Precision Navigation Socioeconomic Study

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Lexington, Massachusetts

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Background

Ports in the United States are an essential part of the economy, providing domestic jobs and access to the international market. In 2018, U.S. ports supported economic activity that accounted for over 26 percent of the national economy, totaling over $5.4 trillion and supporting over 30.8 million jobs (AAPA 2019).

Today's ships are moving through U.S. ports with little room under their keels—in some cases, less than 1 foot. As dredging budgets decrease and vessel drafts increase, with larger ships such as the Post-Panamax ships with drafts of 48 feet or more coming through the Panama Canal and to U.S. seaports, these margins will only become smaller. The "just-in-time" supply chain upon which the U.S. economy depends demands that ports operate continuously. However, delays and lightering due to the uncertainties posed by environmental factors can equate to millions of dollars a year in lost revenue for shipping companies and ports; this lost revenue ripples through and impacts the U.S. economy. Unfortunately, the tools currently available to mariners for making safe operational decisions have not changed significantly over the last 20 years, forcing increased vessel load and wait times in ports.

Precision Navigation provides mariners with a single data source for all navigational products, rather than requiring them to access disparate data sources to determine the best route when navigating congested waterways. NOAA currently holds all of the environmental intelligence that mariners need to make statistically sound, risk-based decisions. However, these data are difficult to locate and are not tightly integrated. Moreover, the data are not provided in interoperable formats that are useful to mariners and port operators. These data are also only available on a transactional basis (i.e., a user must select and download this information file by file). Mariners must then manually synthesize this information and attempt to interpret the data in the context of the ship's current position and planned route.

NOAA and its partners' success with Precision Navigation in the Port of Long Beach has led to increases in the draft allowance of about 4 feet, saving shippers an estimated $10 million per year (NOAA 2017). NOAA is currently working with its regional stakeholders in the top 30 U.S. ports to expand Precision Navigation to other high-volume ports throughout the nation.

Purpose of This Report

This report and project covered three primary objectives:

1. Use quantitative data to identify and prioritize the U.S. seaports that would most benefit from Precision Navigation, as NOAA wants to assess which other U.S. ports would make the most sense economically to implement Precision Navigation in the future.
2. Develop valuation methodologies to estimate the major economic benefits of Precision Navigation.

3. Implement those methodologies and talk with local stakeholders to estimate the economic benefits and impacts associated with implementing Precision Navigation at the Port of New York/New Jersey and the Ports of the Lower Mississippi River.

Port Prioritization Based on Those Most Likely to Benefit from Precision Navigation

Eastern Research Group, Inc. (ERG) prioritized all major U.S. ports based on their potential to benefit from Precision Navigation. We identified and ranked the top 20 U.S. seaports based on quantitative data that could indicate the benefits associated with Precision Navigation, and we described why each port would be a good candidate for Precision Navigation. The top 20 ports, ranked from having the most potential to benefit from Precision Navigation to the least, include the:

1) Ports of the Lower Mississippi River	8) Port of Virginia	15) Port of Jacksonville, Florida
2) Ports of Houston/Galveston, Texas	9) Port of Long Beach, California	16) Ports of Corpus Christi, Texas
3) Ports of Beaumont, Texas	10) Ports of Puget Sound, Washington	17) Port Everglades, Florida
4) Port of New York/New Jersey	11) Ports of the San Francisco Bay Area	18) Port of Mobile, Alabama
5) Port of Savannah, Georgia	12) Ports of the Delaware River and Bay	19) Port of Lake Charles, Louisiana
6) Port of Los Angeles, California	13) Port of Charleston, South Carolina	20) Port of Miami, Florida
7) Ports of the Columbia River, Washington	14) Port of Baltimore, Maryland	

Valuation Methodology

ERG created a methodology and Excel tool to calculate the annual economic benefit that would occur at a specific port from implementing Precision Navigation. We focused on decreased operating costs through the potential to increase each ship's cargo volume, as well as increased safety and decreased physical damage from reduced allisions (vessels colliding with fixed structures like bridges), collisions, and groundings. ERG used the methodology and Excel tool to calculate the economic benefits of implementing Precision Navigation in the Ports of the Lower Mississippi River and the Port of New York/New Jersey, which we describe below.

