Port. Beyond 2021, the cargo and vessel forecasts are primarily driven by the continuous growth of existing facilities, which is expected to be relatively modest. Most of the growth in cargo (see Fig 2) is in crude oil, a commodity that tends to be moved in large ships where possible.

Figure 11. POCC Vessel Forecast Summary



For calculation of berth occupancy in the simulation model, AECOM assumed similar rates of product transfer to 2015. For new terminals where transfer rates are unknown, AECOM assumed berth occupancy of approximately 50%. The goal was to develop loadings without extraordinary levels of berth occupancy that would result in excessive queuing. This scope of this study did not include analysis of the capabilities (either from a structural or operational standpoint) of individual terminals at the Port.

7.3.2 Results

Figure 12 shows the summary results of the simulation model for each of the forecast cases from Figure 11. Each of these data points represents 100 simulated weeks of activity. Mean delay per vessel (including vessels with no delay) is shown, with inbound and outbound delay shown separately in a stacked bar format. Future cases with project (WP) are identified as either Phase 1 or Phase 2 (for 2036 only). The 2036_Ph2 night case allowed all vessels to transit at night. The “meet” cases were sensitivity analysis runs where LNGC ships were treated as regular vessels for the purposes of vessel meeting.

Figure 12. Simulation Results Summary – Mean vessel delay in hours

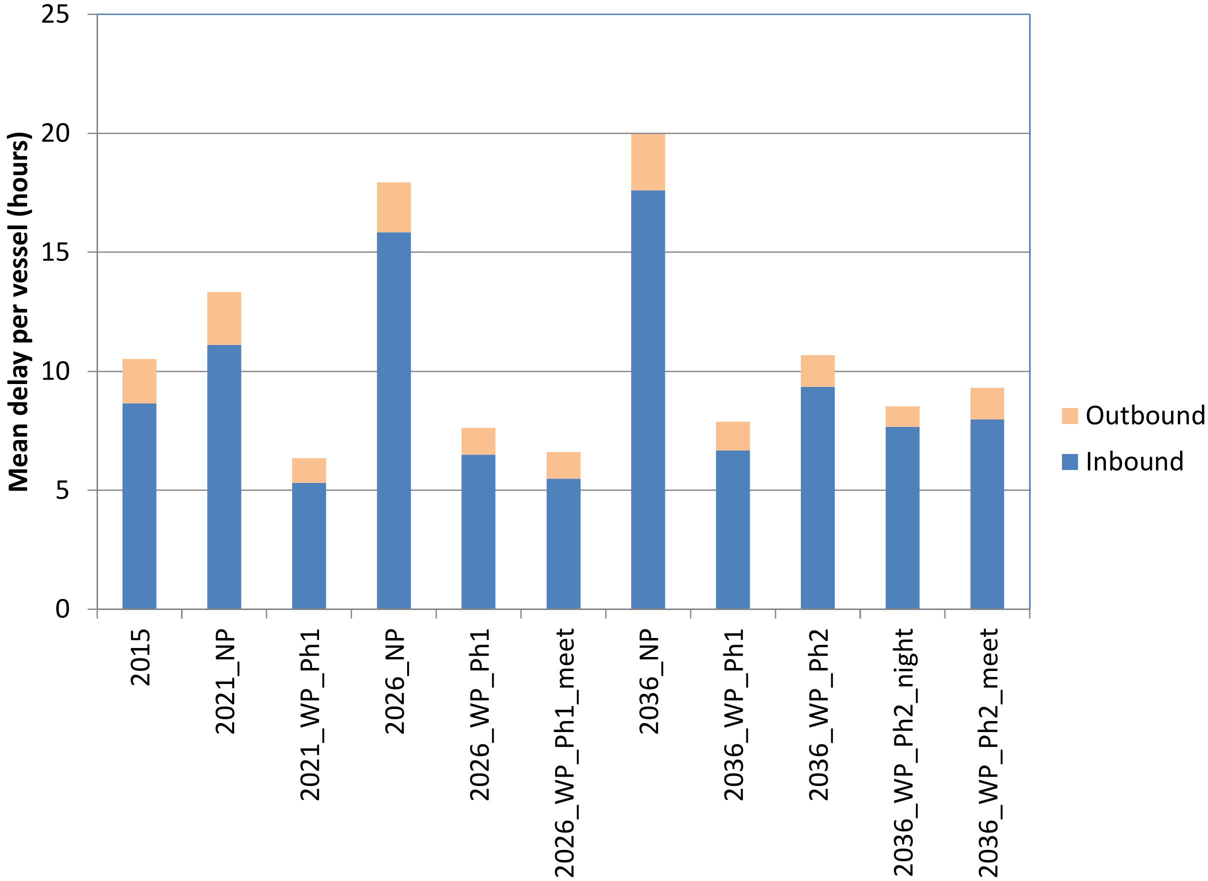
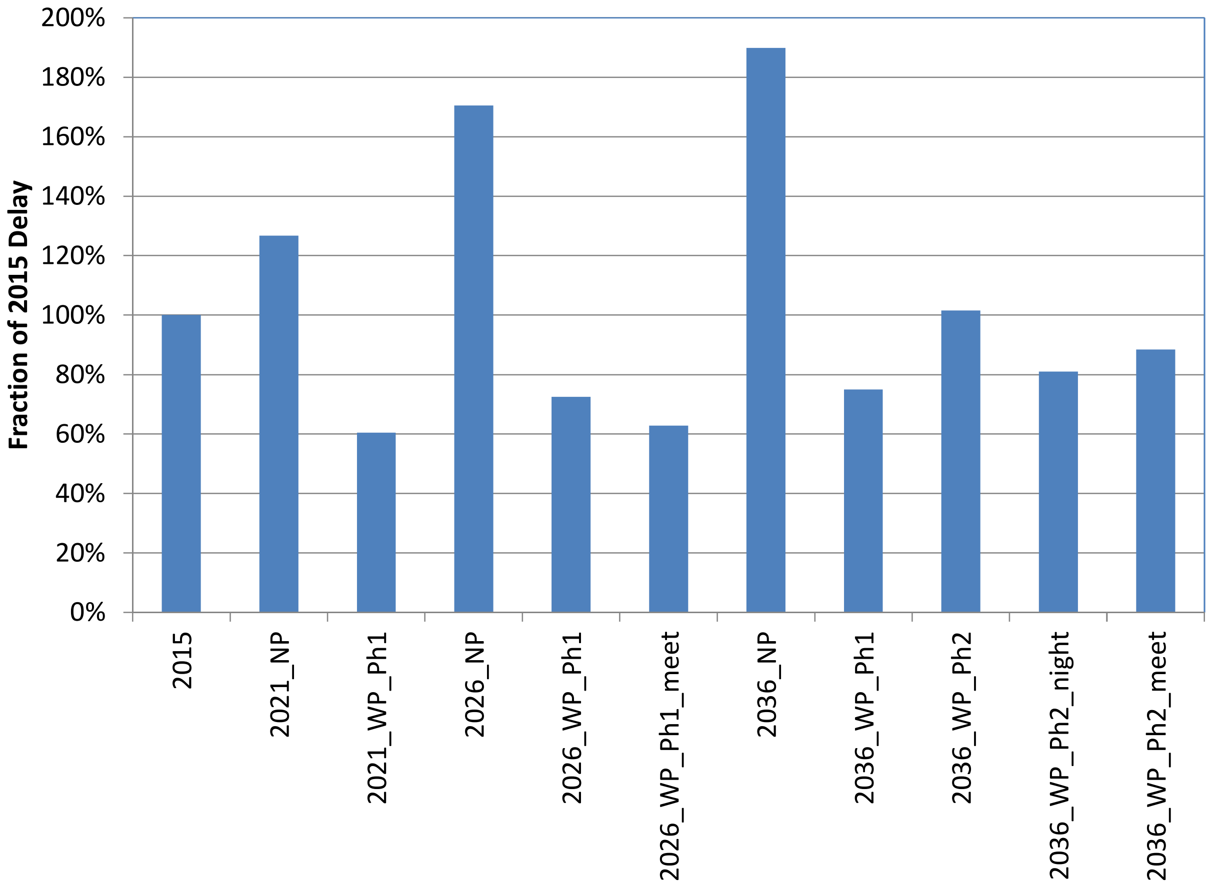


Figure 13 presents the data in Figure 11 as a percentage of current total delay.

Figure 13. Simulation Results Summary Compared to 2015



Connecting the 2015 delay with the future “No Project” cases shows an expected growth in delay as volume increases if there is no dredging done. With the Cut A and Cut B dredging project, delay is substantially reduced, and shows only modest increase between 2021 and 2036. AECOM determined demurrage by multiplying inbound delay at anchorage for each ship by the daily demurrage rate listed in Table 15. These values are presented for illustrative purposes and do not necessarily correlate with real life demurrage fees charged to particular customers. The savings in demurrage costs for Phase 1 vs “No Project” by year are as follows:

- 2021: $26M
- 2026: $40M
- 2036: $52M

These levels of annual savings indicate that the total cumulative savings in demurrage for the project will be in the hundreds of millions of dollars when the entire project life span is taken into consideration.

