SABINE • NECHES
NAVIGATION DISTRICT

Sabine-Neches Waterway Traffic Simulation Model

Draft Report
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David Miller & Associates, Inc.

Executive Summary

The Sabine Neches Navigation District (SNND) developed the Sabine Neches Traffic Simulation Model (model) to evaluate vessel navigation along the Sabine Neches Waterway (waterway). The model incorporates existing and projected navigation rules and restrictions, channel improvements resulting from the waterway Channel Improvement Project (deepening and additional anchorages), projected future terminal expansions and vessel traffic, and potential future channel widening.

Projected future channel dimensions are characterized as either without-widening or with-widening. Under without-widening conditions, the dimensions of the waterway channels include the deepening project currently being constructed. With-widening conditions (Figure E1) add channel widening from Texaco Island to the MARAD Basin by 100 feet on the "red" side (left descending bank). Widening the waterway in these reaches would result in an alteration in the operating protocols established by the Sabine Pilots Association. The revised protocols would eliminate the need for the current daylight restriction, thereby allowing Aframax and Suezmax vessels 24-hour access to facilities on the Neches River and increase the size of vessels that are allowed to meet in the widened reaches. These potential future improvements to navigation along the waterway result in less congestion and fewer delays as compared to without-widening conditions.

Impacts to the "carrying capacity" of the channel are expressed in the number of vessels delayed and the duration of vessel delays presented as annual hours of delay. The model results displayed in the graphs and tables in this report are summarized across all terminals on the waterway. Detailed model results for individual terminals, docks, commodities, and vessel types can be generated and analyzed by request of the terminal operator to Vini Vannicola, Vice President, DMA (vvannicola@dma-us.com). In addition, alternative scenarios, such as changes to the number of docks at a terminal, dock characteristics, vessel size, fleet composition, and tug or pilot availability may be simulated to test alternative future conditions.

The following tables and figures portray summarized model results for the reduction in the number of vessels delayed and the reduction in the duration of vessel delays due to widening the channel from Texaco Island to the MARAD Basin. The model simulations performed for this report assume that tugs and pilots are available as needed. Total wait time is defined as the sum of:

- sea wait time (waiting at sea prior to entering the federal navigation channel);
- dock wait time (after having finished loading or unloading and associated tasks – waiting for the channel to clear so the vessel can depart); and
- anchorage wait time (after having spent the minimum four hours at the anchorage – waiting for the berth or channel to clear so the vessel can get underway).

Total Number of Vessels Delayed

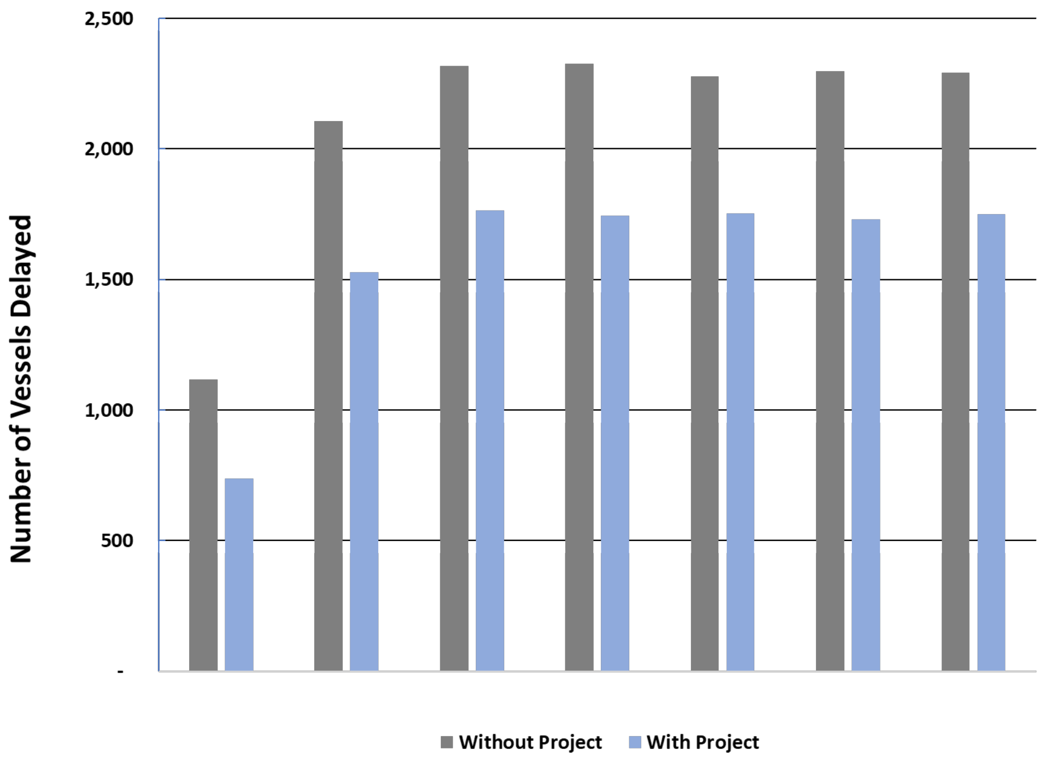
Table E1 and Figure E2 present the total number of vessels delayed under without-widening and with-widening conditions. The modeled delays are attributable to channel congestion and do not reflect resource scarcity concerning tugs and pilots. For each vessel call, the vessel may be delayed on either the inbound or outbound transit. Note that the number of delayed vessels is substantial and is not greatly reduced by widening the channel. For example, in 2019 under without-widening conditions 38% of all vessel calls (1,118 calls) incurred some delay greater than 5 hours. In 2030, that percentage increases to 55% of all vessel calls (2,318 calls) under without-widening conditions; however, under with-widening conditions the percentage of delayed vessels is reduced to 42% (1,764 calls).

Figure E1
Widened Areas Under With-Widening Conditions

Table E1:
Vessels Delayed Under Without and With-Widening Conditions: 2019-2050

		Number of Calls	Vessels Delayed	Percent of Vessel Calls
2019	Without	2,904	1,118	38%
	With	2,904	737	25%
2025	Without	3,886	2,106	54%
	With	3,886	1,527	39%
2030	Without	4,204	2,318	55%
	With	4,204	1,764	42%
2035	Without	4,204	2,328	55%
	With	4,204	1,744	41%
2040	Without	4,204	2,277	54%
	With	4,204	1,753	42%
2045	Without	4,204	2,297	55%
	With	4,204	1,731	41%
2050	Without	4,204	2,292	55%
	With	4,204	1,750	42%

Figure E2:
Vessels Delayed Under Without and With-Widening Conditions: 2019-2050



Duration of Vessel Delays

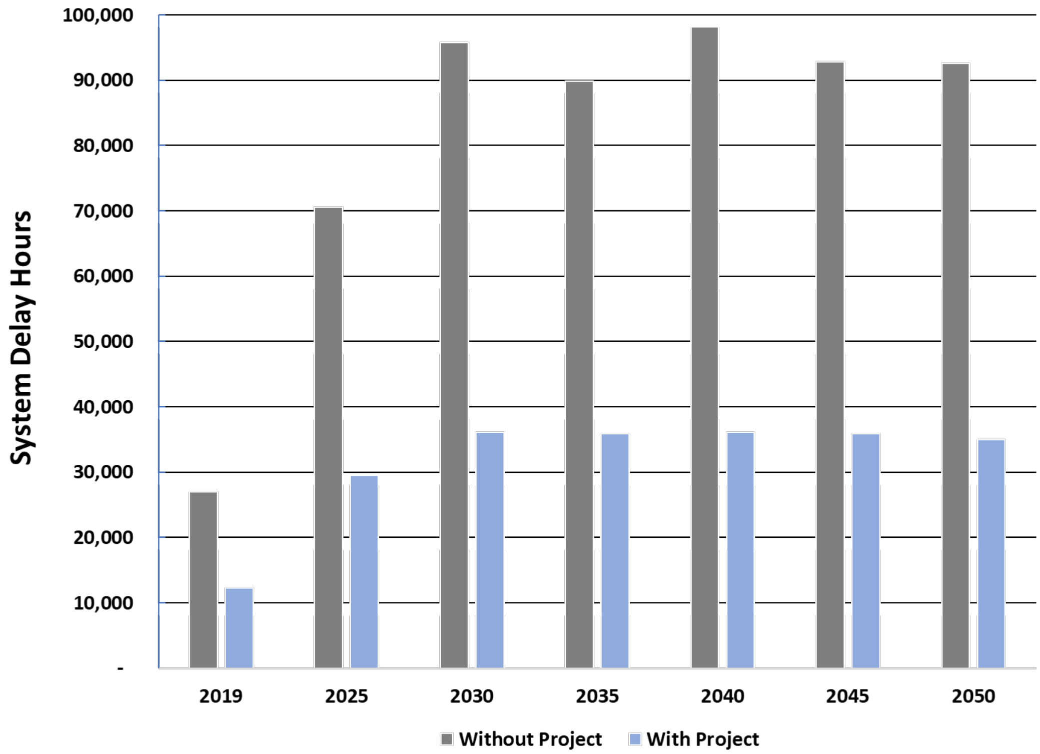
Vessel delay durations are presented in hours per year. Table E2 and Figure E3 show the total vessel delay durations for the entire waterway for each modeled year. The reduction in delay duration due to the widened channel is substantial. If the widened channel had been in place in

2019, the model estimates that there would have been a 54 percent reduction in total delay time for the year. For 2030, the model results indicate that the widened channel would reduce projected delays by 62 percent. Also in 2030, the average delay per vessel call is reduced from 22.8 hours to 8.6 hours.

Table E2:
Reduction in Delay Times: 2019-2050

		Number of Calls	Total Delay Hours	Average Delay Hours	Delay Hours Reduction
2019	Without	2,904	27,000	9.3	14,700
	With	2,904	12,300	4.2	
2025	Without	3,886	70,550	18.2	41,000
	With	3,886	29,550	7.6	
2030	Without	4,204	95,800	22.8	59,700
	With	4,204	36,100	8.6	
2035	Without	4,204	89,850	21.4	53,900
	With	4,204	35,950	8.6	
2040	Without	4,204	98,150	23.3	62,000
	With	4,204	36,150	8.6	
2045	Without	4,204	92,850	22.1	57,000
	With	4,204	35,850	8.5	
2050	Without	4,204	92,600	22.0	57,650
	With	4,204	34,950	8.3	

Figure E3:
Reduction in Delay Hours: 2019-2050



Cost of Vessel Delays

Vessel delay costs provided in Table E3 are calculated only for vessel operations based on the total amount of time that a vessel is in the waterway system – starting at arrival from the sea and ending at leaving the entrance channel for the sea. This approach to calculating cost reductions is based on USACE guidance for the economic evaluation of deep draft navigation projects. The cost reduction calculations due to the widening do not include the benefits of increased berth efficiency or the opportunities for servicing more vessels at a berth. Alternative terminal-related cost savings and potential benefit calculations may be evaluated through additional model simulations and calculation methods to test alternative future conditions, at the request of the terminal operator.

Had the channel been widened in 2019, there would have been a reduction of $23 million in vessel operating costs within the waterway that year. The cost reduction for 2025 is estimated to be $64.2 million and $99.4 million in 2030. Annual vessel operating cost savings increase by 179 percent from 2019 to 2025 and increase again by 55 percent from 2025 to 2030. All cost savings are directly attributed to the channel widening from Texaco Island to the MARAD Basin.

Table E3:
Reduction in Delay Costs: 2019-2050 ($)

		Number of Calls	Vessel Delay Operating Costs	Vessel Delay Operating Costs Reduction
2019	Without	2,904	40,600,000	23,000,000
	With	2,904	17,600,000	
2025	Without	3,886	109,900,000	64,200,000
	With	3,886	45,700,000	
2030	Without	4,204	156,400,000	99,400,000
	With	4,204	57,000,000	
2035	Without	4,204	146,500,000	89,400,000
	With	4,204	57,100,000	
2040	Without	4,204	163,100,000	105,800,000
	With	4,204	57,300,000	
2045	Without	4,204	152,400,000	95,100,000
	With	4,204	57,300,000	
2050	Without	4,204	152,100,000	96,600,000
	With	4,204	55,500,000	

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1 Introduction

The Sabine Neches Waterway is the focus of a substantial and sustained series of investments that increase waterway tonnage and the number of vessels transiting the waterway. From 2011 to 2021 $53 Billion in industry and terminal projects have been completed or are currently under construction. In addition, another $30 Billion in proposed investments have been identified. In 2009, there were 3,300 vessel transits with drafts of 20 feet or greater; in 2019, that number increased to 5,600. In the five years from 2014 to 2019, export tonnage more than doubled from 32 million short tons to 85 million short tons. The increase in transits and tonnage is projected to continue as ongoing construction projects along the waterway are completed and proposed projects are implemented.

The federal channel along the waterway is currently being deepened from -40 feet MLLW to -48 feet MLLW, but the ongoing deepening project does not widen the channel and current navigation restrictions will remain in effect after the channel is deepened. The channel currently is and will remain 400 feet wide in the Sabine-Neches Canal and the Neches River reaches. In 2019, there were 4,500 vessel transits along these reaches. Based on navigation rules for the waterway, Panamax vessels cannot meet other Panamax-size or larger vessels in the 400-foot channel reaches. In 2019, there were 4,300 transits by Panamax-size or larger vessels. In addition, Aframax and Suezmax vessels are restricted to transiting the 400-foot channel reaches in daylight only causing 1,200 vessel daylight restricted transits in 2019.

The navigation restrictions required for a 400-foot-wide channel combined with the increasing number of vessels transiting the waterway is the cause of substantial congestion and vessel delays. Vessels that are too large to meet in the narrow channel must wait for the channel to clear before entering from the sea or leaving from the dock. Vessels too large for nighttime transits must wait for daylight and a clear channel before entering from the sea or leaving from the dock. These delays also exacerbate weather delays because the more time a vessel spends in the system the more exposed that vessel is to weather delays during the difficult weather season.

There has long been a concerted effort among waterway users to reduce delays and maximize the navigational opportunities along the waterway. Vessel scheduling, the use of "caravans", and queuing rules are all a part of the choreography of getting vessels to and from their berths as efficiently as possible. The effectiveness of these operational efforts is limited by the physical constraint of a 400-foot-wide channel, the size of vessels using the channel, and the number of these vessels.

The Sabine Neches Navigation District (SNND) undertook an analysis to investigate how channel widening might improve navigation along the waterway to relieve congestion and reduce vessel delays. This analysis requires incorporation of

- existing and projected navigation rules and restrictions,
- ongoing channel deepening and additional anchorages resulting from the waterway Channel Improvement Project,
- projected future terminal expansions and associated increases in tonnage and traffic, and
- alternative future channel widths at various locations.

The Sabine Neches Traffic Simulation Model (model) was developed to evaluate how different channel widths along various channel reaches, different terminal configurations, and different traffic forecasts would affect navigation along the waterway. The model simulates a full year of traffic flow to test the effects of various conditions on all vessels' time in the system, including time waiting to enter the channel and time waiting to leave the dock. Simulations for different future years reflect projected future traffic, tonnage, and terminal configurations for that year. The model is a planning tool that can identify optimal channel widths and traffic flow conditions, such as number of docks, number and type of vessels, and tonnage.

Projected future channel dimensions are characterized as either without-widening or with-widening conditions. Under without-widening conditions, the dimensions of the waterway channels include the deepening project's phased construction: 44-foot depth in 2025 and 48-foot depth in 2030 and future years. The without-widening condition is the reference against which alternative improvements are compared. With-widening conditions include widening the channel to varying widths at multiple locations.

The model evaluates projections of traffic flow along the waterway at 5-year intervals from 2025 to 2050 that are analyzed to determine impacts of future commodity and fleet distributions on projected future vessel traffic and terminals. Model output is used to evaluate traffic flow under alternative future channel width conditions to identify opportunities for potential traffic flow improvements.

The model consists of four key components:

1. Waterway geographic configuration,
2. Vessel call lists for Years 2019, 2025, 2030, 2035, 2040, 2045, and 2050
3. Sabine-Neches Traffic Simulator, and
4. Simulation output.

The waterway geographic configuration includes the entire federal navigation channel and associated terminals, docks, turning areas and anchorages. The vessel call lists include all deep draft traffic, including articulated tug-barges (ATBs). The waterway geographic configuration and vessel call lists are model inputs based on historical and projected data. The Sabine-Neches Traffic Simulator contains the model logic that reflects alternative traffic rules, resource availability, operating procedures, and operating conditions such as daytime/nighttime and weather. The Simulation output calculates each vessel's total time within the Sabine Neches Waterway including time spent waiting to enter the federal channel from the sea, time spent working at the dock, time spent waiting to leave the dock, time at anchorage, and time spent delayed by weather. Outputs are aggregated for the entire waterway to avoid the risk of violating any confidentiality agreements. That said, the simulation output for with-widening and without-widening conditions are available for every vessel in the call lists for each modeled year, and can be displayed and analyzed by terminal, dock, and vessel type. Detailed simulation output tables for each terminal will be provided to authorized terminal representatives by request of the terminal operator to Vini Vannicola, Vice President, DMA (vvannicola@dma-us.com).

1.1 Organization of Report

The model was developed with extensive assistance and input from vessel and terminal operators as described in Section 2. The model consists of four components: the waterway geographic configuration (Section 3), vessel call lists (Section 4), Sabine Neches Traffic Simulator (Section

5), and simulation output (Section 6). Model results and further analytical capabilities are described in Section 7.

2 Coordination with Terminal Operators, Pilots, and USCG

Vessel operations data for 2018 and 2019 were provided by the Sabine Pilots Association for all piloted vessel transits. The United States Coast Guard provided 2018 and 2019 Vessel Traffic System data for all vessel (ships, tugs, and tows) movements within the waterway.

Vessel cargo data was based on 2018 and 2019 PIERS data that was verified, corrected, and augmented by data provided by 16 terminals representing 92% of waterway tonnage.

The model logic contained within the Sabine-Neches Traffic Simulator was developed in consultation with the Sabine Pilots Association and verified through a video interface that allowed the pilots to witness and review simulated traffic flow. After multiple sessions of video review by the pilots, model logic was adjusted to better reflect operating procedures and protocols.

Ship simulation modeling included sessions at the Marine Pilots Institute and the San Jacinto Maritime College. Desktop simulations performed at the SNND offices were also used to verify vessel operating procedures under alternative with-widening conditions. Full bridge simulations included ship and tow interactions with members of the Sabine Pilots Association operating the ship and multiple tow operators from the Gulf Intracoastal Canal Association operating the tow.

3 Waterway Configuration

The geographic representation of the waterway and associated port facilities was mapped using GIS software and consists of channels, docks, turning areas, and anchorages.