Estimated Benefits of Precision Navigation at the Ports of the Lower Mississippi and Port of New York/New Jersey

Table ES-1 presents the estimated benefits and impacts of implementing Precision Navigation at the Port of New York/New Jersey and the Ports of the Lower Mississippi River, including the Port of New Orleans, Port of South Louisiana, Port of Plaquemines, Port of St. Bernard, and Port of Baton Rouge.[1] We have not summed up the individual benefits, as they often benefit different stakeholders; some are economic benefits while others are economic impacts; and, in some cases, only of a portion of the benefits are attributable to Precision Navigation. Each row in Table ES-1 presents these benefits as a value chain, beginning with what Precision Navigation impacts, the associated change of that impact, and the benefit and value of that impact. We have provided additional context in the far-right column of Table ES-1, which is important for understanding how Precision Navigation may contribute to a benefit.

Table ES-1. Summary of benefits from Precision Navigation for the Ports of the Lower Mississippi and the Port of New York/New Jersey.

Impact Description	Change	Ports of the Lower Mississippi Value	Port of New York/New Jersey Value	Context of Benefit
Pilots are more comfortable operating with less under-keel clearance.	Ships can load more cargo or wait less time and reduce operating costs.	A small portion of **$200 million to $440 million per year in** reduced operating costs.	A small portion of **$216 million to $472 million per year** in reduced operating costs.	This is related to the value of using an extra foot of draft. Precision Navigation could help ships capture a small portion of this benefit as pilots are more comfortable operating with less under-keel clearance than without Precision Navigation. This may be particularly true on days with inclement weather or conditions. *"One of the biggest issues facing pilots is accurate determination of under-keel clearance. Maximizing vessel draft has a very significant impact on commerce." – Captain John Betz, Port of Los Angeles*
Pilots use the real-time data from Precision Navigation to operate more safely.	Ships experience fewer allisions, collisions, and groundings.	**$515,000 to $1,030,000 per year** saved for physical damage and injuries; about **$3.7 to $9.8 million per year** when considering more	**$176,000 to $351,000 per year** saved for physical damage and injuries; about **$1.7 to $3.3 million per year** when considering	The lowest range includes savings to ships and insurance companies related to physical damage, injuries, and deaths. The larger range additionally accounts for environmental damage and waiting time from shutting down waterways. Taken one step further, a day-long closure impacts about $590 million of

[1] The Port of St. Bernard data set was subsumed by another Lower Mississippi River port—the Port of New Orleans—in most of the data sets, most likely due to geography, but was included as one of the five ports in our analysis.

Impact Description	Change	Ports of the Lower Mississippi Value	Port of New York/New Jersey Value	Context of Benefit
		comprehensive economic losses.	more comprehensive economic losses.	cargo at the Ports of the Lower Mississippi (Burkley 2019) and over $500 million at the Port of New York/New Jersey (Census 2017), which could potentially lead to an economic impact of over a **$1 billion** loss at both ports when considering the ripple effect on the economy and impact on the supply chain. If Precision Navigation can help avoid one accident that would shut down the port, it would contribute to a huge economic impact.
Pilots can better time and work around weather events.	Fewer ships are delayed by weather-related events.	Qualitative	Qualitative	Precision Navigation will help lessen the operating costs for ships associated with delays from weather closures or tide restrictions. *"Having all weather information in one central location would have a huge benefit to pilots. When a weather event is imminent, such as fog, having access to all the available information has a huge impact on decisions and efficiency." – Pilot from Port of Tampa Bay*