Dredging the Inner Harbor (Phase 2) actually increases vessel delay compared with dredging Cuts A+B only (Phase 1) because ships can now be loaded heavier and some conflict will now occur between inbound and outbound heavy vessels (See Fig 10). In the 2036 Phase 1 case, there were never any meeting restrictions because no vessels could be loaded heavy enough to cause a conflict due to the limitations of the shallow Inner Harbor.

Presumably, the Phase 2 dredging of the Inner Harbor will be of great value to at least some Port customers due to better economies of scale for cargo shipping worldwide, but it will actually be somewhat counterproductive from the goal of getting ships in and out of POCC with minimum delay.

If the restriction on Suezmax and heavily laden Aframax ships moving only during daylight can be eliminated, vessel delay can be reduced by 20%, and demurrage costs can be reduced by over $10M per year vs the case with the current rules intact.

8. Conclusions

The Port currently experiences a substantial amount of queuing, which will only get worse as the total number of ships increases and as ships grow in size over time. Dredging the channels in Cuts A and B to allow for effectively any to ships to meet will dramatically reduce the queuing at the Port, and will save tens of millions of dollars per year in demurrage.

The widening of the channel via the Phase 1 project should also increase safety considerably. This wider channel will allow coastal barges to operate outside of the main channel on barge shelves. This has the double benefit of allowing faster ship movement, and greater safety due to the larger amount of physical separation between ships and barges.

The Phase 2 project, which dredges the Inner Harbor, actually increases vessel delay somewhat due to the occasional conflict between heavily laden vessels. The benefit of this project will be in network cost savings for operators of large ships, who will need to deploy fewer vessels to move the same amount of cargo. Analysis of this savings was beyond the scope of this project so AECOM cannot comment on the expected overall net benefit of the Phase 2 dredging project.

As the fraction of large ships at the Port increases over time, and as LNGC ships begin to call at the Port, the restrictions around the movement of these ships will have an ever larger impact on overall Port activity. If the restriction to daytime operations only can be lifted, a considerable amount of delay and related demurrage costs can be saved. The same can be said for relaxation of rules prohibiting any ship from meeting an LNGC. These rules are based on safety considerations where the pilots and Coast Guard will have the final say, but in both cases a wider channel is a prerequisite to any potential relaxation of restrictions.

It is important to note that after the dredging project is completed, vessel delay at POCC will not be completely eliminated. Most of the remaining queuing is due to high berth occupancy at busy terminals. Investigation of individual terminal operations was beyond the scope of this study but is an opportunity for follow-on studies (see Chapter 9) to help POCC and its customers better understand where to focus future infrastructure investments in order to effectively increase Port and terminal capacity over the long-term planning horizon.

9. Areas for Future Study

It is important to note the market projections and information about specific new projects or vessel deployment strategies by tenants at POCC are very dynamic and can change very rapidly. Periodic updates to this type of study can ensure that the management and tenants at the Port are making investment decisions based on the best possible information.

Areas for future study include but are not limited to:

Fresh market projections adjusted for recent activity and new projects. Model inputs can be adjusted to take into account recent new specific project or trends in broad economic indicators such as the price of crude or LNG. Further sensitivities can be done to changes in growth to products being imported vs exported, or moved on ships of different sizes.

Sensitivity analysis on different vessel operating strategies. Sensitivity models could be run to examine the impact of mandating convoys for travel, or by setting specific time of day vs direction rules in the harbor.

Analysis of impacts on different Port neighborhoods. Assuming confidentiality issues can be resolved, the impact of dredging can be evaluated on individual Port regions as opposed to the Port-wide focus of this initial study.

Dynamic linking of cargo volume moved to vessel draft. The model can be updated to specifically calculate the departing draft of a vessel based on arrival draft, the shape of the vessel, and amount of cargo transferred. This will give a more detailed analysis of potential meeting conflicts due to draft, and present an integrated input story that ties annual throughput to vessel behavior. This feature can also tie in with evaluation in changes in imports vs exports as it will impact the draft of vessels moving inbound vs outbound.

Analysis of different dredging projects. Any number of alternate physical projects could be analyzed such as:

- Widening only
- Only widening Cut B to match Cut A
- Different rules for ADM/Citgo pinch point operations

Analysis of individual terminal operations to determine throughput capacity and optimal upgrades to berth and backland equipment. In addition to harbor-wide models, terminal specific analysis tools could be used to analyze the throughput capacity of individual terminals and to analyze the impact and the benefit vs cost of individual terminal upgrades such as wharf deepening, or additional of backland storage capability.