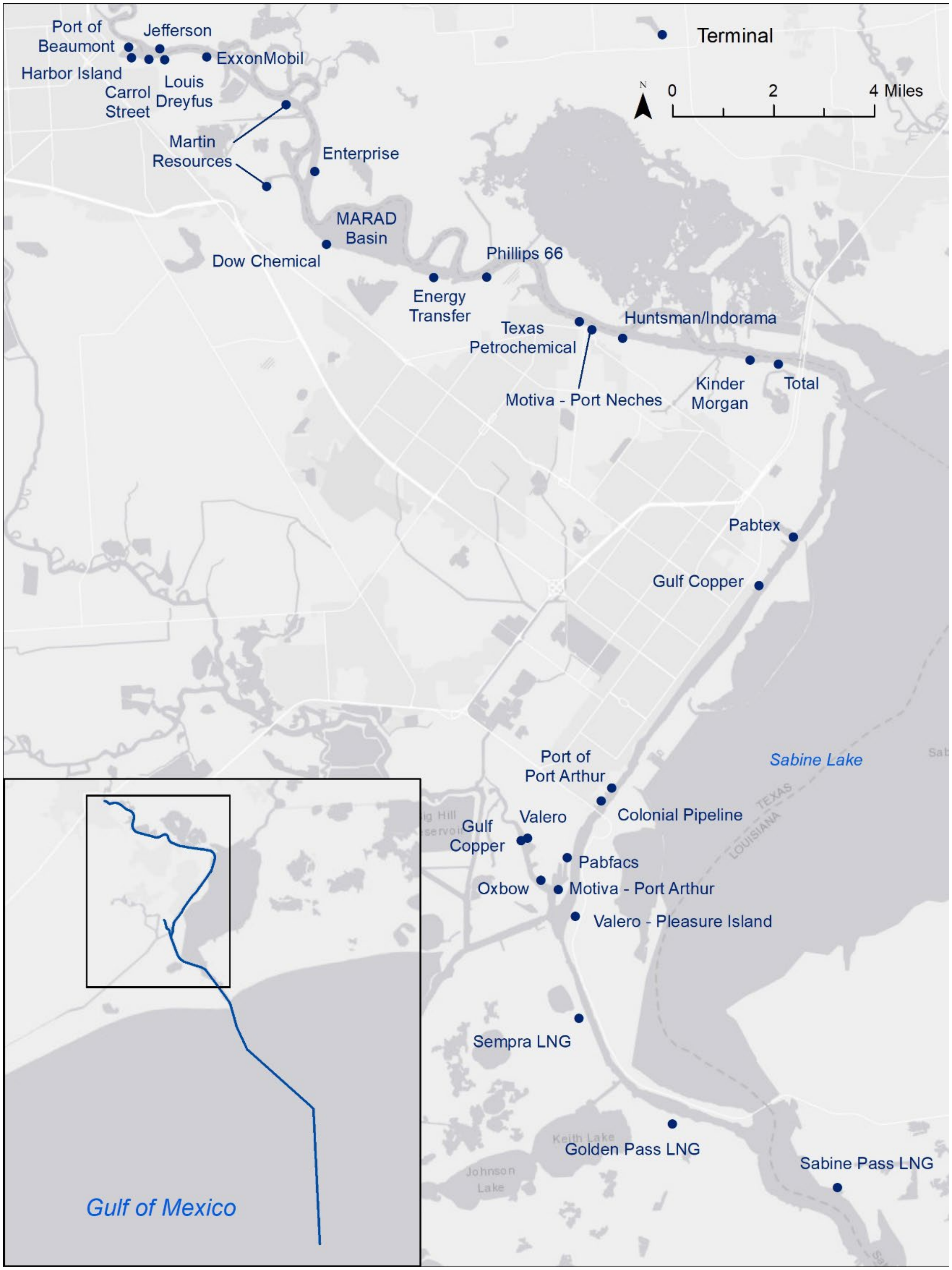
3.1 Channels

The federal navigation channel is measured in feet from the entrance in the Gulf of Mexico to the Neches River upstream of the Port of Beaumont, including a fork allowing access into Taylor's Bayou. In 2019 model runs, channel depth is -40 feet MLLW and the beginning of the Federal channel is located at the current location of the Sabine Sea Buoy (model-foot-marker 69,695); however, channel deepening will move the entrance more than 13 miles farther offshore. Model runs for 2025 include a 44-foot channel depth, therefore the channel entrance begins at model-foot-marker 34,847.5. Model runs for 2030 and future years include a 48-foot channel depth, therefore the channel entrance begins at model-foot-marker 0. Federal anchorage depths are equivalent to channel depths in all modeled years.

Channel widths are a variable parameter of the model. Future without-widening condition channel widths are equivalent to existing condition channel widths, with the exception of the Sabine Bank Channel that will be reduced from 800 feet to 700 feet as a part of the deepening project. Future with-widening channel widths can be varied in alternative model runs to assess the effects on traffic flow. The length and location of widened reaches are also variable within the model.

The waterway is represented using two distinct "routes". The Taylor's Bayou Route provides access to those docks within Taylor's Bayou and the Port Arthur-Neches River Route provides access to those docks above Texaco Island. The channel below the intersection at Texaco Island is shared by both routes. Figure 1 depicts the waterway; note that all terminals shown are in operation with the exception of the Sempra LNG and Golden Pass LNG, which are under construction.

Figure 1
Overview of the Sabine-Neches Waterway and Deep Draft Terminal Locations



3.2 Docks

Terminal operators on the Sabine-Neches Waterway use one or more docks to service deep draft vessels and barges. Dock properties include dock name, route, and model-foot-marker (distance from the channel entrance in the Gulf of Mexico). Each dock is situated at a unique location within the waterway in the vessel traffic simulator. Additional dock properties including the vessel type and commodity type(s) accommodated at the dock and commodity transfer rate. Commodity tonnage and transfer rate are used to determine the work-time duration of a dock visit within the vessel call list. Dock berth controlling depth is identical to the adjacent channel depth.

Terminal operators provided information on current and projected future use of their docks, including projected dock modification and future dock construction. In addition, model output for future years was analyzed for docks with exceptionally high utilization that were causing unacceptably long delays. At some terminals, an additional dock was included in a vessel's choice set by the modeler (either as modification of underutilized existing docks to accommodate additional vessel types or as construction of a new dock adjacent to or near to existing terminal facilities) to reduce vessel delays attributable to exceptionally high dock utilization rates. This adjustment was made to better reflect likely future conditions.

3.3 Turning Areas

Turning areas in the Sabine-Neches Waterway are used to turn light-loaded vessels as is standard operating procedure on the waterway. There are 14 turning areas, including six Federal turning areas and eight non-federal turning areas. Turning area properties include name, route, and model-foot-marker. In addition, the maximum vessel length and maximum vessel deadweight tonnage are properties assigned to each turning area used to determine whether a vessel may use a turning area. Turning area depth is coincident with channel depth. Dock-turning area associations were verified with the Pilots.

3.4 Anchorages

Model configuration includes seven anchorages in the Sabine-Neches Waterway (three Federally authorized and maintained; five privately maintained), all of which are found in the Neches River. Anchorage properties include name, route, model-foot-marker, and controlling draft, such that only those vessels with a current draft less than or equal to the controlling draft may use the anchorage. In-bound vessels may go to an anchorage and wait for the appropriate dock to be vacated. This practice occurs regularly on the waterway and allows vessels to avoid being impacted by the daylight restrictions. Vessels do not typically go from a dock to an anchorage for the purpose of freeing up the dock for another vessel. Doing so may be advantageous to the terminal operator, but it is expensive for the vessel because it creates two separate vessels movements each requiring tugs and pilots. The minimum time at anchorage is assumed to be four hours, based on an examination of VTS anchorage data.

4 Vessel Call Lists

The vessel call list identifies each vessel transit through the waterway for a modeled year. The 2019 vessel call list is built from data on actual vessel transits that occurred in 2019 and is the basis for all future call lists. Vessel call lists for 2025 – 2050 are developed from the 2019 vessel call list by adding or removing cargo or vessel calls as guided by the commodity and fleet forecasts (discussed below). The 2019 vessel call list is the accumulation of observed and recorded data for each deep draft vessel and ATB call. Data from four different sources was used to time stamp vessel movements, quantify cargo loads, and identify dock and anchorage usage for each vessel call in 2019.

4.1 2019 Vessel Call List Development

The data sources for the 2019 vessel Call List are listed below, briefly introduced, and referenced throughout the remainder of this Section in technical discussions.

- Port Import/Export Reporting System (PIERS), a database of import and export data at the detailed, bill-of-lading level, which mirror data that are filed with US Customs. PIERS data specific to the Sabine Neches Waterway were used as the first step in establishing import and export cargo volumes. PIERS data include the following cargo information:
    - Cargo designation of export or import
    - Date of cargo transfer from or to a vessel
    - Foreign country of cargo origin or destination
    - Cargo commodity group, codes, and descriptions
    - Cargo quantity and units of measure (non-weight based)
    - Cargo weight
    - Vessel IMO number
    - Vessel name
- Confidential Cargo Data voluntarily provided by Sabine Neches Waterway terminal operators established refined volumes of import and export cargo volumes. In addition to verifying (and correcting) PIERS foreign cargo volumes and/or tonnages, the individual terminal data contained information on domestic cargo volumes, which is absent from PIERS data.
- Sabine Pilots Vessel Transit Data provide vessel movement data for all vessels requiring pilot assistance for the years 2018 and 2019. Each vessel movement is contained in a single record (or row) in the data provided by the Sabine Pilots. For example, one record will provide data on the vessel's movement from open water to an anchorage, and a separate record will provide data on the vessel's movement from the anchorage to a dock, and a final record will provide data on the vessel's movement from a dock to open water. Vessel transit data include:
    - Vessel Name
    - Vessel Description
    - Vessel IMO number
    - Vessel Call Sign
    - Vessel Draft upon boarding
    - Location and time at which a pilot boarded a vessel
    - Location and time at which a pilot disembarked a vessel
- Lloyds List Intelligence, an on-line subscription database used to gather information on the existing and future projected fleet of crude oil vessels (i.e., vessel deadweight tons (DWT), immersion rate, design draft, vessel liquid capacity volume).

Blending of the four data sets (see Figure 2) creates a list of distinct vessel visits carrying a specific type and amount of cargo to or from a dock within the waterway during 2019. Each vessel call begins at a specified date and time at the channel entrance, as noted by the pilot's data. The vessel name, IMO, type, draft, and destination dock are cross referenced from multiple data sets. Vessel characteristics are based on Lloyds List Intelligence data for self-propelled vessels, and VTS data for articulated tug-barge units. Cargo type, tonnage, and import, export or domestic designation are also cross referenced with PIERS and terminal data. The 2019 vessel call list tonnage (128.3 million short tons) is within 2.6% of the 2019 Sabine Neches Waterway cargo tonnage (125.1 million short tons) as identified in the 2019 USACE Waterborne Commerce Statistics. Cargo transfer rates and working time at the dock are based on terminal records or estimated from terminal records and confirmed by the terminals. Vessel departure time and departure draft are based on pilot's data cross referenced with terminal data.

4.2 Vessel Call Lists for Years 2025 – 2050

The 2019 vessel call list was used as the template for future-year vessel call lists. The commodity forecast and the fleet forecast were used to adjust the 2019 vessel call list for future years. Additionally, future-year vessel call lists include a dock choice set for each vessel call and randomized vessel arrival times. Each future-year vessel call list begins in November of the previous year so the modeled year (01Jan – 31Dec) does not begin with an empty waterway. This adjustment better reflects reality and increases the number of vessels in the system during the first week of the year by nearly 50%. All model output and post-processing excludes the previous year's November and December traffic.

4.2.1 Commodity Forecasts

The commodity forecast incorporates national import and export forecasts published in the Energy Information Administration's (EIA) Annual Energy Outlook (February 2021) and individual forecasts by terminal operators. Non-hydrocarbon based commodities, which were only 3.7% of total waterway cargo in 2019, were assumed to have no growth throughout the period of analysis.

Future-year vessel call list commodity tonnage was generated by applying the appropriate growth rate (for commodity type, year, and direction of trade) to cargo identified in the 2019 vessel call list. Changes to 2019 cargo tonnage was applied terminal-by-terminal with the intention of using available capacity in the existing fleet calling at each terminal prior to adding additional vessels. Additional cargo, if any, as identified by the commodity forecast in future years was loaded onto vessels in the 2019 vessel call list according to commodity type, terminal, trade direction and vessel type.

Vessel loading is based on the vessel's 2019 cargo tonnage, loaded draft, immersion factor, draft capacity, and volumetric capacity. Note that channel depth (-44 feet in 2025 and -48 feet in 2030) constrains vessel loading for large deep draft vessels. If a vessel reached a capacity constraint, available capacity on another vessel with the same commodity type, terminal, trade direction and vessel type combination was used. If there was no such capacity available, then capacity on the next largest vessel type that met the same commodity type, terminal, and trade direction was used.

Commodity forecasts provided by individual terminal operators, based on planned terminal improvements, were used to add additional cargo to the commodity forecast and to add additional vessels to the fleet forecast.

Figure 2
Databases Used in Development of 2019 Vessel Call List

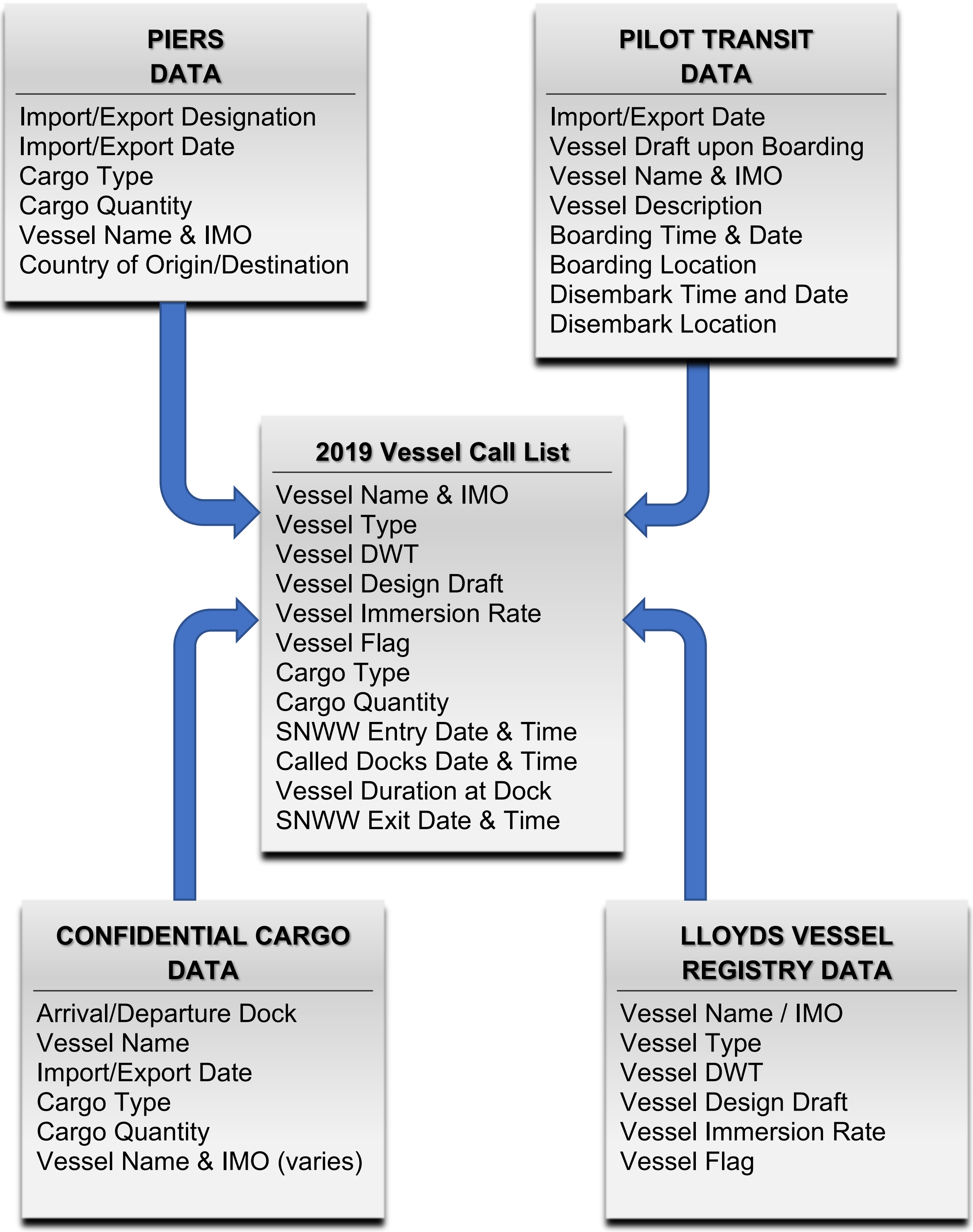


Table 1 shows the growth rates calculated from the 2021 Annual Energy Outlook (2021 AEO) in five-year increments. Table 2 shows the national tonnages for each 2021 AEO commodity category used in this analysis. Table 3 provides the national increase or decrease in commodity tonnages in five-year increments. Table 4 presents the SNWW commodity tonnages used in this analysis, and Table 5 presents the SNWW increase or decrease in commodity tonnages in five-year increments

Table 1
Five-Year Annual Percentage Growth Rates from 2021 AEO

Commodity	2025*	2030	2035	2040	2045	2050
Crude Oil Gross Imports	1.3	-1.6	0.1	1.4	-0.6	1.0
Crude Oil Exports	2.7	-1.2	0.8	-0.3	-0.9	0.4
Gross Refined Product Imports	-5.6	2.9	-0.2	0.5	0.7	-0.3
Refined Product Exports	4.3	0.4	-0.9	-0.4	-0.9	-1.5

*2025 represents a six -year growth rate from 2019 to 2025
Source: 2021 Annual Energy Outlook (February 2021)

Table 2
National Tonnages for Select 2021 AEO Commodities
(Metric Tons x 1000)

Commodity	2025	2030	2035	2040	2045	2050
Crude Oil Gross Imports	379,651	349,928	351,032	376,385	365,867	384,383
Crude Oil Exports	158,383	148,878	154,664	152,395	145,814	148,684
Gross Refined Product Imports	28,770	33,132	32,809	33,653	34,830	34,330
Refined Product Exports	336,631	344,136	328,527	321,203	307,423	284,969

Calculated from 2021 Annual Energy Outlook (February 2021)

Table 3
2021 AEO National Tonnage Estimates 5-Year Incremental Change
(Metric Tons x 1000)

Commodity	2025	2030	2035	2040	2045	2050
Crude Oil Gross Imports	53,438	21,133	-15,575	-27,579	-9,344	-6,527
Crude Oil Exports	74,493	-29,723	1,104	25,353	-10,518	18,516
Gross Refined Product Imports	5,207	-9,506	5,787	-2,269	-6,582	2,870
Refined Product Exports	-15,093	4,362	-323	844	1,177	-500

Calculated from 2021 Annual Energy Outlook (February 2021)

Table 4
Sabine-Neches Waterway Commodity Tonnages Used in Traffic Model
(Metric Tons x 1000)

Commodity	2025	2030	2035	2040	2045	2050
Crude Oil Imports	22,124	20,180	19,974	20,653	20,760	21,037
Crude Oil Exports	47,384	45,337	45,535	44,334	42,572	42,657
LNG (Export)	43,913	65,657	65,657	65,657	65,657	65,657
LPG (Export)	18,813	18,920	18,828	18,673	18,601	18,469
Product & Related Imports	2,559	1,978	2,112	2,483	2,617	2,731
Product & Related Export	39,904	40,808	39,149	37,935	36,991	35,955
Not Oil &Gas Related	4,268	4,266	4,266	4,266	4,266	4,266
Total	**178,965**	**197,146**	**195,521**	**194,002**	**191,464**	**190,773**

Table 5
Change in Sabine-Neches Waterway Commodity Tonnages (5-Year Increments)
(Metric Tons x 1000)

Commodity	2025	2030	2035	2040	2045	2050
Crude Oil Imports	2,211	-1,944	-207	679	108	277
Crude Oil Exports	16,419	-2,048	199	-1,201	-1,763	86
LNG (Export)	20,990	21,744	0	0	0	0
LPG (Export)	13,731	107	-93	-155	-73	-131
Product & Related Imports	-930	-580	134	371	134	113
Product & Related Export	10,154	904	-1,659	-1,214	-944	-1,037
Not Oil &Gas Related	1	-2	0	0	0	0
Total	62,576	18,181	-1,625	-1,519	-2,538	-692

2025 represents a six -year growth rate from 2019 to 2025

4.3 Fleet Forecast

The fleet observed in the 2019 vessel call list is the basis for the fleet forecast. As described in the commodity forecast discussion, commodity growth as forecasted in the 2021 AEO was distributed to the 2019 fleet. All vessels added due to individual terminal projections were also based on the 2019 vessel call list so that added vessels matched physical and operational characteristics of vessels that called at the terminal in 2019. The 2019 vessel call list, because it displays the actual date and time of arrival and departure, identifies the scheduling patterns for each dock. All added vessel calls were inserted into future-year vessel call lists with arrival dates that mesh with the 2019 scheduled vessel arrivals to avoid schedule conflicts. In future year vessel call lists, the time of arrival at the sea buoy is randomized by adding a randomly selected amount of time between 0 and 12 hours. Table 6 displays the number of vessel calls by vessel class for 2019 and each modeled year.