Recommendations to Agency

ERG performed the prioritization and economic analyses with limited data on the effectiveness of Precision Navigation, as it has only been implemented for oil tankers in the Port of Long Beach to date. In valuing the many benefits of Precision Navigation, we relied on feedback from pilots who might implement the technology and data from similar systems (e.g., PORTS®) that have generated benefits similar to those expected from Precision Navigation. We estimated ranges and approximated values that could be more confidently estimated once more ports implement Precision Navigation. We have generated the following recommendations to improve the results of this study in the future:

- **Study Precision Navigation's effectiveness in reducing incidents after implementing the technology for several years.** ERG based the effectiveness in reducing allisions, collisions, and groundings on PORTS®, which is incorporated into Precision Navigation but is not the only data used to increase safety. After collecting several years of data at a handful of ports, this information could help establish a defensible estimate of the expected reduction of incidents resulting from Precision Navigation. This would help estimate reduced damage, as well as the reduced number of events that might shut down a waterway and cause significant impacts due to ships not delivering commodities on time.

- **Interview more pilots after implementing Precision Navigation to better understand associated behavior changes.** As part of this study, ERG interviewed pilots at the Port of Long Beach, California, who used Precision Navigation to help bring in oil tankers. The pilots integrated Precision Navigation with an under-keel clearance system, which increased the declared draft allowance by a few feet. It is unclear from this study alone how much Precision Navigation and the under-keel clearance system each contributed to this declared draft increase. The pilots ERG interviewed at the Ports of New York/New Jersey and the Lower Mississippi River agreed that Precision Navigation may help loosen their draft restrictions. However, they had a hard time quantifying how much this would help without implementing the technology. Depending on the port and situation, pilots seemed to indicate that Precision Navigation's real-time data could increase their comfort when dealing with less under-keel clearance or adverse conditions, and that Precision Navigation could result in a permanent draft increase or a lessening of tide and weather-related restrictions.
- **Gather more data and interview more pilots to better understand the scope of vessel delays from weather-related events**. We have only developed a qualitative estimate for Precision Navigation's impact on weather-related delays, including tide restrictions. To more fully understand Precision Navigation's impact on reducing these delays, more information from pilots and the port is needed to understand how these delays transpire. Additionally, it will be important to gain knowledge about what information/data pilots and ports need to decrease the length and number of delays that occur, and whether Precision Navigation will meet those needs.

1. Purpose and Background

1.1 Project Background

Today's ships are moving through U.S. ports with little room under their keels—in some cases, less than 1 foot. Ships are getting larger, and the "just-in-time" supply chain is placing increasing demands on port operations. Unfortunately, the tools currently available to mariners for making safe operational decisions have not changed significantly over the last 20 years, forcing increased vessel load and wait times in ports.

Precision Navigation provides mariners with a single data source for all navigational products, rather than requiring them to access disparate data sources to determine the best route when navigating congested waterways. Ports that implement Precision Navigation should see increases in efficiency and safety that, as outlined in this report, will benefit many stakeholders. Such is the case at the Port of Long Beach, where NOAA and its partners have implemented Precision Navigation.

1.2 Project Purpose

The purpose of this project includes three primary objectives:

1. Use quantitative data to identify and prioritize the U.S. seaports that would most benefit from Precision Navigation, as NOAA wants to assess which other U.S. ports would make the most sense economically to implement future projects.
2. Develop valuation methodologies to estimate the major economic benefits of Precision Navigation.
3. Implement those methodologies and talk with local stakeholders to estimate the economic benefits and impacts associated with implementing Precision Navigation at the Port of New York/New Jersey and the Ports of the Lower Mississippi River.