In addition, vessels in future year vessel call lists have a choice set of docks that may be used at each terminal. Dock choice sets range from one to four docks depending on terminal, commodity type, and vessel type. If high rates of berth utilization were found to cause delays, additional docks were added to a terminal or dock attributes were modified to allow handling of multiple commodities. In this manner, hours in the system calculated by the SNTS were not unduly influenced by high berth utilization rates that would likely be addressed by the terminal operators.

Table 6
Vessel Calls by Vessel Class for 2019 and Modeled Years

	2019	2025	2030	2035	2040	2045	2050
Aframax Tanker	549	595	595	595	595	595	595
Aframax Bulk	7	7	7	7	7	7	7
ATB	328	326	326	326	326	326	326
Handy Bulk	237	237	237	237	237	237	237
Handy Tanker	179	178	178	178	178	178	178
LNG	336	643	961	961	961	961	961
Long RORO	4	4	4	4	4	4	4
LPG	136	420	420	420	420	420	420
Panamax Tanker	806	1,008	1,008	1,008	1,008	1,008	1,008
Panamax Bulk	187	187	187	187	187	187	187
Pmax RoRo	36	36	36	36	36	36	36
Suezmax	99	245	245	245	245	245	245
TOTAL	**2,904**	**3,886**	**4,204**	**4,204**	**4,204**	**4,204**	**4,204**

5 Sabine Neches Traffic Simulator

The Sabine Neches Traffic Simulator (SNTS) is a configurable engine for processing the vessels and cargo in a vessel call list through the navigation channel, docks, turning areas, and anchorages in the Sabine-Neches Waterway according to the navigation rules implemented by the pilots. The SNTS is specifically designed to emulate the operations of the Sabine-Neches Waterway and is not directly applicable to other ports. The vessel call list is used to provide the day and time the vessel arrives "over the horizon" at the waterway, number and order of docks to be visited, working duration of each dock visit (including total time for docking, commodity transfer, and undocking), and turning area(s) to be used. Anchorage use is opportunistic according to anchorage availability and is not scripted by the vessel call list. An arriving vessel will use an anchorage if using the anchorage allows the arriving vessel to avoid being delayed by the daylight restriction. Note that the Pilots will move an otherwise daylight restricted vessel from the anchorage to a nearby dock at night.

5.1 SNTS Concepts

The SNTS is built from a group of components that together implement the model logic. Each component is identified below and its function in model implementation is described.

5.1.1 Timestep

The simulator implements a time series used to track vessel movements through the waterway over the simulation duration. The fundamental unit of time is the timestep, a configurable value measured in integer minutes. The model timestep used throughout the analyses presented here is 10 minutes, such that all vessels and associated navigation conditions are assessed in 10-minute intervals throughout the full simulation duration.

5.1.2 Simulation Duration

Each model simulation has a begin date and an end date, as defined by a starting date and the number of minutes to simulate. The model analysis period begins January 1 at 00:00 and a duration of 525,600 minutes (one year); however, to avoid model simulations beginning with an empty port, an additional two months of model simulation (November and December of the previous year) are used to simulate a fully loaded port at the time of model initiation. As such, the full simulation duration is typically 613,440 minutes. All analyses of model output are restricted to only one year (January 1 through December 31).

5.1.3 Channel Entrance

A vessel transit begins when a vessel “arrives” at the channel start location according to the arrival time provided in the vessel call list; however, given the traffic and weather conditions in the waterway at the arrival time, the vessel may be required to wait at sea before entering. Waiting at sea is a common occurrence and there are multiple offshore areas where a vessel may wait. Neither the vessel call list nor the SNTS designates where the vessel might wait.

5.1.4 Channel Widths

Existing channel widths are a part of the port configuration; however, the existing channel width may be overridden within the SNTS to create with-widening conditions, such that one or more reaches of the waterway is modified according to project alternatives within the simulation.

5.1.5 Weather

Weather delays due to fog or high seas are a common occurrence during the winter months in the Sabine-Neches Waterway and must be considered when modeling vessel traffic.

Weather delays are implemented in the model so that all vessels in motion or attempting a move (entering the waterway, departing a dock, or departing an anchorage) are held in their present position and may not move again until the end of the weather delay. During a weather delay, vessels transferring cargo or bunkering when the weather delay begins continue those operations unimpeded (i.e., vessels at dock continue to accrue dock working time associated with commodity transfer and vessels at anchorage continue to accrue anchorage time associated with bunkering). Once a weather delay has elapsed, vessels in motion prior to the delay continue their movements through the waterway.

For SNTS simulations, a statistically equivalent synthetic year of weather events was created using weather delay data from 2007 to 2019. This synthetic record of weather delays was used for all simulations.

Weather delay data covering the 13-year period of January 1 2007 through December 31 2019 were obtained from Sabine Pilots. The data includes a description of whether the channel was closed or open, the date and time the event began, and the time and date the event ended. The frequency of weather delay events by each year in the 13-year examination period is provided in Table 7 below.

Table 7
Frequency of Weather Delay Events by Year

Year	Frequency
2007	47
2008	47
2009	31
2010	27
2011	30
2012	34
2013	32
2014	44
2015	47
2016	43
2017	13
2018	44
2019	47

The median frequency of events per year for the data shown in Table 7 above is 43, which was taken as the target number of weather events for the simulated weather year. Next, the frequency of weather delays by month was generated to further refine the simulated weather year targeted days by month.

Table 8
Frequency of Weather Delay Events by Month
(13 Years, 486 Weather Events)

Month	Frequency	Percent
1	99	20%
2	96	20%
3	70	14%
4	37	8%
5	8	2%
6	4	1%
7	4	1%
8	4	1%
9	7	1%
10	16	3%
11	55	11%
12	86	18%

A frequency of each day of the year on which a weather delay occurred was generated. The median number of weather events per year from 2007 – 2019 is 43. Days of the year were sorted by their frequency of occurrence, and the 43 days with the highest frequency of weather events in the 13 years of data were selected for use in the simulated weather year. Weather event start time in the simulated weather year was calculated for each of the 43 days as the average channel closure start time as recorded by the pilots for each weather event day. The duration of channel closures in the simulated weather year was calculated as the average channel closure duration for each of the 43 days used in the simulated weather year.

5.1.6 Pilots

Pilots are used to navigate vessels through the port as identified in the Ship Traffic Operating Protocol for the Sabine-Neches Waterway. The number of pilots used by a vessel depends on vessel type and dimensions. Two pilots are used when piloting a vessel with a beam 120 feet or more or a length over all of 860 feet or more. Smaller vessels use one pilot. Pilots are assumed to be available and ready when the vessel is ready to be underway, as such, the time it takes for a pilot to arrive at a vessel is not considered in the vessel traffic simulator. The SNTS tracks the number of pilots used at every timestep and can constrain the total number of pilots available for use. When pilots are constrained, vessels must wait at dock or at sea until the appropriate number of pilots are available.

5.1.7 Tugs

The number and type of tugs (pusher tugs vs tractor tugs) used to guide vessels through the channel and at turning areas and docks varies with vessel characteristics and location within the channel. The SNTS tracks the number and type of tugs used at each timestep. Terminals with dedicated tugs are not considered when tracking tug usage. Tugs are used in the following situations:

- Two tugs are used during the 15 minutes prior to turning;
- Two tugs are used during turning;
- Two tugs are used during the first 60 minutes of dock time during the mooring process;

- Two tugs are used during the first 40 minutes of the unmooring process;
- One tug is used to accompany Aframax and Suexmax vessels transiting the channel above Texaco Island;
- Loaded vessels mooring at Pleasure Island Dock use three tugs.

The time it takes for a tug to arrive from a different location within the channel is not considered in the vessel traffic simulator. The number and type of tugs available during a simulation can be constrained. Unless constrained, the appropriate number and type of tugs are assumed to be available for use during the timestep when and where they are required. When tugs are constrained, vessels must wait at dock until the appropriate number and type of tugs are available. Inbound vessels arriving from the sea are not affected by the number of available tugs.

5.1.8 Vessel Speed

All simulated vessels transiting the waterway abide by the same speeds. Those vessels in the entrance channel, but outside the jetty tips, travel at 12.0 knots, whereas vessels anywhere inside the jetty tips and up to the Port of Beaumont travel at 6.0 knots. Using consistent travel speeds for all vessels ensures that in the model no vessels overtake another vessel traveling in the same direction, which is consistent with standard operating procedures for the waterway.

5.1.9 Daylight Restrictions

According to the Sabine Pilots Association operations protocols, vessel movement within the Sabine-Neches Waterway is currently restricted to daylight-only for vessels moving above Texaco Island if the vessels have a deadweight tonnage greater than 85,000, have a length overall of 875 feet or greater, or have a beam of 125 feet or greater, i.e., Aframax and Suezmax vessels. The SNTS determines whether it is daylight according to astronomical tables for Port Arthur, TX. Dawn and dusk times vary throughout the year and according to the definition of daylight used. The simulator can use the definitions of civil daylight, nautical daylight, or astronomical daylight, with the default setting of nautical daylight. The determination of the daylight status occurs at each 10-minute timestep.

It should be noted that the pilotage rules permit moving a daylight-restricted vessel between docks and nearby anchorages at night, such that vessels below the Neches River Beacon 26A may move to another point on the Neches River below Beacon 26A and vessels above Beacon 26A may move to another point above Beacon 26A, but not above Stanolind Anchorage. These rules are included in the SNTS.

5.1.10 Vessel Meetings

Before initiating a vessel movement, the SNTS determines if the vessel attempting to move will encounter another moving vessel within the waterway. If an oncoming vessel will be met, the channel dimensions at location of the predicted meeting and the characteristics of both vessels are used to determine if the meeting will be permitted according to the pilotage rules.

The following pilotage rules must be satisfied to permit a vessel meeting under existing conditions:

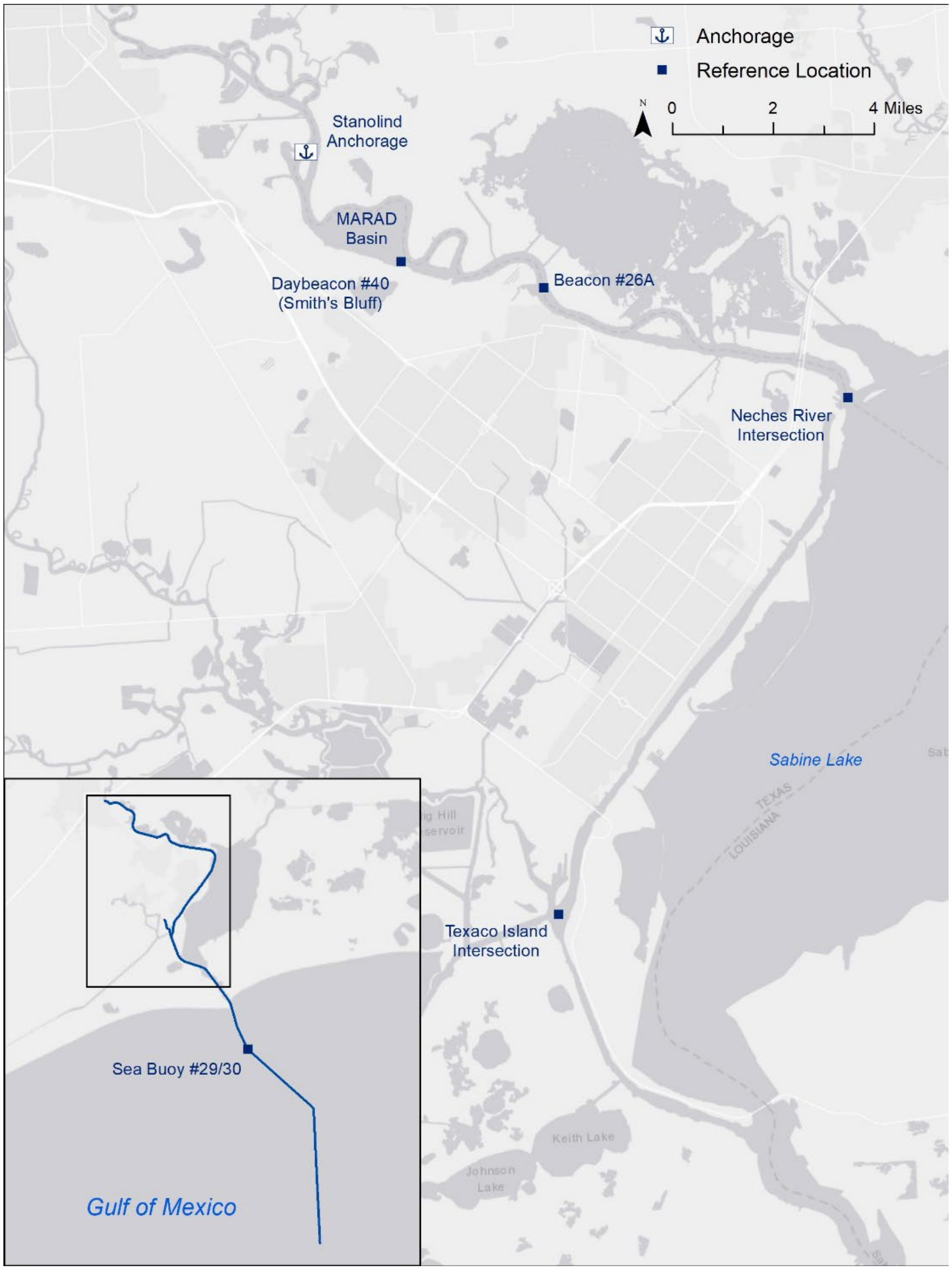
1. Vessels with a combined beam that equals or exceeds 1/2 the channel width will not meet day or night.
2. Vessels 85,000 metric deadweight tons or more will not meet vessels of either 30,000 metric deadweight tons or more, or 25-foot draft or more above Texaco Island intersection.

3. Vessels 85,000 metric deadweight tons or more will not meet vessels of 30,000 metric deadweight tons or more with a draft of 30 feet or more, above buoys 29 and 30.
4. Vessels 48,000 metric tons or more with a draft of 30 feet or more will not meet above buoys 29 and 30.
5. Vessels with a combined draft of 70 feet or more will not meet between the Neches River intersection and daybeacon #40 (Smith's Bluff) at night.
6. Vessels with a combined draft of 65 feet or more will not meet above daybeacon #40 at night.

All pilotage meeting rules involving vessel drafts are unmodified in future conditions, despite additional channel depth. This is in accordance with consultation with the Sabine Pilots who advised that a reasonable additional draft allowance cannot be assessed at this time and that a conservative assumption is that no additional draft for vessel meetings would be granted.

Figure 3 shows locations relevant to daylight restrictions and meeting area restrictions.

Figure 3
Restriction Location Markers



5.1.11 Dock Assignment and Use

The vessel destination within the port is at a terminal; however, for some vessel and cargo types as many as three different docks at a terminal (the dock choice set) may be plausibly used by the vessel. The actual dock to be used by the vessel is determined dynamically when the vessel meets the SNTS requirements to transit the waterway to the dock, either entering from the sea or leaving an anchorage and subsequently arriving at dock.

5.1.12 Turning Area Use

All vessels entering the waterway must turn around in a turning area to exit the waterway (see Figure 4). Loaded vessels arrive at dock in a "head in" orientation (will turn after visiting the dock) and light loaded vessels arrive at dock in a "head out" orientation (turns before visiting the dock). Light loaded vessels turn in the nearest upstream turning area capable of facilitating the overall length of the vessel. Vessels occupy the turning area for thirteen minutes based on the average turning time identified by the pilots.

5.1.13 Bunkering

Analysis of bunkering practices in the waterway reveals that vessels receive bunkering at anchorage and some terminals. All vessels visiting an anchorage are assumed to bunker at the anchorage and must stay at anchorage a minimum amount of time to facilitate bunkering. Vessels visiting multiple docks where one dock does not have commodity transfer are assumed to bunker while at dock.