2. Report Organization

This report is organized as follows:

- Section 3 presents ERG's method for ranking over 300 U.S. ports based on their potential to benefit from Precision Navigation. We identified and prioritized the top 20 U.S. seaports based on quantitative data that could serve as a good indicator of Precision Navigation's effectiveness.
- Section 4 presents our economic benefit calculation methodology. This includes a methodology based on decreased operating costs through the potential to bring larger ships into the port (either through an increased draft allowance or through comfort bringing in ships with less room under their keel). We also developed a methodology to estimate the benefit of increased safety from reduced allisions, collisions, and groundings. This methodology could broadly apply to any impacts associated with an allision, collision, or grounding for which data are available (e.g., physical damage, environmental damage, economic impacts of not delivering goods on time, and lost time associated with shutting down vessel traffic in a channel).
- Section 5 presents results of applying the methodology to the Port of New York/New Jersey and the Ports of the Lower Mississippi River.
- Section 6 provides recommendations to NOAA for further and improved analysis after Precision Navigation is more widely implemented at U.S. ports.
- Section 7 includes references cited for this work.
- Appendix A presents the port profiles for the top 20 ports that could most benefit from Precision Navigation, which we identify in Section 3. We have included maps of allisions, collisions, and groundings as well as data we used that served as inputs into the port rankings.
- Appendix B contains supporting data for the economic estimates of impacts from allisions collisions, and groundings.

3. Port Prioritization

The top 20 ports, ranked from having the most potential to benefit from Precision Navigation to the least, include the:

1) Ports of the Lower Mississippi River	8) Port of Virginia	15) Port of Jacksonville, Florida
2) Ports of Houston/Galveston, Texas	9) Port of Long Beach, California	16) Ports of Corpus Christi, Texas
3) Ports of Beaumont, Texas	10) Ports of Puget Sound, Washington	17) Port Everglades, Florida
4) Port of New York/New Jersey	11) Ports of the San Francisco Bay Area	18) Port of Mobile, Alabama
5) Port of Savannah, Georgia	12) Ports of the Delaware River and Bay	19) Port of Lake Charles, Louisiana
6) Port of Los Angeles, California	13) Port of Charleston, South Carolina	20) Port of Miami, Florida
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Appendix A contains a profile for each of the top 20 ports with data ERG used to rank the ports; maps of the ports (BTS 2017); and spatial maps of allisions, collisions, and groundings near each port between 2001 and 2015 (USCG 2015).

3.1 Prioritization Methods

3.1.1 Step 1: Identify and Collect Data for Metrics That Correlate with Precision Navigation's Potential Impact

Three major outcomes of Precision Navigation are reduced delays, increased cargo from increased draft utilization, and increased safety when navigating to the berth. To prioritize the ports, ERG collected data that could indicate how much a given U.S. port would benefit from Precision Navigation information. ERG identified data points for this analysis that positively correlate with Precision Navigation's potential impacts: value of cargo; tonnage; nearby allisions, collisions, and groundings; number of vessel calls; and number of vessel calls close to the draft allowance.

ERG used the following four data sources to better understand the ports that could most benefit from Precision Navigation:

- U.S. Coast Guard (2015) Marine Information for Safety and Law Enforcement (MISLE) data listing incidents by waterway from 2001 to 2015.
- U.S. Census Bureau (2017) data listing import and export values by port.
- Waterborne Commerce Statistics Center (WCSC) (2017) data on inbound and outbound vessel entrances and clearances.
- WCSC (2017) data on tonnage by port.

3.1.2 Step 2: Extract Relevant Data from Data Sources and Combine into One Database

U.S. Coast Guard MISLE Data

One metric ERG used to determine Precision Navigation's potential impact and value is the number of safety incidents at a port. Therefore, ERG used the MISLE data set to evaluate the need for safety improvements at each U.S. port. Ports with more safety incidents may see a greater benefit from using Precision Navigation. The raw data set lists all incidents by waterway. To link each incident to a port, we performed a distance calculation based on the latitude and longitude values provided for each incident, as well as the latitude and longitude values for all U.S. ports we found on USA Trade Online. ERG manipulated the data to only include incident type, specific vessel types and services likely to use Precision Navigation, and distance to port. ERG analyzed the following vessel types, vessel services, vessel classes, and incident types and excluded all incidents and vessels not listed below:

- **Vessel types:** Articulated tug and barge (tug), barge carrier (e.g., LASH), bulk liquid cargo (tank) barge, chemical tank ship, combination carrier (e.g., OBO), container barge, container ship, cutter/dredger barge, deck barge, dry cargo barge, gas carrier, general, harbor cruise vessel, heavy load carrier, integrated tug and barge (barge), integrated tug and barge (tug), ocean cruise vessel, ore carrier, pallets carrier, petroleum oil tank ship, river cruise vessel, roll-on/roll-off (ro-ro)/container, vegetable oil tank ship, vehicle carrier, and woodchips carrier.
- **Vessel services:** Freight barge, freight ship, passenger (inspected), passenger (more than six), public tankship/barge, tank barge, tank ship, and towing vessel.
- **Vessel classes:** Barge, bulk carrier, general dry cargo ship, refrigerated cargo ship, ro-ro cargo ship, tank ship, and towing vessel.
- **Incident types:** Allision, collision, and grounding.
- **Distance to port**: 10 km, 5 km, 3 km, and 1 km.

U.S. Census Data: Cargo by Value

ERG used Census data to determine which U.S. ports handle the most cargo by value. ERG hypothesized that cargo value and the value of Precision Navigation have a positive relationship; cargo values may increase due to larger economic gains from decreased delays and an increased draft allowance permitted by Precision Navigation implementation. The raw data set lists import and export values by port. ERG combined import and export values for each port using 2017 data (Census 2017).

Entrance and Clearance Data: Calls Close to Maximum Draft

ERG used the WCSC entrance and clearance data (WCSC 2017) to determine the number of vessel calls closest to the maximum draft. This is important because those vessels could take advantage of an extra foot of under-keel clearance if pilots use Precision Navigation to become more comfortable navigating with less distance under keel. ERG included both inbound and outbound data to produce a table consisting of the total number of vessel calls at each U.S. port, broken down by the number of vessel calls at each different number of draft feet. ERG determined the maximum draft allowance at each port using 1) U.S. Army Corps of Engineers (USACE) channel project summaries (if available), 2) Bureau of Transportation Statistics (BTS) Freight Statistics Program data (BTS 2017) (if the information was not available through the USACE channel project summaries), or 3) the maximum value from the entrance and clearance data (if neither USACE nor BTS draft data were available) (WCSC 2017). ERG used the declared or determined maximum draft allowance and vessel call table to determine how many vessel calls at each U.S. port occurred within 1 foot and 5 feet of the maximum draft allowance.

WCSC Data: Cargo by Tonnage

ERG used this data set to determine which U.S. ports handled the most foreign cargo by tonnage (much of the domestic traffic is shallow draft traffic). Like cargo value, tonnage provided insight about how ports that use Precision Navigation could yield economic gains from decreased delays and increased draft allowance. We uploaded the raw data to our database with no manipulation.

3.1.3 Step 3: Create a System to Prioritize Ports Based on a Combined Analysis of All Metrics Used

Below, we describe how we synthesized the data to rank and prioritize the ports based on Precision Navigation's potential impact.

Develop Port Identification System

Each data source had slightly different names for each port, and some ports were included in only one or two data sources, while other ports were included in all four data sources. We assigned each port a unique ID that was placed alongside each port name in our database. This allowed ERG to refer to each individual port by its ID and to capture data from all four data sources related to the individual port. We based these codes on WCSC and entrance and clearance port codes embedded in the raw data, and we created new unique IDs for any port only from a data source without an existing port code. (ERG coded these new unique IDs as number 10,001 and above.)

Create Index Scores

ERG initially ranked all the ports for each specific metric by value. The WCSC ranked ports based on their 2017 foreign tonnage values. The U.S. Census Bureau ranked ports based on their 2017 combined import and export value. The MISLE metric ranked ports based on the number of allisions, collisions, and groundings within 3 km of each port between 2002 and 2013. The entrance and clearance metrics ranked ports based on total number of vessel calls and total number of vessel calls within both 5 feet and 1 foot of maximum draft.