5.1.14 Anchorage Use - From Sea

If all suitable terminal docks are occupied at the time a vessel can enter the waterway from sea, the vessel may reserve and transit to an unoccupied and unreserved anchorage (see Figure 5) suitable according to the vessel's current draft. If multiple anchorages are available, the anchorage closest to the destination dock is chosen. Once a vessel arrives at the destination anchorage, it must occupy the anchorage for a minimum amount of time to accommodate bunkering. The minimum time at anchorage is configurable, with a default value of four hours, which is consistent with historical anchorage use and Pilot's experience. This minimum anchorage use time also avoids overly opportunistic use of anchorages, such as staying at anchorage for much less than four hours before proceeding to the dock, that does not occur at the waterway. Once the minimum anchorage time has expired, the vessel may proceed to the terminal dock when the dock becomes available and channel transit rules are satisfied.

5.1.15 Anchorage Use - From Dock

Vessels do not typically go from a dock to an anchorage for the purpose of freeing up the dock for another vessel. Doing so may be advantageous to the terminal operator, but it is expensive for the vessel because it creates two separate vessels movements each requiring tugs and pilots. Nevertheless, the SNTS may be configured to enable anchorage use from a dock. If there is a vessel movement from dock to anchorage, like a vessel arriving from sea, once the vessel arrives at the destination anchorage, it must occupy the anchorage for a minimum amount of time before being permitted to exit the waterway.

Figure 4
Sabine Neches Waterway Turning Area Locations

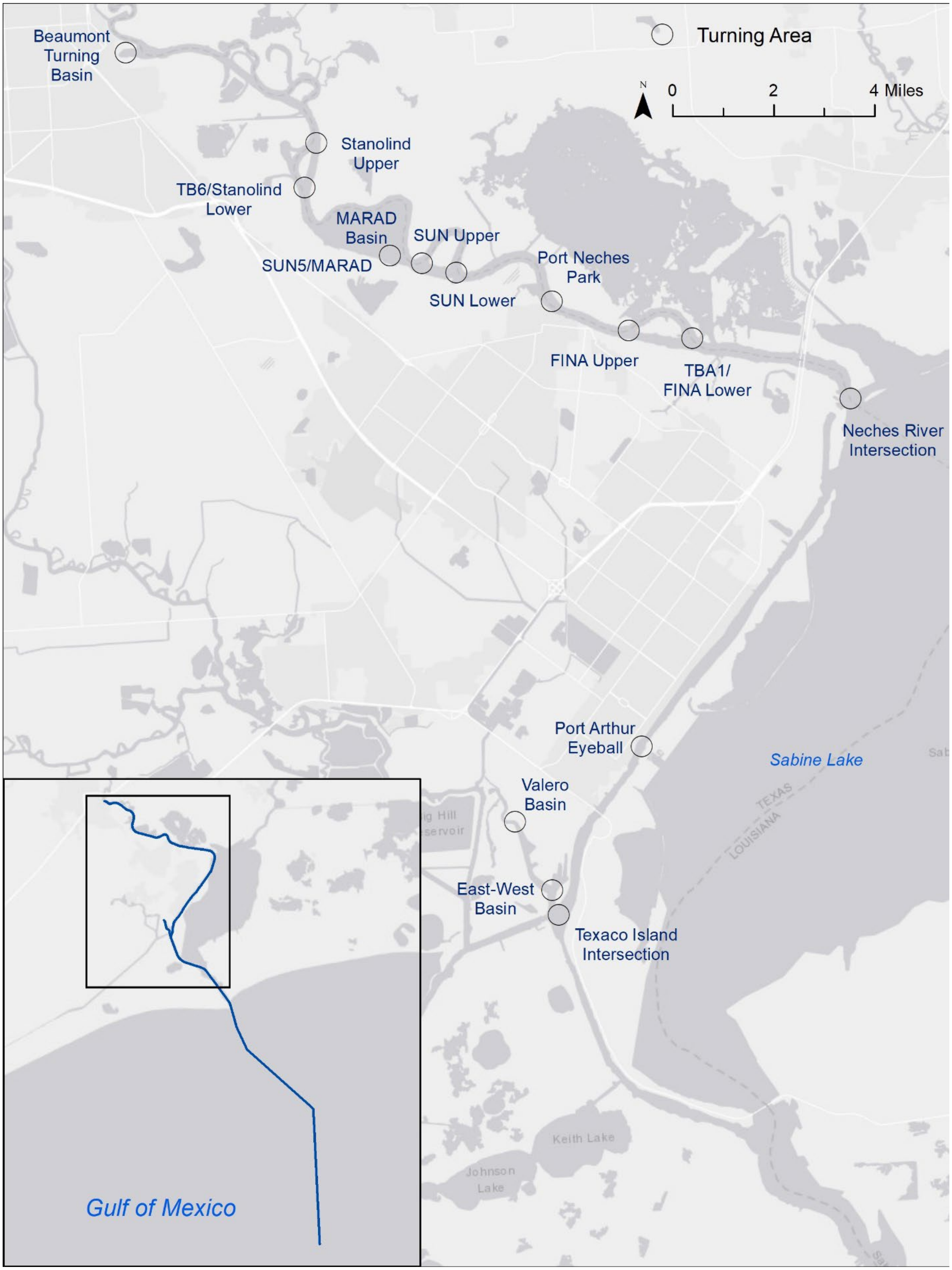
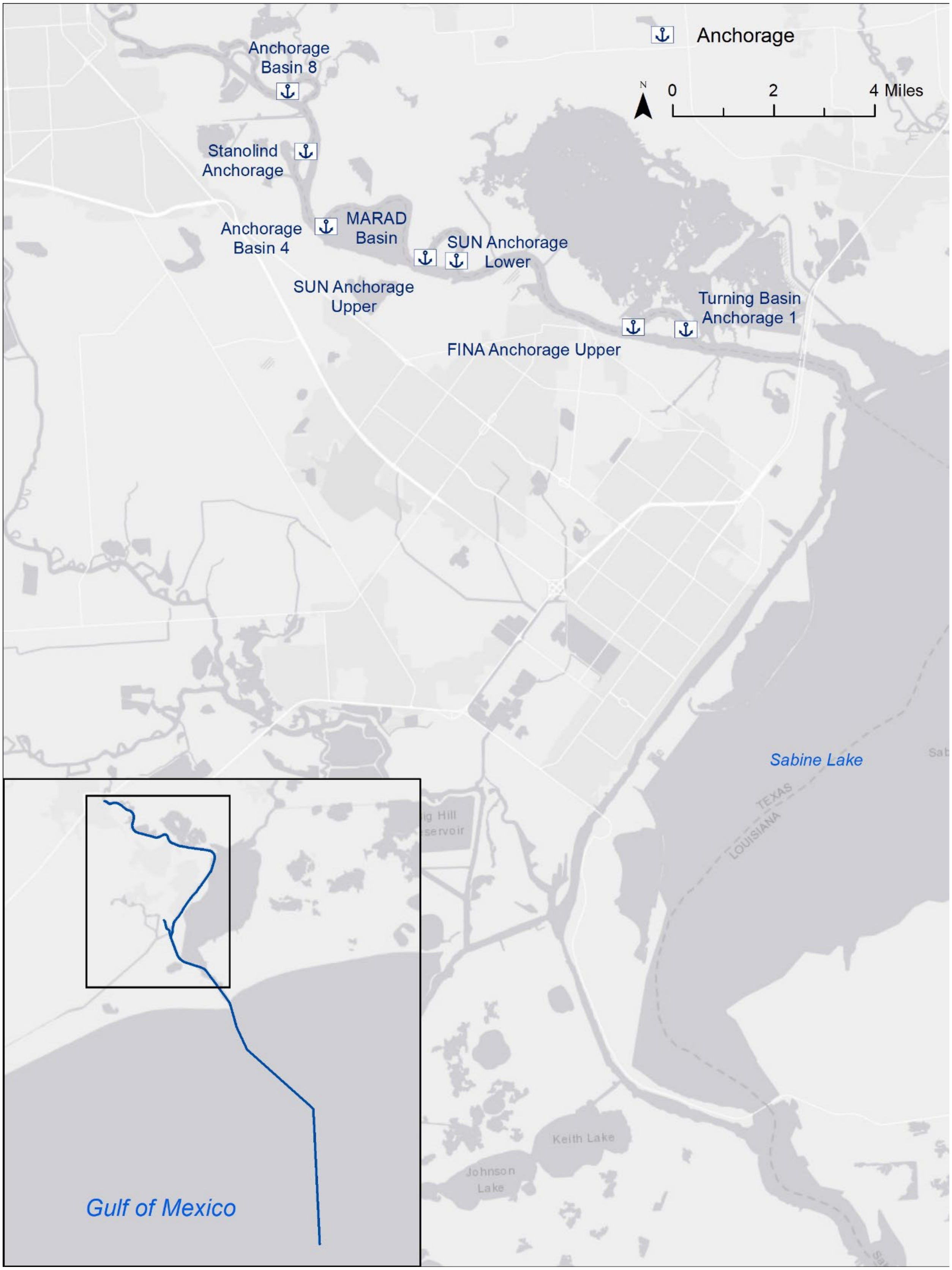


Figure 5
Sabine Neches Waterway Anchorage Locations



5.1.16 Order of Vessel Movements within a Timestep

Vessels in the vessel call list with an arrival date prior or equal to the current timestep date that have not already exited the simulation are evaluated within each timestep. To accommodate pilot operating rules, the sequence of assessment is:

1. Vessels traveling within the waterway, either inbound or outbound, are processed first so that vessels underway continue to move.
2. Vessels at dock, from low model-foot-marker to high model-foot-marker within the waterway (e.g., a vessel at dock at Sabine Pass LNG is assessed prior to a vessel at dock at Enterprise).
3. Vessels at anchorage, in order of arrival date so that vessels that have been active in the waterway longest are given priority when determining if they can continue their transit (e.g., a vessel at Anchorage Basin 4 that is waiting for a dock to become available is assessed prior to a vessel at sea attempting to reach the same dock).
4. Inbound vessels at sea, in order of dock location, from high model-foot-marker to low model-foot-marker within the waterway (e.g., a vessel going to ExxonMobil is assessed prior to a vessel going to Valero).

The order of operations within each timestep creates a system of vessel queuing within the SNTS that mimics the queuing operations used by the pilots. Vessels exiting the waterway are given priority over those entering the waterway and vessels entering the waterway are queued such that vessels at the front of the queue are headed farthest into the waterway.

5.1.17 Initiating a Vessel Move

Prior to initiating a vessel move, either from sea, anchorage, or dock, the SNTS considers multiple factors to determine if the vessel may begin the move. Once a vessel is in motion, only a weather event can halt progress.

The following conditions must be met before a vessel can enter the waterway from the sea:

1. The waterway must not be closed due to a weather event.
2. There must be enough pilots available for the vessel if the number of pilots is constrained.
3. All vessels use the same point of entry into the waterway; therefore the point of entry must not already be occupied by a vessel. The minimum distance between vessels entering the waterway is 1.5 miles. Only one vessel may enter the channel during each timestep.
4. At least one dock capable of handling the vessel type and cargo type must be available at the appropriate terminal. If no docks are available, the vessel may be able to reach a nearby anchorage instead.
5. If daylight restrictions are in place, the vessel must be unrestricted.
6. If the entering vessel will meet another vessel during the transit, the meeting must be permitted to occur according to the pilotage meeting rules.

The following conditions must be met before a vessel can leave an anchorage:

1. The vessel must have been at anchor for the minimum amount of time to allow for bunkering. Bunkering time is a parameter setting with a default value of 4 hours.
2. The waterway must not be closed due to a weather event.

3. If daylight restrictions are in place, the vessel must be unrestricted.
4. There must be enough pilots available for the vessel if the number of pilots is constrained.
5. There must be enough tugs available to move the vessel if the number of tugs is constrained.
6. The channel must be clear for one mile both upstream and downstream of the anchorage.
7. The vessel leaving the anchorage must not encounter other vessels moving within the waterway or, if the vessels will meet, the meeting is permitted to occur according to the pilotage meeting rules.
8. If the destination for the vessel is a dock, at least one suitable dock at the terminal must be available.

The following conditions must be met before a vessel can leave a dock:

1. The vessel must have been at dock enough time to accommodate docking, commodity transfer, and undocking. This duration is specific to the commodity, quantity, and terminal used.
2. The waterway must not be closed due to a weather event.
3. If daylight restrictions are in place, vessel specifications must not exceed pilot restriction limits.
4. There must be enough pilots available for the vessel if the number of pilots is constrained.
5. There must be enough tugs available to move the vessel if the number of tugs is constrained.
6. The channel must be clear for one mile both upstream and downstream of the dock.
7. The vessel leaving the dock, must not encounter other vessels moving within the waterway or, if the vessels will meet, the meeting is permitted to occur according to the pilotage meeting rules.

If all conditions are met, the vessel may proceed. If these conditions are not met, the vessel must wait at the current location until such time as the conditions permit a move.

5.1.18 Wait Time Calculation

Whether at sea, dock, or anchorage, vessels are not permitted to transit the channel unless the aforementioned conditions are met. If a vessel is ready to begin a transit but the transit conditions do not permit movement, wait time is accrued and tracked by the SNTS. Wait times are categorized as either weather related or non-weather related. Wait times due to weather conditions are unavoidable and affect all vessels attempting motion within the waterway. Non-weather related wait times may be caused by pilotage rules (e.g., daylight restrictions or vessel meeting requirements), waterway traffic conditions (e.g., waterway congestion, limited tug or pilot availability), or dock and anchorage availability.

6 Simulation Output

Every model simulation exports a set of tables used to describe and summarize the output. These tables are used to compare simulations. Table 9 describes the SNTS output.

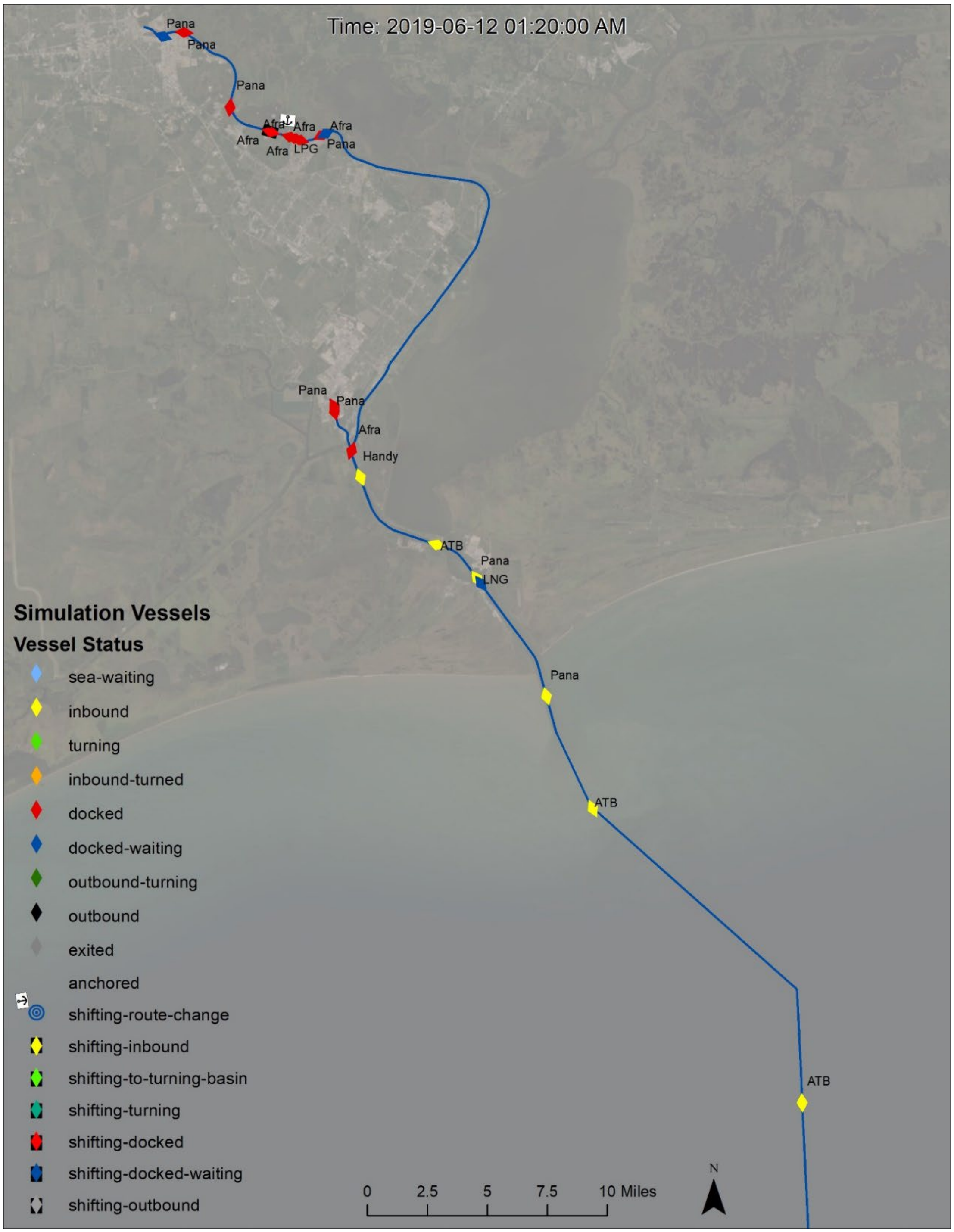
Table 9
SNTS Output

Table	Description
Model Parameters	A list of all parameters used for the simulation, including any channel modifications or model constraints.
Vessel Call List	The vessel call list used in the simulation, which also includes the dock visited, vessel transit duration, and any time spent waiting and at anchorage.
Timestep Summary	A list of every timestep in the simulation and the aggregate number of vessels in motion, at dock, at sea, or anchored. Also recorded is the number of pilots and tugs used at each timestep. Finally, any vessel occupying each dock is recorded.
Weather Delays	The modeled weather delays used in the simulation.
Dock Use	A list when each vessel reserved a dock, arrived at the dock, and departed the dock.
Anchorage Use	A list of when a vessel reserved an anchorage for use and when the vessel departed the anchorage.
Vessel Meetings	A list of every vessel's potential passing of another vessel. Each vessel is identified as either in-transit or seeking transit. Included is where the meeting would take place in the waterway, the channel width at that location, each vessel's physical characteristics, whether the meeting is permitted, and if the vessel meeting is denied, the reason for denying the vessel meeting.
Vessel Movements Complete	A list of every vessel's completed voyage through the waterway. Included is the vessel's location and status at each timestep the vessel is active within the SNTS, including waiting times and the reason for the delay.
Vessel Movements	A list of every vessel that did not complete the voyage through the waterway before the end of the simulation period. Included is the vessel's location and status at each timestep the vessel is active within the waterway, including waiting times and the reason for the delay. These vessels have not yet exited the waterway at the end of the simulation.

6.1.1 Simulation Rendering

Output from SNTS simulations is visualized in time-series animations in ArcGIS. The movement of each vessel through the waterway can be viewed in each ten-minute timestep. Each vessel is labeled by vessel class and symbolized by the vessel status (i.e., inbound, docked, anchored, outbound, etc.). Simulation animation rendering is helpful for visually validating vessel motions and vessel interactions. Figure 6 portrays the simulated state of the waterway on June 12 at 1:20 AM. Note the six yellow inbound vessels, ten docked vessels, three blue vessels that are docked, but waiting to exit, and one vessel at anchorage.

Figure 6
Simulated State of Waterway on June 12 at 1:20 AM



7 Model Results and Analytical Capabilities

Model results compare traffic flow under the with-widening condition to traffic flow under the without-widening condition. Many alternative widening conditions were evaluated by the model, including widening to various widths at multiple locations. The widening alternative that provides the largest net economic benefit, i.e., the largest benefit relative to construction costs, includes widening the channel from Texaco Island to the MARAD Basin by 100 feet on the “red” side (left descending bank) – see Figure 7. Model results presented in this report are limited to this optimal widening scenario.

Navigating under this widened condition has been tested in full-bridge simulations by the Sabine Pilots and multiple tow operators from the Gulf Intracoastal Canal Association. The simulations confirm that widening the waterway in these reaches will allow Suezmax vessels 24-hour access to facilities on the Neches River that eliminates the need for the current daylight restriction. In addition, widening the waterway increases the size of vessels that are allowed to meet in the widened reaches. These projected future improvements to navigation along the waterway result in less congestion and fewer delays as compared to the without-widening conditions.

Impacts to the “carrying capacity” of the channel are expressed in number of vessels delayed and the duration of vessel delays presented as annual hours of delay. The model results displayed in the graphs and tables in this report are summarized across all terminals on the waterway. Detailed model results for individual terminals, docks, commodities, and vessel types can be generated and analyzed by request of the terminal operator to Vini Vannicola, Vice President, DMA (vvannicola@dma-us.com). In addition, alternative scenarios, such as changes to the number of docks at a terminal, dock characteristics, vessel size, fleet composition, and tug or pilot availability may be simulated to test alternative future conditions.

The following tables and figures portray summarized model results for the reduction in the number of vessels delayed and the reduction in the duration of vessel delays due to widening the channel from Texaco Island to the MARAD Basin. Summarized model results are presented for without-widening (WITHOUT) and with-widening (WITH) conditions in tabular and graphic formats for the overall waterway system and for vessel classes used in the model. The model simulations performed for this report assume that tugs and pilots are available as needed. Total wait time is defined as the sum of:

- sea wait time (waiting at sea prior to entering the federal navigation channel);
- dock wait time (after having finished loading or unloading and associated tasks – waiting for the channel to clear so the vessel can depart); and
- anchorage wait time (after having spent the minimum four hours at the anchorage – waiting for the berth or channel to clear so the vessel can get underway).

7.1.1 Total Number of Vessels Delayed

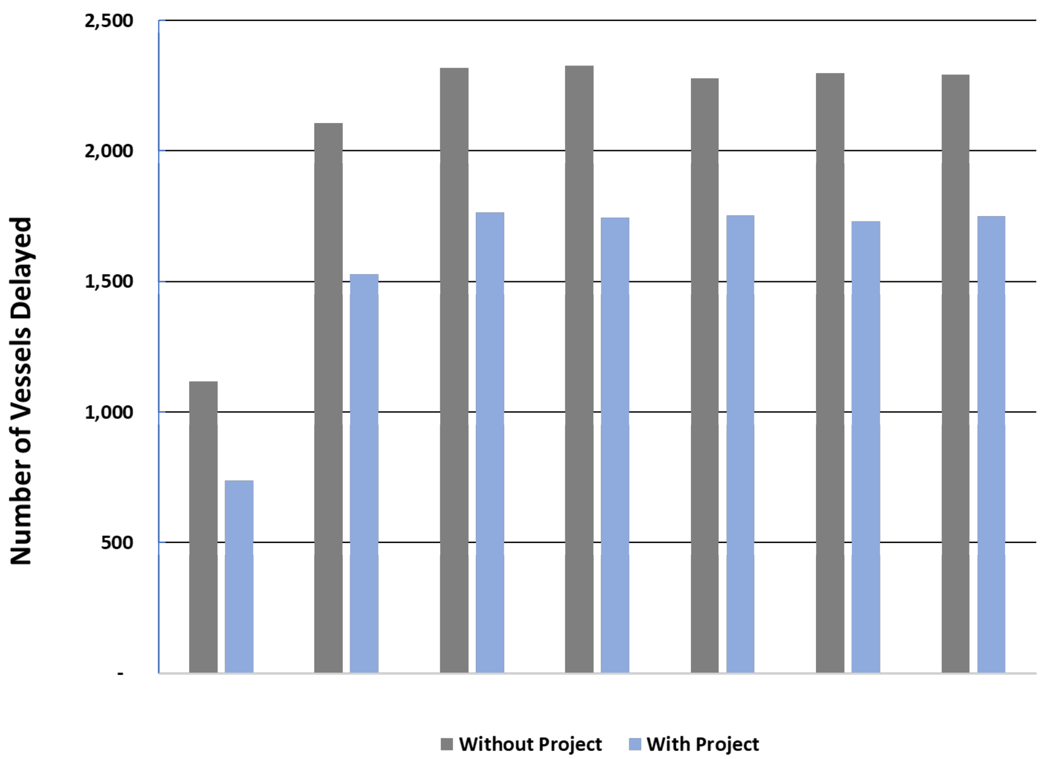
Table 10 and Figure 8 present the total number of vessels delayed under with-widening and without-widening conditions. The modeled delays are attributable to channel congestion and do not reflect resource scarcity concerning tugs and pilots. For each vessel call, the vessel may be delayed on either the inbound or outbound transit. Note that the number of delayed vessels is substantial and is not greatly reduced by widening the channel. For example, in 2019 under without-widening conditions 38% of all vessel calls (1,118 calls) incurred some delay. In 2030, that percentage increases to 55% (2,318 calls) and also in 2030 under with-widening conditions the percentage of delayed vessels is reduced to 42% (1,764 calls).

Figure 7
Widened Areas Under With-widening conditions

Table 10:
Vessels Delayed Under WITHOUT and WITH Conditions: 2019-2050

		Number of Calls	Vessels Delayed	Percent of Vessel Calls
2019	WITHOUT	2,904	1,118	38%
	WITH	2,904	737	25%
2025	WITHOUT	3,886	2,106	54%
	WITH	3,886	1,527	39%
2030	WITHOUT	4,204	2,318	55%
	WITH	4,204	1,764	42%
2035	WITHOUT	4,204	2,328	55%
	WITH	4,204	1,744	41%
2040	WITHOUT	4,204	2,277	54%
	WITH	4,204	1,753	42%
2045	WITHOUT	4,204	2,297	55%
	WITH	4,204	1,731	41%
2050	WITHOUT	4,204	2,292	55%
	WITH	4,204	1,750	42%

Figure 8:
Vessels Delayed Under WITHOUT and WITH Conditions: 2019-2050



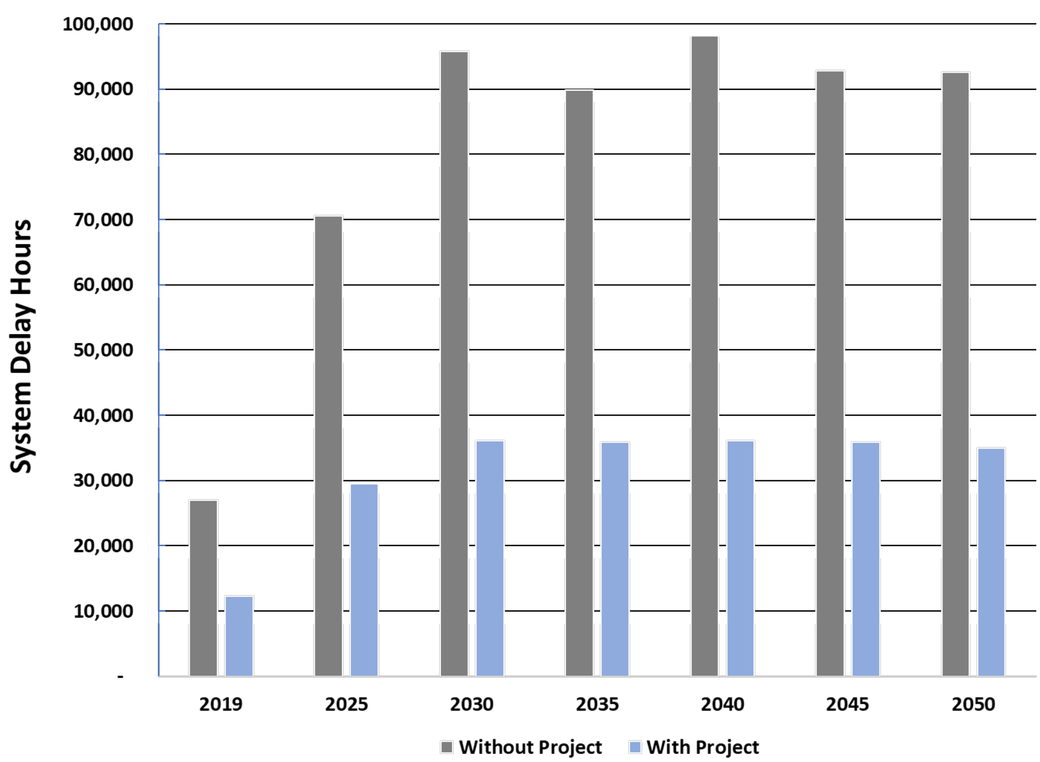
7.1.2 Duration of Vessel Delays

Vessel delay durations are presented in hours per year. Table 11 and Figure 9 show the total vessel delay durations for the entire waterway for each modeled year. The reduction in delay duration due to the widened channel is substantial. If the widened channel had been in place in 2019, the model estimates that there would have been a 54 percent reduction in total delay time for the year. For 2030, the model results indicate that the widened channel would reduce projected delays by 62 percent. Also in 2030, the average delay per vessel call is reduced from 22.8 hours to 8.6 hours.

Table 11:
Reduction in Delay Times: 2019-2050

		Number of Calls	Total Delay Hours	Average Delay Hours	Delay Hours Reduction
2019	WITHOUT	2,904	27,000	9.3	14,700
	WITH	2,904	12,300	4.2	
2025	WITHOUT	3,886	70,550	18.2	41,000
	WITH	3,886	29,550	7.6	
2030	WITHOUT	4,204	95,800	22.8	59,700
	WITH	4,204	36,100	8.6	
2035	WITHOUT	4,204	89,850	21.4	53,900
	WITH	4,204	35,950	8.6	
2040	WITHOUT	4,204	98,150	23.3	62,000
	WITH	4,204	36,150	8.6	
2045	WITHOUT	4,204	92,850	22.1	57,000
	WITH	4,204	35,850	8.5	
2050	WITHOUT	4,204	92,600	22.0	57,650
	WITH	4,204	34,950	8.3	

Figure 9:
Reduction in Delay Hours: 2019-2050



7.1.3 Cost of Vessel Delays

Vessel delay costs provided in Table 12 are calculated only for vessel operations based on the total amount of time that a vessel is in the waterway system – starting at arrival from the sea and ending at leaving the entrance channel for the sea. This approach to calculating cost reductions is based on USACE guidance for the economic evaluation of deep draft navigation projects. The cost reduction calculations due to the widening do not include the benefits of increased berth efficiency or the opportunities for servicing more vessels at a berth. Alternative terminal-related cost savings and potential benefit calculations may be evaluated through additional model simulations and calculation methods to test alternative future conditions, at the request of the terminal operator.

The reduction in vessel operating cost as calculated using methods aligned with USACE guidance increase by 179 percent from 2019 to 2025, and increase again by 55 percent from 2025 to 2030. Had the channel been widened in 2019, there would have been a reduction of $23 million in vessel operating costs within the waterway. The cost reduction for 2025 is estimated to be $64.2 million and $99.4 million in 2030. All cost savings are directly attributed to the channel widening from Texaco Island to the MARAD Basin.

Table 12:
Reduction in Delay Costs: 2019-2050 ($)

		Number of Calls	Vessel Delay OP Costs	Vessel Delay OP Costs Reduction
2019	WITHOUT	2,904	40,600,000	23,000,000
	WITH	2,904	17,600,000	
2025	WITHOUT	3,886	109,900,000	64,200,000
	WITH	3,886	45,700,000	
2030	WITHOUT	4,204	156,400,000	99,400,000
	WITH	4,204	57,000,000	
2035	WITHOUT	4,204	146,500,000	89,400,000
	WITH	4,204	57,100,000	
2040	WITHOUT	4,204	163,100,000	105,800,000
	WITH	4,204	57,300,000	
2045	WITHOUT	4,204	152,400,000	95,100,000
	WITH	4,204	57,300,000	
2050	WITHOUT	4,204	152,100,000	96,600,000
	WITH	4,204	55,500,000	

7.1.4 Detailed Results Tables

The remainder of this document provides summarized model results for without-widening (WITHOUT) and with-widening (WITH) conditions in tabular and graphic formats for the overall waterway system and for vessel classes used in the model. Note that only LNG vessels incur a minor increase in delay time and operating costs as a result of channel widening from Texaco Island to the MARAD basin. The small increase in delays for LNG vessels occurs because under the without-widening condition the channel is less congested at night and LNG vessels transiting at night are less likely to be delayed. Under with-widening conditions, Aframax and Suezmax vessels are also transiting the channel at night, which increases the likelihood that an LNG vessel transiting the channel at night might be delayed because Aframax, Suezmax, and LNG vessels all exceed the Pilots' meeting restrictions. This relatively small increase in delays and costs in the with-widening condition is overwhelmed by the substantial cost reductions spread across all other vessel classes and is taken into account in the total delay and cost reduction calculations.

It should be stated again that aggregated model results shown on the following pages are available disaggregated by terminal and dock but are not provided in this document to avoid violating nondisclosure agreements.

Table R1: All Vessels
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	2,904	5,500	18,700	2,800	27,000
	WITH	2,904	4,400	7,650	250	12,300
2025	WITHOUT	3,886	13,900	42,100	14,550	70,550
	WITH	3,886	8,350	17,100	4,100	29,550
2030	WITHOUT	4,204	27,400	49,750	18,650	95,800
	WITH	4,204	9,800	21,800	4,500	36,100
2035	WITHOUT	4,204	25,600	48,600	15,650	89,850
	WITH	4,204	10,150	21,200	4,600	35,950
2040	WITHOUT	4,204	33,600	48,350	16,200	98,150
	WITH	4,204	10,000	21,850	4,300	36,150
2045	WITHOUT	4,204	27,300	50,150	15,400	92,850
	WITH	4,204	10,200	21,650	4,000	35,850
2050	WITHOUT	4,204	26,400	50,150	16,050	92,600
	WITH	4,204	10,250	21,100	3,600	34,950

Table R2: All Vessels
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	Vessel OP Costs Reduction
2019	WITHOUT	2,904	8,400,000	32,200,000	40,600,000	23,000,000
	WITH	2,904	6,300,000	11,300,000	17,600,000	
2025	WITHOUT	3,886	23,400,000	86,500,000	109,900,000	64,200,000
	WITH	3,886	13,000,000	32,700,000	45,700,000	
2030	WITHOUT	4,204	49,400,000	107,000,000	156,400,000	99,400,000
	WITH	4,204	15,600,000	41,400,000	57,000,000	
2035	WITHOUT	4,204	45,900,000	100,600,000	146,500,000	89,400,000
	WITH	4,204	16,200,000	40,900,000	57,100,000	
2040	WITHOUT	4,204	61,900,000	101,200,000	163,100,000	105,800,000
	WITH	4,204	15,900,000	41,400,000	57,300,000	
2045	WITHOUT	4,204	49,300,000	103,100,000	152,400,000	95,100,000
	WITH	4,204	16,200,000	41,100,000	57,300,000	
2050	WITHOUT	4,204	47,300,000	104,800,000	152,100,000	96,600,000
	WITH	4,204	16,400,000	39,100,000	55,500,000	