While these rankings are useful, a simple ranking does not show the relative difference between ports within each metric (i.e., whether the second-ranked port is nearly the same as the top-ranked port or is

⅓ the value). ERG assigned index scores to each port within every metric to address this issue. For each metric, ERG gave the top-ranked port an index score of 100. For each port in that specific metric's ranking, ERG assigned an index score proportional to the top port. For example, the top-ranked port for tonnage was Houston, Texas, with 173,210,955 short tons of foreign cargo, and the second-ranked port was South Louisiana with 134,871,437. ERG gave Houston, Texas, an index score of 100 and South Louisiana an index score of 78 (i.e., 134,871,437 ÷ 173,210,955 = 0.78).

Using index score, ERG could compare the relative difference of ports within each metric; for instance, a port with an index score of 50 has exactly half the value of a port with an index score of 100 and twice the value of a port with an index score of 25. ERG also used index scores to develop composite scores across metric by weighting each metric across all ports.

Create Weighting System

ERG weighted each metric to reflect the importance of the metric when considering the overall impact that Precision Navigation will have at each port. An individual "weight system" prioritizes ports by ranking them by the sum of all their respective index scores for each metric. Each metric is given a weight (percentage from 0 to 100) that represents the percentage of the total ranking that is derived from that specific metric. ERG's prioritization considered three weighting systems: one that equally emphasized all metrics; one that gave more emphasis to tonnage, import, and export values; and one that gave more emphasis to vessels close to the maximum draft allowance and allisions, collisions, and groundings within 3 km of port (see Table 1 below as an example of this third weighting system). We ranked the ports according to all three of these weighting systems, which helped us identify the 20 ports we developed port profiles for in Appendix A.

Table 1. Top 25 ports with the most weight on vessels near max draft allowance and allisions, collisions, and groundings.

Port Name	Vessel Calls Score (8%)	WCSC Tonnage Score (8%)	Number of Vessels Within 1 Foot of Max Draft Score (25%)	Number of Vessels Within 5 Feet of Max Draft Score (25%)	U.S. Census Bureau Value Score (8%)	Incidents Within 3 km Score (25%)	Aggregate Score
Lower Mississippi River	4.8	8	25	25	2.2	15.7	80.7
Beaumont, TX	1.9	2.8	21.9	19.3	0.8	25	71.9
Houston/Galveston, TX	8	7.4	3.8	8	4.3	18.8	50.4
Savannah, GA	2	1.3	15.9	20.8	2.5	0.2	42.7
Columbia River, OR/WA	1.1	1.7	23.9	8.2	0.6	1.8	37.2
Duluth, MN – Superior, WI	0.3	0.3	14.1	7.3	0	0	21.9
Jacksonville, FL	1.1	0.4	7.6	7.2	0.7	1.1	18.1
Ketchikan, AK	0.4	0	5.5	11.7	0	0	17.7