Figure R1: All Vessels
Reduction in Delay Times: 2019-2050

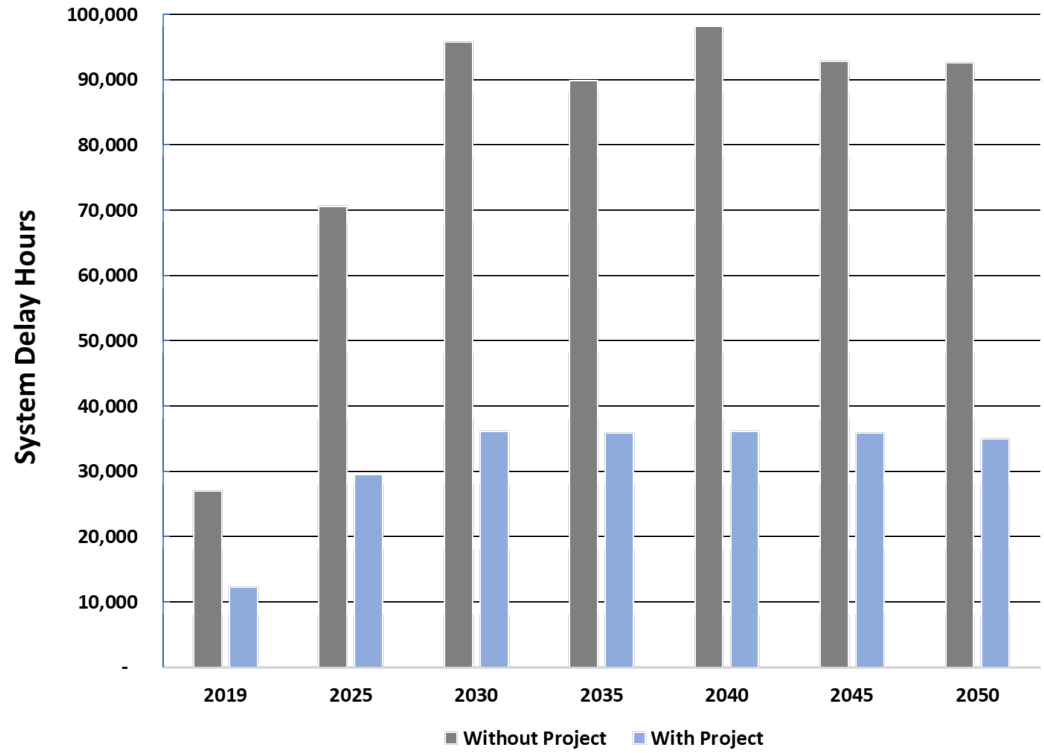


Figure R2: All Vessels
Reduction in Delay Costs: 2019-2050

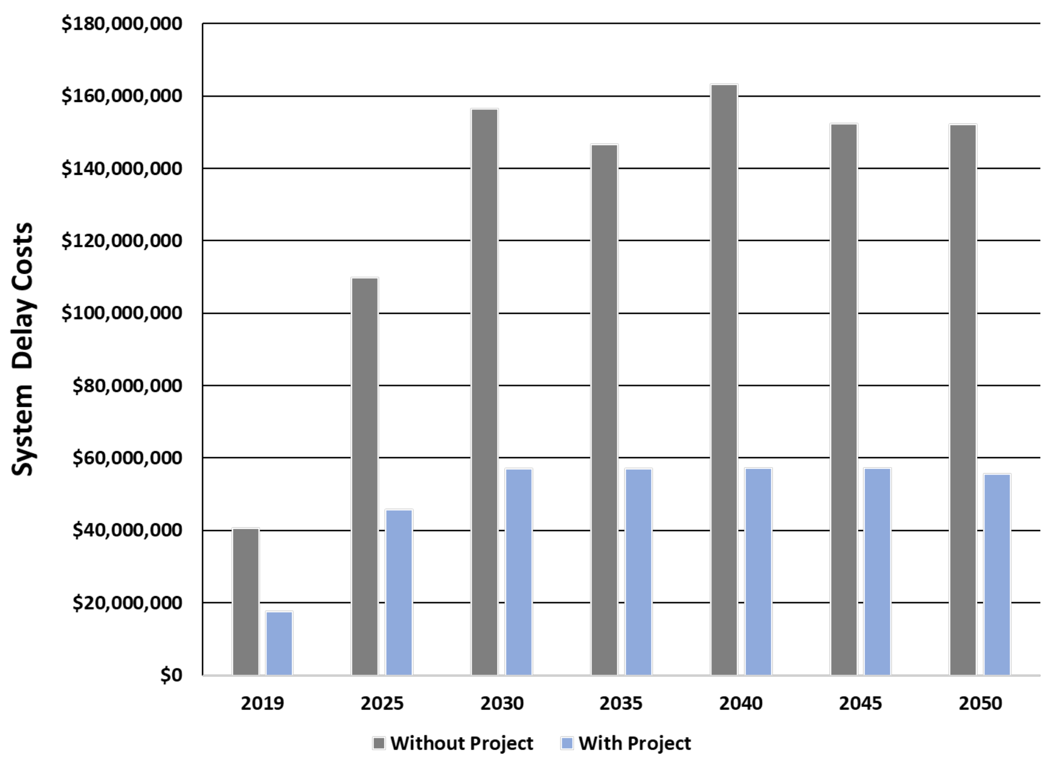


Table R3: Aframax
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	556	2,050	9,050	1,600	12,700
	WITH	556	1,200	3,400	100	4,700
2025	WITHOUT	602	5,000	15,900	5,750	26,650
	WITH	602	2,150	6,350	1,150	9,650
2030	WITHOUT	602	10,600	18,750	8,050	37,400
	WITH	602	2,050	7,250	1,350	10,650
2035	WITHOUT	602	9,950	17,400	7,300	34,650
	WITH	602	2,250	7,100	1,450	10,800
2040	WITHOUT	602	14,250	18,050	8,100	40,400
	WITH	602	2,250	7,050	1,150	10,450
2045	WITHOUT	602	11,350	18,400	6,250	36,000
	WITH	602	2,450	7,000	1,100	10,550
2050	WITHOUT	602	10,850	18,250	7,500	36,600
	WITH	602	2,350	6,700	1,050	10,100

Table R4: Aframax
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	556	3,700,000	19,100,000	22,800,000	14,300,000
	WITH	556	2,200,000	6,300,000	8,500,000	
2025	WITHOUT	602	8,900,000	38,400,000	47,300,000	30,200,000
	WITH	602	3,800,000	13,300,000	17,100,000	
2030	WITHOUT	602	19,000,000	47,700,000	66,700,000	47,700,000
	WITH	602	3,700,000	15,300,000	19,000,000	
2035	WITHOUT	602	17,800,000	44,000,000	61,800,000	42,500,000
	WITH	602	4,000,000	15,300,000	19,300,000	
2040	WITHOUT	602	25,500,000	46,500,000	72,000,000	53,400,000
	WITH	602	4,000,000	14,600,000	18,600,000	
2045	WITHOUT	602	20,300,000	43,800,000	64,100,000	45,300,000
	WITH	602	4,300,000	14,500,000	18,800,000	
2050	WITHOUT	602	19,300,000	45,900,000	65,200,000	47,200,000
	WITH	602	4,200,000	13,800,000	18,000,000	

Figure R3: Aframax
Reduction in Delay Times: 2019-2050

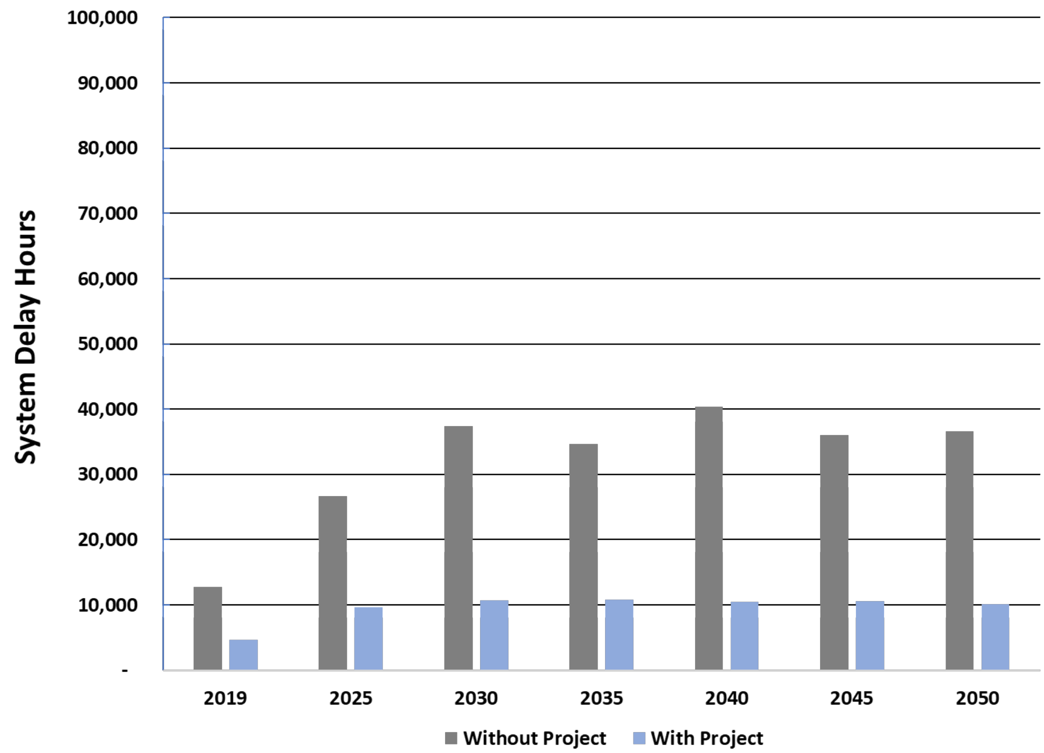


Figure R4: Aframax
Reduction in Delay Costs: 2019-2050

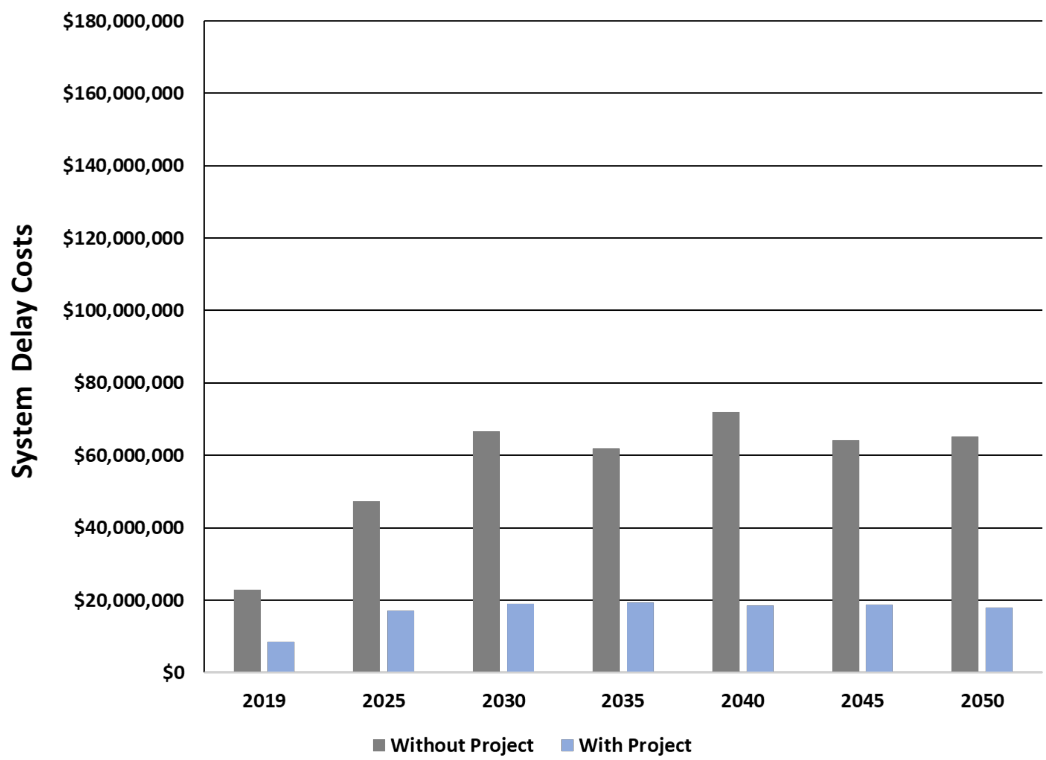


Table R5: ATB
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	328	500	500	100	1,100
	WITH	328	500	250	0	750
2025	WITHOUT	326	400	650	250	1,300
	WITH	326	450	300	50	800
2030	WITHOUT	326	500	500	500	1,500
	WITH	326	400	250	50	700
2035	WITHOUT	326	550	500	550	1,600
	WITH	326	400	250	100	750
2040	WITHOUT	326	550	550	400	1,500
	WITH	326	450	250	100	800
2045	WITHOUT	326	550	500	400	1,450
	WITH	326	400	250	100	750
2050	WITHOUT	326	500	450	400	1,350
	WITH	326	450	250	100	800

Table R6: ATB
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	328	300,000	100,000	400,000	0
	WITH	328	300,000	100,000	400,000	
2025	WITHOUT	326	300,000	300,000	600,000	200,000
	WITH	326	300,000	100,000	400,000	
2030	WITHOUT	326	300,000	300,000	600,000	200,000
	WITH	326	300,000	100,000	400,000	
2035	WITHOUT	326	400,000	300,000	700,000	300,000
	WITH	326	300,000	100,000	400,000	
2040	WITHOUT	326	300,000	300,000	600,000	200,000
	WITH	326	300,000	100,000	400,000	
2045	WITHOUT	326	400,000	200,000	600,000	200,000
	WITH	326	300,000	100,000	400,000	
2050	WITHOUT	326	300,000	200,000	500,000	100,000
	WITH	326	300,000	100,000	400,000	

Figure R5: ATB
Reduction in Delay Times: 2019-2050

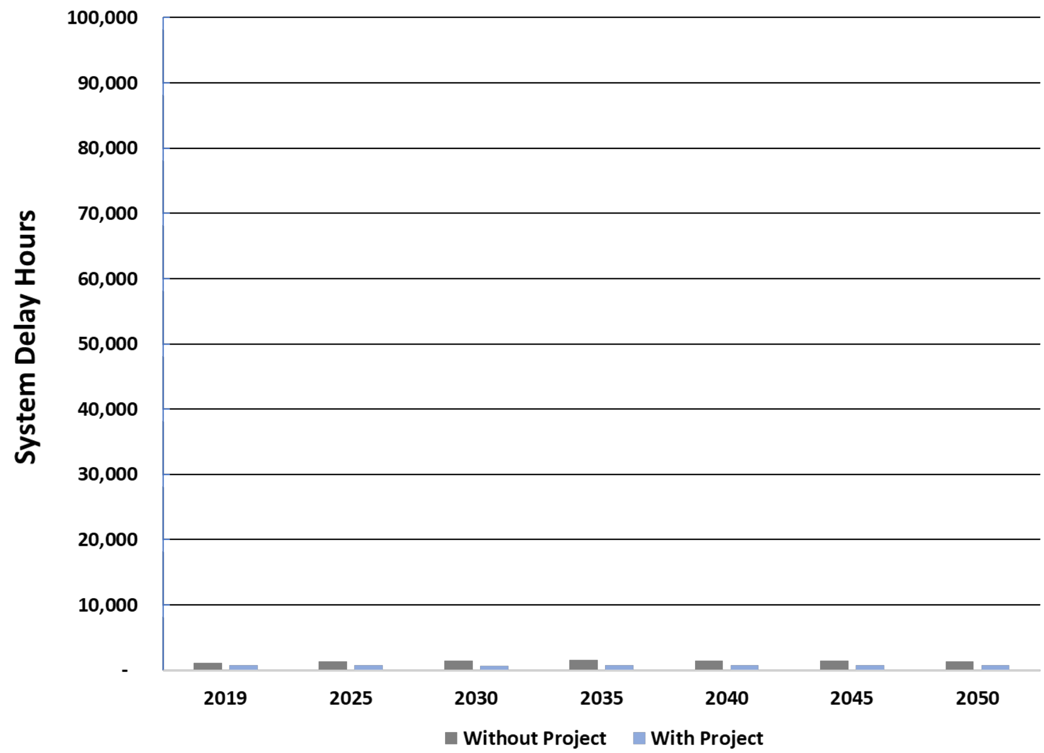


Figure R6: ATB
Reduction in Delay Costs: 2019-2050

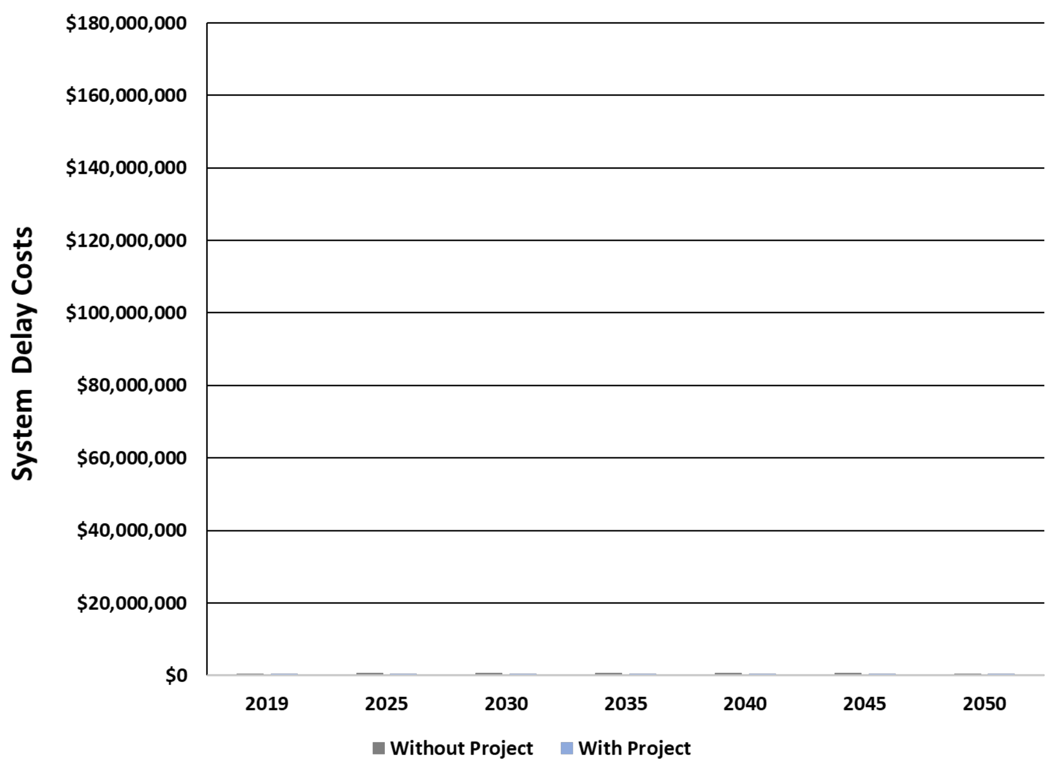


Table R7: Handy Size
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	416	250	700	0	950
	WITH	416	200	300	0	500
2025	WITHOUT	415	400	1,050	650	2,100
	WITH	415	400	350	400	1,150
2030	WITHOUT	415	400	1,000	450	1,850
	WITH	415	300	300	250	850
2035	WITHOUT	415	350	1,050	300	1,700
	WITH	415	300	350	250	900
2040	WITHOUT	415	350	950	400	1,700
	WITH	415	300	400	250	950
2045	WITHOUT	415	300	1,150	350	1,800
	WITH	415	300	300	250	850
2050	WITHOUT	415	300	1,200	400	1,900
	WITH	415	300	300	250	850

Table R8: Handy Size
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	416	200,000	200,000	400,000	200,000
	WITH	416	100,000	100,000	200,000	
2025	WITHOUT	415	300,000	600,000	900,000	300,000
	WITH	415	300,000	300,000	600,000	
2030	WITHOUT	415	300,000	500,000	800,000	400,000
	WITH	415	200,000	200,000	400,000	
2035	WITHOUT	415	200,000	400,000	600,000	200,000
	WITH	415	200,000	200,000	400,000	
2040	WITHOUT	415	300,000	500,000	800,000	400,000
	WITH	415	200,000	200,000	400,000	
2045	WITHOUT	415	200,000	500,000	700,000	300,000
	WITH	415	200,000	200,000	400,000	
2050	WITHOUT	415	200,000	500,000	700,000	300,000
	WITH	415	200,000	200,000	400,000	