Port Name	Vessel Calls Score (8%)	WCSC Tonnage Score (8%)	Number of Vessels Within 1 Foot of Max Draft Score (25%)	Number of Vessels Within 5 Feet of Max Draft Score (25%)	U.S. Census Bureau Value Score (8%)	Incidents Within 3 km Score (25%)	Aggregate Score
New York/New Jersey	3.1	3.1	0.4	3.6	5.4	0.9	16.5
Lake Charles, LA	0.8	0.9	6.2	5.6	0.3	0.2	14
Port of Virginia	1.6	2.1	1.6	1.9	2.1	4.3	13.5
Key West, FL	0.2	0	5.5	7.6	0	0	13.3
Charleston, SC	1.5	0.8	1.8	5.9	2	0.4	12.5
Delaware River, DE	1.7	1.8	3.1	1.8	1.2	2.8	12.3
Los Angeles, CA	1.3	2	0	0	8	0.7	12
Bay Area, CA	2.2	1.5	2.3	1.9	2	1.6	11.5
Juneau, AK	0.3	0	0.2	8.2	0	0	8.6
Long Beach, CA	1.7	2.5	0	0.3	2.8	1.1	8.4
Puget Sound, WA	2.9	1.5	0.7	0.9	2.3	0.1	8.3
Boston, MA	0.6	0.4	2.1	4.8	0.3	0	8.1
Douglas Harbor, AK	0.1	0	4.6	3.1	0	0	7.8
Baltimore, MD	1.5	1.3	0.1	2.7	1.5	0.7	7.8
Port of Mobile, AL	1.1	1.2	0	0	0.4	4.7	7.5
Corpus Christi, TX	1.3	2.1	1.4	0.7	0.6	1	7.2
Greenville, MS	0	0	0	0	0	7	7

Table 2 contains the overall rank for the top 20 aggregated ports for each of the three ranking systems. We input the results from Table 1 into the far-right column of Table 2. Additionally, ERG developed two different weighting schemes to better understand the sensitivity associated with valuing different metrics linked to the benefits of Precision Navigation.

Table 2. Port rankings under three different weighting systems.

Port Name	Rank for Equal Weights for All 6 Metrics (Averaging Vessels Close to 1 and 5 Feet of Max Draft)	Rank for More Weight Given to Tonnage and Value	Rank for More Weight Given to Incidents and Number of Vessels Close to Max Draft
Lower Mississippi River, LA	1	2	1
Houston/Galveston, TX	2	1	3
Beaumont, TX	3	5	2
New York/New Jersey	4	4	9
Savannah, GA	5	6	4
Los Angeles, CA	6	3	15
Columbia River, OR/WA	7	11	5
Port of Virginia	8	8	11
Long Beach, CA	9	7	18
Puget Sound, WA	10	9	19
Bay Area, CA	11	10	16
Delaware River, DE	12	12	14
Charleston, SC	13	13	13
Baltimore, MD	14	14	22
Jacksonville, FL	15	17	7
Corpus Christi, TX	16	15	24
Port Everglades, FL	17	19	26
Port of Mobile, AL	18	16	23
Lake Charles, LA	20	18	10
Miami, FL	21	20	40

Port Aggregation

Precision Navigation could theoretically be implemented in several areas of interest (such as the Lower Mississippi River) to serve multiple ports within a region. ERG aggregated data from ports near these areas of interest based on direction from NOAA and expert consultation on exactly which ports to aggregate within the given areas.

ERG aggregated port data for the following areas: Lower Mississippi River; Houston/Galveston, Beaumont, Corpus Christi, and Brownsville, Texas; Columbia River; Puget Sound; Port of New York/New Jersey; Delaware River; San Francisco Bay Area; Port of Virginia; and Port of Mobile, Alabama. We aggregated ports together based on the following criteria:

1. The port/river segment handles oceangoing traffic.

2. The various ports share a common river or entrance point from the ocean/gulf.
3. The various ports/river segments are in close enough proximity that a single NOAA observation system would serve them all.

We used these criteria to determine how to aggregate individual ports based on geographic regions of interest. These criteria should not be viewed as limiting factors for NOAA to bring Precision Navigation to other specific ports or regions.

3.2 Port Profiles

ERG developed port profiles for the top 20 ports it identified during the prioritization analysis (see Appendix A). Profiles contain the following data (where available):

- ERG-created spatial maps of allisions, collisions, and groundings around the port between 2001 and 2015 using MISLE incident data (USCG 2015).
- A port area map that includes bridge locations and air draft information, pulled directly from BTS (2017).
- Data from all metrics used in the port prioritization analysis.
- A brief summary of port characteristics and information about current navigational technology in use at the port. This information is based on conversations with contacts knowledgeable about each port, such as pilots or the port authority. Many profiles do not have this section because we did not reach contacts at all ports.
- A brief explanation of how the data indicate a port could be a candidate for Precision Navigation (e.g., many vessel calls are near the maximum draft, which may indicate that a lot of ships may want to load heavier cargo and take advantage of pilots being comfortable operating with less under-keel clearance). ERG primarily based this on the data it gathered and summarized in each port profile and, when available, insights from a contact with knowledge of the port.