Figure R7: Handy Size
Reduction in Delay Times: 2019-2050

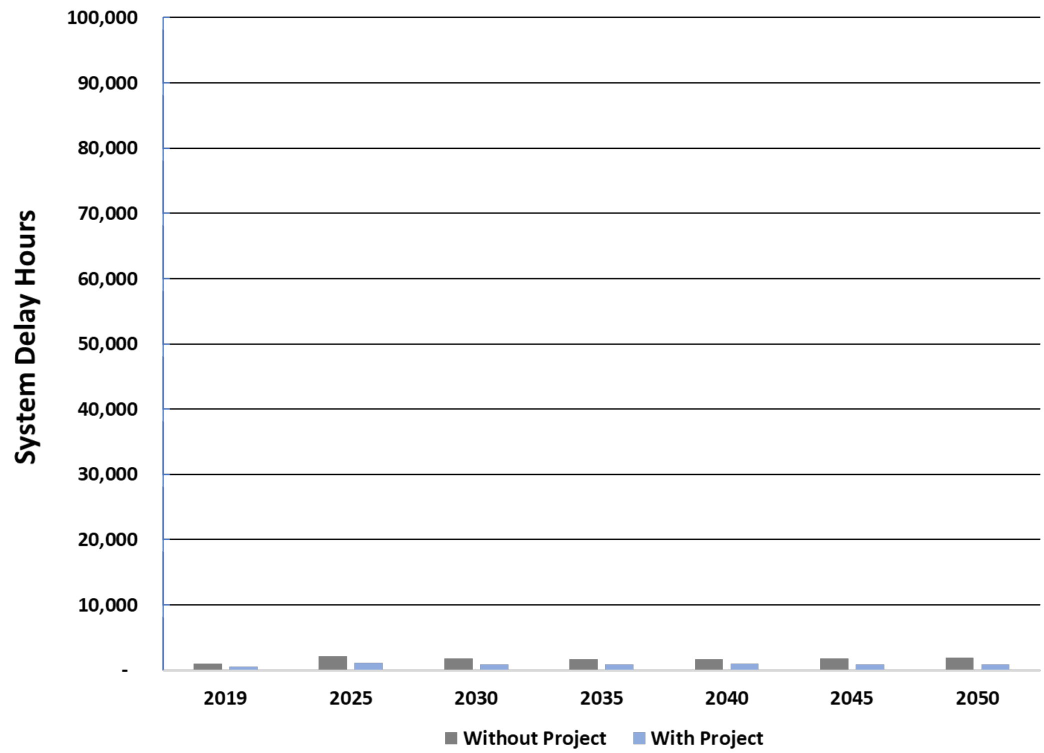


Figure R8: Handy Size
Reduction in Delay Costs: 2019-2050

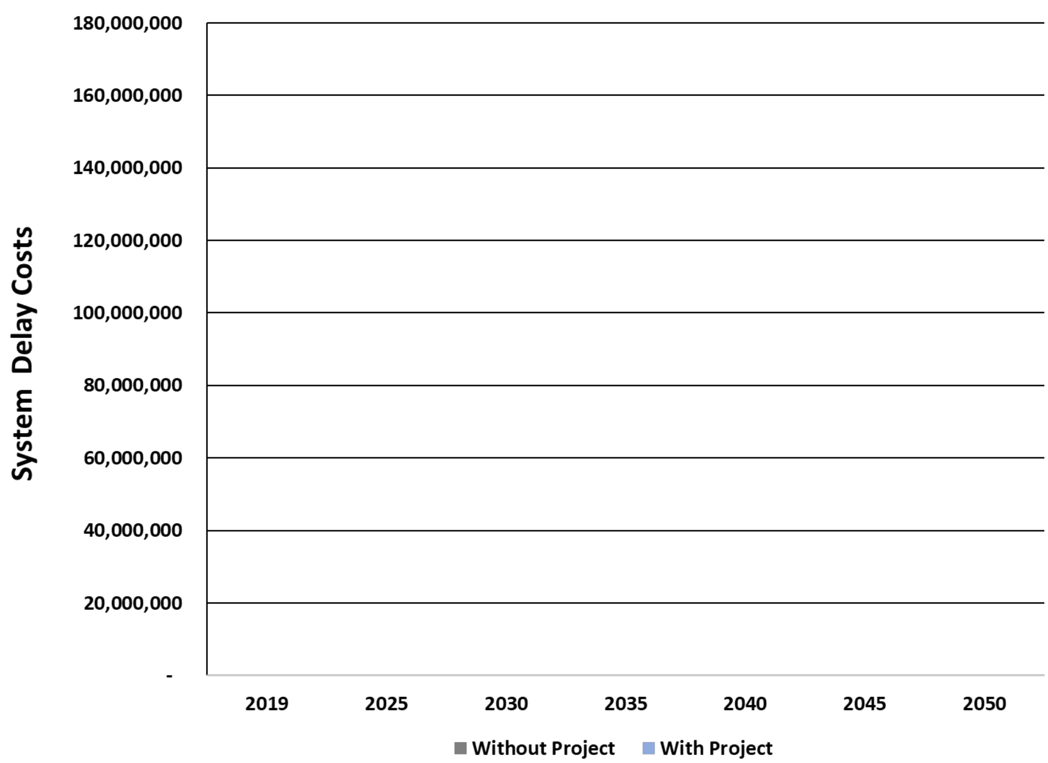


Table R9: LNG
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	336	600	600	0	1,200
	WITH	336	700	650	0	1,350
2025	WITHOUT	643	1,950	2,300	0	4,250
	WITH	643	2,400	2,000	0	4,400
2030	WITHOUT	961	2,350	4,200	0	6,550
	WITH	961	3,550	4,000	0	7,550
2035	WITHOUT	961	2,450	4,300	0	6,750
	WITH	961	3,600	4,050	0	7,650
2040	WITHOUT	961	2,400	4,100	0	6,500
	WITH	961	3,450	4,050	0	7,500
2045	WITHOUT	961	2,350	4,200	0	6,550
	WITH	961	3,350	4,150	0	7,500
2050	WITHOUT	961	2,350	4,050	0	6,400
	WITH	961	3,500	4,050	0	7,550

Table R10: LNG
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	Vessel OP Costs Reduction
2019	WITHOUT	336	1,000,000	1,000,000	2,000,000	-300,000
	WITH	336	1,200,000	1,100,000	2,300,000	
2025	WITHOUT	643	3,400,000	4,000,000	7,400,000	-300,000
	WITH	643	4,200,000	3,500,000	7,700,000	
2030	WITHOUT	961	4,000,000	7,200,000	11,200,000	-1,800,000
	WITH	961	6,100,000	6,900,000	13,000,000	
2035	WITHOUT	961	4,200,000	7,400,000	11,600,000	-1,500,000
	WITH	961	6,200,000	6,900,000	13,100,000	
2040	WITHOUT	961	4,100,000	7,000,000	11,100,000	-1,700,000
	WITH	961	5,900,000	6,900,000	12,800,000	
2045	WITHOUT	961	4,000,000	7,200,000	11,200,000	-1,600,000
	WITH	961	5,700,000	7,100,000	12,800,000	
2050	WITHOUT	961	4,000,000	7,000,000	11,000,000	-2,000,000
	WITH	961	6,000,000	7,000,000	13,000,000	

Figure R9: LNG Tanker
Reduction in Delay Times: 2019-2050

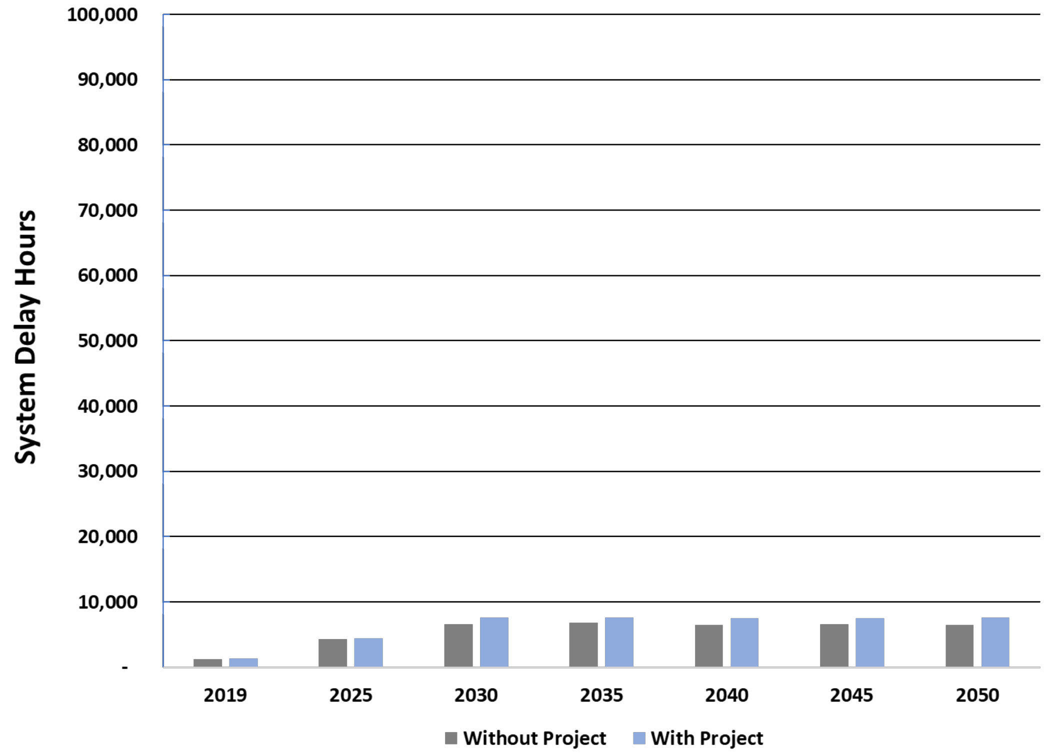


Figure R10: LNG Tanker
Reduction in Delay Costs: 2019-2050

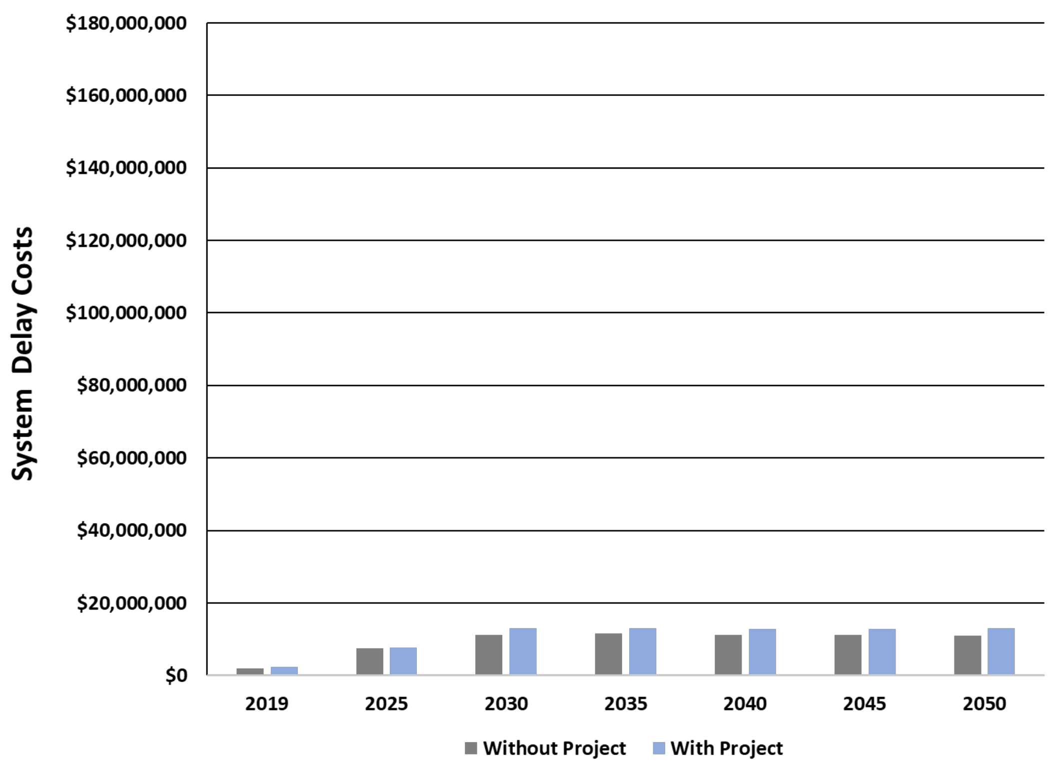


Table R11: LPG
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	136	150	1,000	150	1,300
	WITH	136	150	450	0	600
2025	WITHOUT	420	1,050	5,000	1,550	7,600
	WITH	420	600	1,750	400	2,750
2030	WITHOUT	420	1,750	5,550	2,300	9,600
	WITH	420	550	2,250	450	3,250
2035	WITHOUT	420	1,650	5,200	1,250	8,100
	WITH	420	600	2,050	400	3,050
2040	WITHOUT	420	1,700	5,500	1,700	8,900
	WITH	420	550	2,150	400	3,100
2045	WITHOUT	420	1,650	5,350	2,000	9,000
	WITH	420	700	2,100	400	3,200
2050	WITHOUT	420	1,550	5,400	1,300	8,250
	WITH	420	600	2,100	500	3,200

Table R12: LPG
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	136	200,000	1,400,000	1,600,000	900,000
	WITH	136	200,000	500,000	700,000	
2025	WITHOUT	420	1,400,000	8,400,000	9,800,000	6,300,000
	WITH	420	700,000	2,800,000	3,500,000	
2030	WITHOUT	420	2,300,000	10,100,000	12,400,000	8,200,000
	WITH	420	700,000	3,500,000	4,200,000	
2035	WITHOUT	420	2,100,000	8,100,000	10,200,000	6,300,000
	WITH	420	800,000	3,100,000	3,900,000	
2040	WITHOUT	420	2,200,000	9,200,000	11,400,000	7,400,000
	WITH	420	700,000	3,300,000	4,000,000	
2045	WITHOUT	420	2,100,000	9,400,000	11,500,000	7,400,000
	WITH	420	900,000	3,200,000	4,100,000	
2050	WITHOUT	420	2,000,000	8,500,000	10,500,000	6,300,000
	WITH	420	800,000	3,400,000	4,200,000	

Figure R11: LPG Tanker
Reduction in Delay Times: 2019-2050

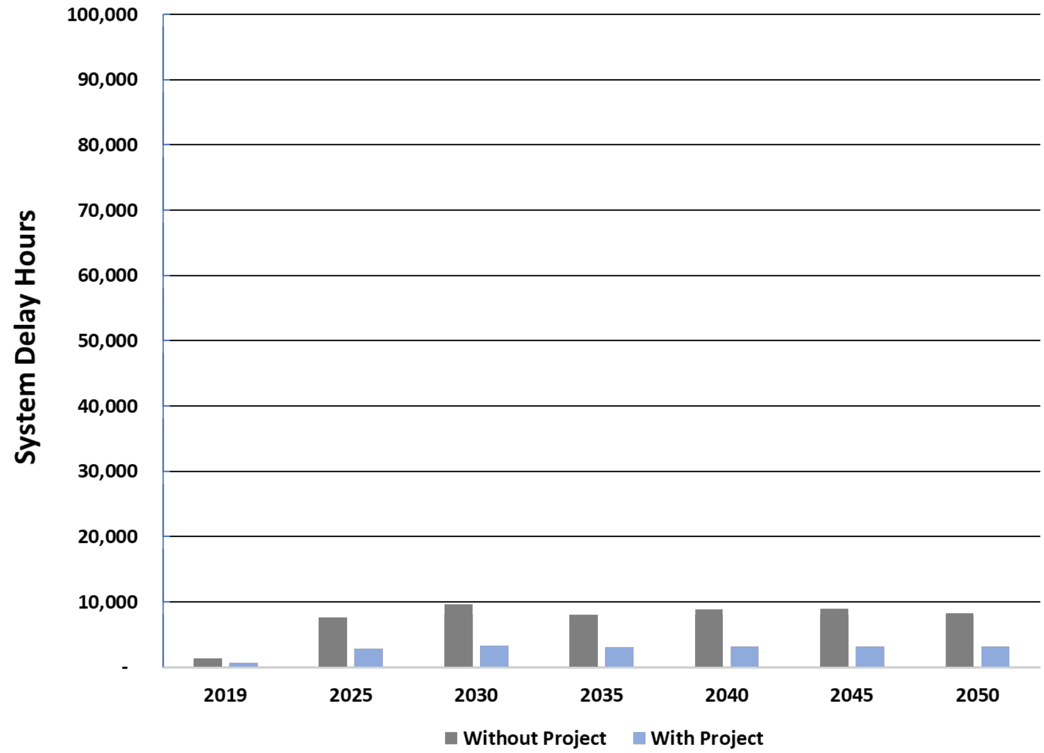


Figure R12: LPG Tanker
Reduction in Delay Costs: 2019-2050

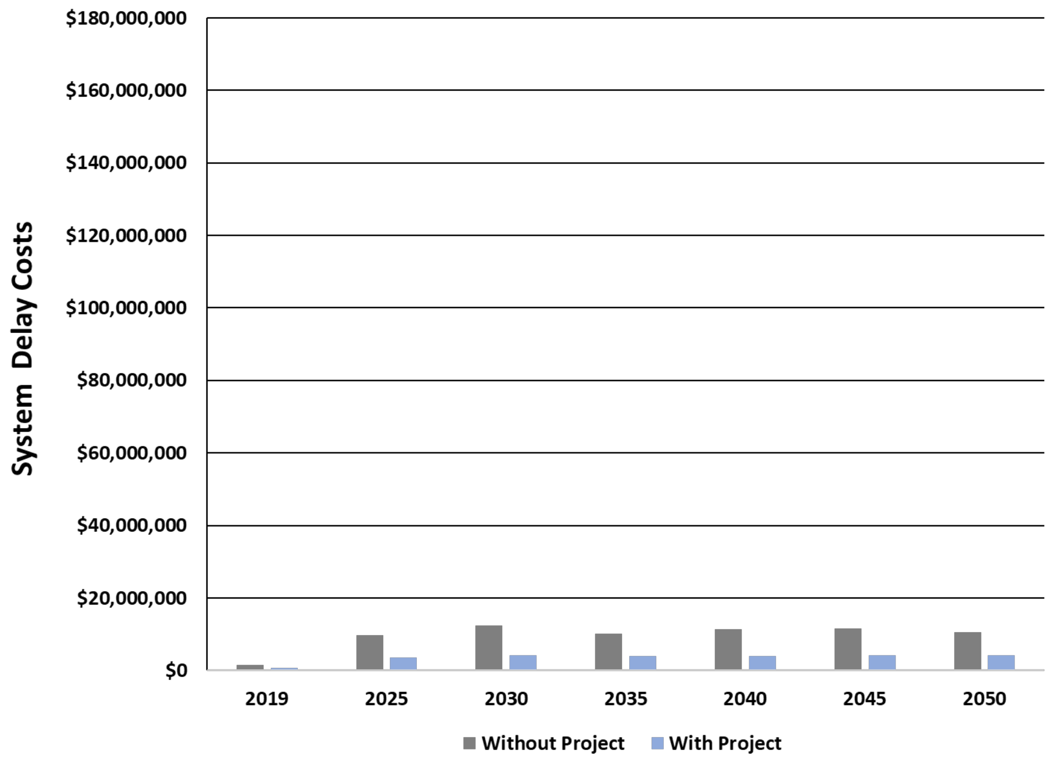


Table R13: Panamax
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	993	1,350	4,550	400	6,300
	WITH	993	1,350	1,950	100	3,400
2025	WITHOUT	1,195	2,100	8,850	3,100	14,050
	WITH	1,195	1,600	3,100	1,300	6,000
2030	WITHOUT	1,195	2,850	9,450	4,150	16,450
	WITH	1,195	1,900	3,900	1,400	7,200
2035	WITHOUT	1,195	2,800	9,800	2,950	15,550
	WITH	1,195	1,950	3,550	1,350	6,850
2040	WITHOUT	1,195	2,800	9,550	2,650	15,000
	WITH	1,195	1,900	4,000	1,100	7,000
2045	WITHOUT	1,195	2,750	9,850	2,850	15,450
	WITH	1,195	1,950	3,700	1,050	6,700
2050	WITHOUT	1,195	2,900	9,900	2,700	15,500
	WITH	1,195	1,900	3,750	900	6,550

Table R14: Panamax
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	993	1,700,000	4,200,000	5,900,000	2,400,000
	WITH	993	1,700,000	1,800,000	3,500,000	
2025	WITHOUT	1,195	2,700,000	9,900,000	12,600,000	6,700,000
	WITH	1,195	2,000,000	3,900,000	5,900,000	
2030	WITHOUT	1,195	3,700,000	11,500,000	15,200,000	7,900,000
	WITH	1,195	2,500,000	4,800,000	7,300,000	
2035	WITHOUT	1,195	3,600,000	10,300,000	13,900,000	7,000,000
	WITH	1,195	2,500,000	4,400,000	6,900,000	
2040	WITHOUT	1,195	3,600,000	10,100,000	13,700,000	6,800,000
	WITH	1,195	2,400,000	4,500,000	6,900,000	
2045	WITHOUT	1,195	3,500,000	10,600,000	14,100,000	7,400,000
	WITH	1,195	2,500,000	4,200,000	6,700,000	
2050	WITHOUT	1,195	3,700,000	10,400,000	14,100,000	7,400,000
	WITH	1,195	2,500,000	4,200,000	6,700,000	

Figure R13: Panamax
Reduction in Delay Times: 2019-2050

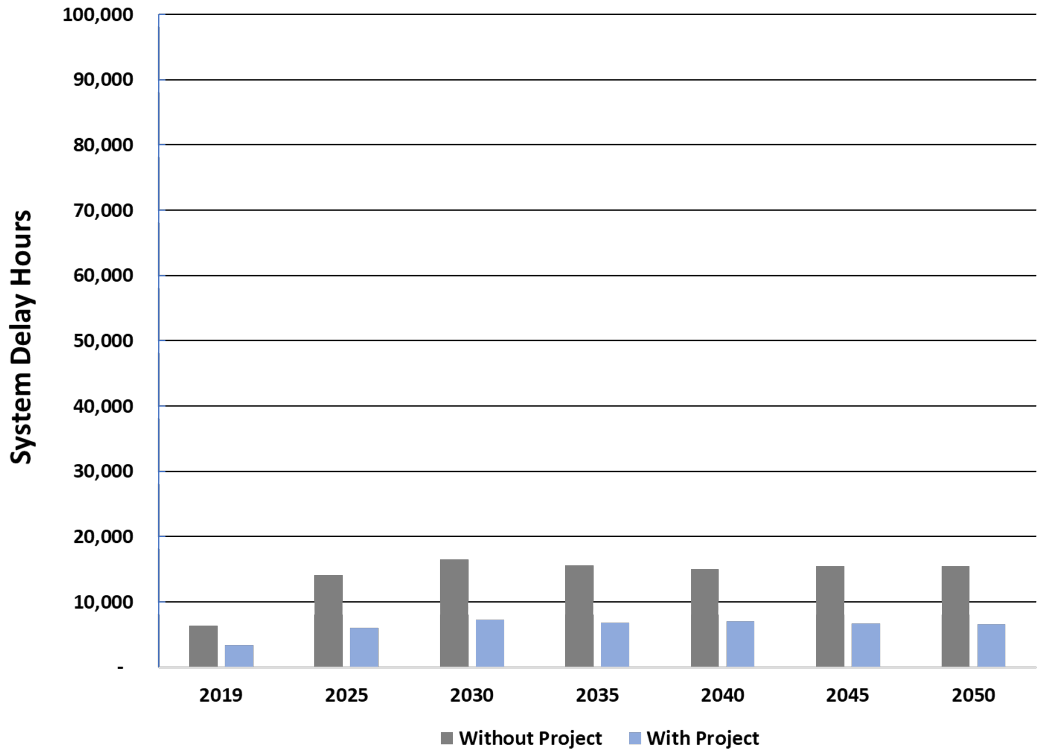


Figure R14: Panamax
Reduction in Delay Costs: 2019-2050

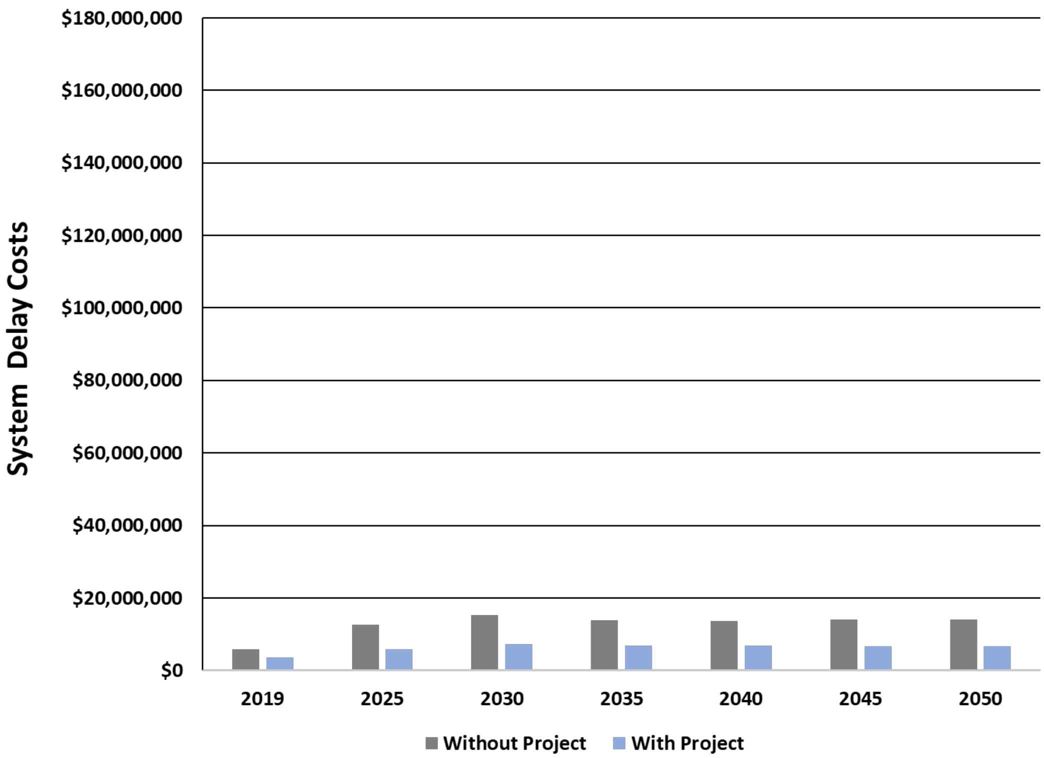


Table R15: RollOn-RollOff
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	40	50	150	0	200
	WITH	40	50	50	0	100
2025	WITHOUT	40	50	550	0	600
	WITH	40	50	100	0	150
2030	WITHOUT	40	0	250	0	250
	WITH	40	0	100	0	100
2035	WITHOUT	40	0	300	0	300
	WITH	40	0	100	0	100
2040	WITHOUT	40	0	300	0	300
	WITH	40	50	50	0	100
2045	WITHOUT	40	0	300	0	300
	WITH	40	0	100	0	100
2050	WITHOUT	40	0	250	0	250
	WITH	40	0	100	0	100

Table R16: RollOn-RollOff
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	40	0	0	0	0
	WITH	40	0	0	0	
2025	WITHOUT	40	0	200,000	200,000	200,000
	WITH	40	0	0	0	
2030	WITHOUT	40	0	100,000	100,000	100,000
	WITH	40	0	0	0	
2035	WITHOUT	40	0	100,000	100,000	100,000
	WITH	40	0	0	0	
2040	WITHOUT	40	0	100,000	100,000	100,000
	WITH	40	0	0	0	
2045	WITHOUT	40	0	100,000	100,000	100,000
	WITH	40	0	0	0	
2050	WITHOUT	40	0	100,000	100,000	100,000
	WITH	40	0	0	0	

Figure R15: RollOn-RollOff
Reduction in Delay Times: 2019-2050 (note values are small)

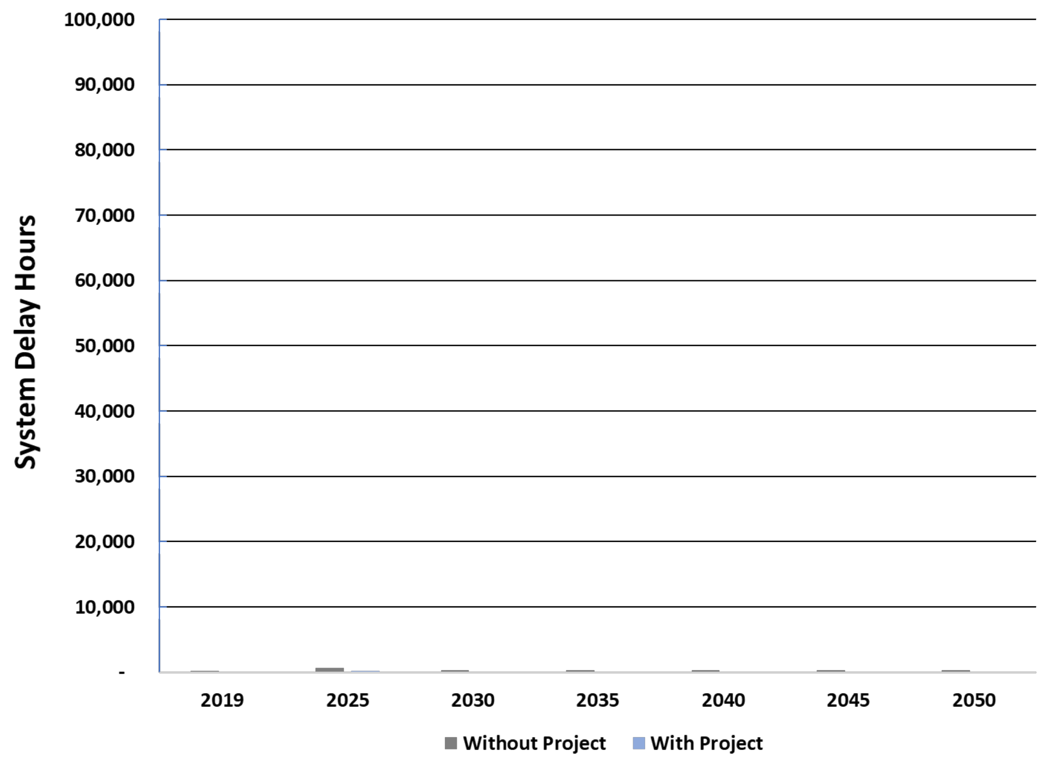


Figure R16: RollOn-RollOff
Reduction in Delay Costs: 2019-2050 note values are small)

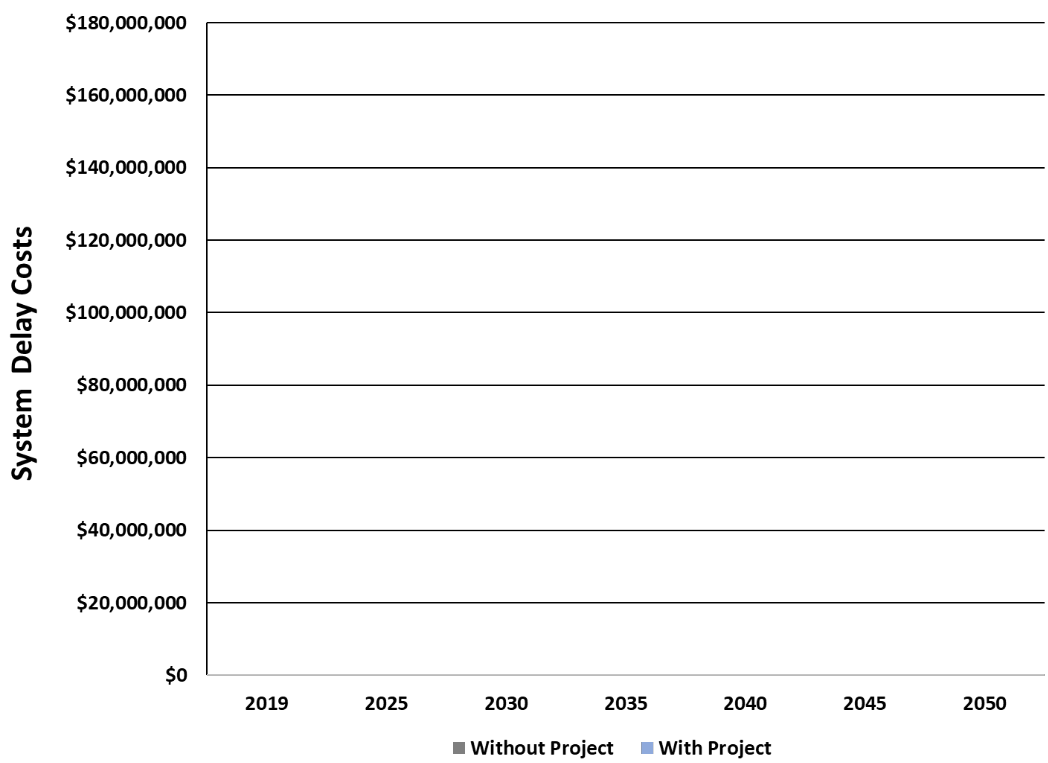


Table R17: Suezmax
Reduction in Delay Times: 2019-2050

		Number of Calls	Sea Delay Hours	Dock Delay Hours	Anch Delay Hours	Total Delay Hours
2019	WITHOUT	99	600	2,150	600	3,350
	WITH	99	250	650	0	900
2025	WITHOUT	245	2,900	7,850	3,250	14,000
	WITH	245	800	3,150	750	4,700
2030	WITHOUT	245	8,850	10,050	3,200	22,100
	WITH	245	1,000	3,800	950	5,750
2035	WITHOUT	245	7,800	10,050	3,300	21,150
	WITH	245	1,000	3,750	1,050	5,800
2040	WITHOUT	245	11,550	9,400	2,900	23,850
	WITH	245	1,050	3,950	1,250	6,250
2045	WITHOUT	245	8,350	10,400	3,550	22,300
	WITH	245	1,000	4,150	1,100	6,250
2050	WITHOUT	245	7,900	10,650	3,700	22,250
	WITH	245	1,150	3,800	850	5,800

Table R18: Suezmax
Reduction in Delay Costs: 2019-2050

		Number of Calls	At-Sea Vessel OP Costs	Dock& Anch Vessel OP Costs	Total Vessel OP Costs	OP Costs Reduction
2019	WITHOUT	99	1,300,000	6,100,000	7,400,000	5,400,000
	WITH	99	600,000	1,400,000	2,000,000	
2025	WITHOUT	245	6,500,000	24,800,000	31,300,000	20,700,000
	WITH	245	1,800,000	8,800,000	10,600,000	
2030	WITHOUT	245	19,800,000	29,600,000	49,400,000	36,500,000
	WITH	245	2,200,000	10,700,000	12,900,000	
2035	WITHOUT	245	17,500,000	29,900,000	47,400,000	34,400,000
	WITH	245	2,200,000	10,800,000	13,000,000	
2040	WITHOUT	245	26,000,000	27,500,000	53,500,000	39,500,000
	WITH	245	2,300,000	11,700,000	14,000,000	
2045	WITHOUT	245	18,700,000	31,200,000	49,900,000	36,000,000
	WITH	245	2,200,000	11,700,000	13,900,000	
2050	WITHOUT	245	17,700,000	32,100,000	49,800,000	36,900,000
	WITH	245	2,500,000	10,400,000	12,900,000	

Figure R17: Suezmax
Reduction in Delay Times: 2019-2050

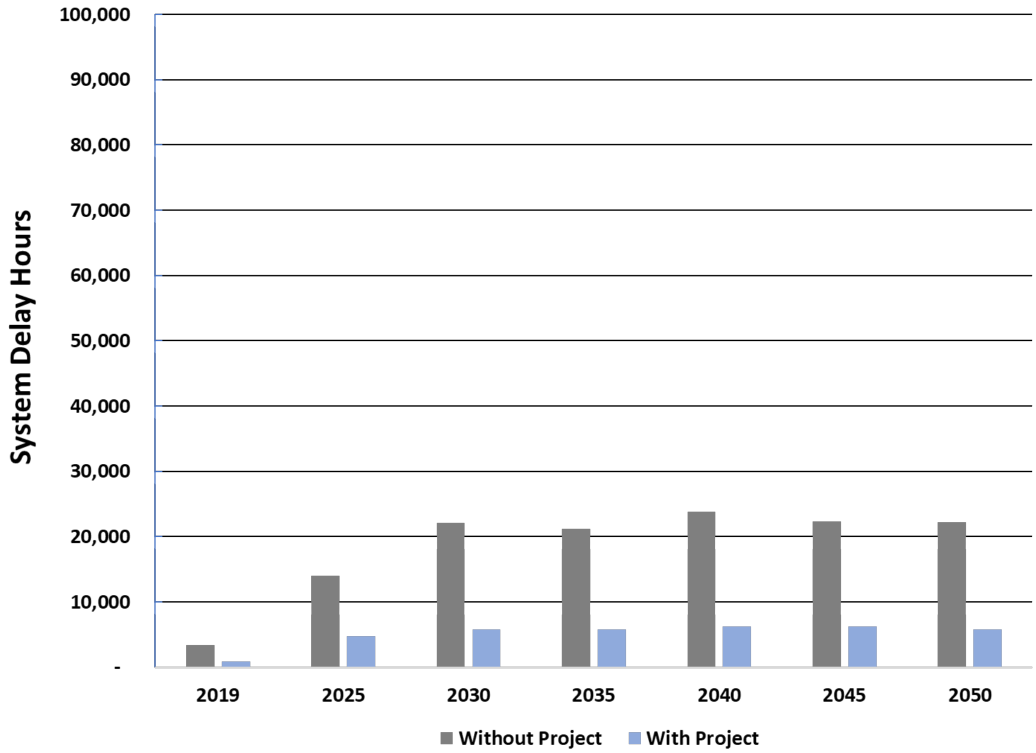


Figure R18: Suezmax
Reduction in Delay Costs: 2019-2050