3.3 Limitations on Prioritization

ERG Focused on Major Ports During Aggregation

ERG focused its aggregation on major ports due to limited resources. There is the potential that a few smaller ports or waterways outside the top 20 were not aggregated, which may impact the rankings outside the top 20 or 25. This likely had little or no impact on what ports ERG included in the top 20.

ERG Compiled Maximum Draft Allowance Data from Multiple Data Sets

Due to resource constraints, ERG could not individually locate all of the declared maximum draft allowances if they were not included in the USACE or BTS data sets of declared maximum drafts—with the exception of the Ports of Virginia; Kalama, Washington; and Longview, Washington, which were identified from their port authority websites. In cases where we did not have a declared maximum draft from USACE or BTS, we used the actual maximum draft value from the entrance and clearance data as a proxy for the declared maximum draft allowance. In some cases, this value may be less than the declared draft (or more if they rode in a high tide). This discrepancy would impact the index score for some ports (mostly smaller ports outside the top 20) but most likely would not have been significant enough to have changed the prioritization itself.

ERG Made Some Judgment Calls on Ports Near the Bottom of the Top 20

The top 20 ports selected for prioritization fall very close to the ranking based on equal weighting for each metric. ERG did not include the Port of Duluth–Superior in its port profiles because NOAA has requested profiles for coastal ports instead of inland ports at this time. Coastal ports that fell just outside the threshold for port profiles included Boston, Massachusetts; Ketchikan, Alaska; and Key West, Florida. These ports ranked highly for the safety and draft allowance weight system but did not rank in the top 20 for the other two weighting systems. NOAA may also want to include other factors when determining final port priorities for Precision Navigation, such as the presence of U.S. military facilities, liquified natural gas (LNG) facilities, or other energy development facilities.

Some Ports Had No Data Available from Certain Data Sets

Some ports (typically smaller ones) appear to have no data for any metric. ERG initially added these ports because they had incident data for either 10 km or 5 km away from port. They remain in the database if NOAA requires future analyses for incidents farther than 3 km from port.

Some Data Sources Excluded Data for Smaller Ports

Most ports do not have data for all metrics. ERG has two explanations for why this could be:

- The U.S. Census Bureau and WCSC only had data for the top 150 and 200 U.S. ports, respectively; therefore, some smaller ports were not included.
- MISLE had no data for some ports because there were no allisions, collisions, or groundings within 3 km of port.

This may have affected some of the port rankings because some of the small ports within the larger aggregated ports may have had incomplete data; however, due to the small number of ports excluded, this issue most likely did not change the ranking of any ports in the prioritization.

Ports with Lower Maximum Draft Allowance May Have Inflated Scores

Some ports had a high number of vessels entering that were close to the maximum allowable draft, but the maximum draft allowances were low in comparison to the drafts of large deep draft vessels that will be most impacted by Precision Navigation. Therefore, these ports' scores for the vessels close to the maximum draft allowance metric are likely artificially high, especially when considering Precision Navigation's impact, which will likely be for larger vessels. More specifically, if a port with a maximum draft allowance of 15 feet had a high number of vessels coming into port at 13 and 14 feet, it would have a high index score for the "vessels close to maximum draft" metric, but Precision Navigation will most likely not be able to help increase those specific vessels' draft. This, however, did not have much of an impact on the top 20, as this limitation impacted much smaller ports with lower drafts.

ERG Did Not Evaluate the Likelihood for Pilots to Operate with Less Under-Keel Clearance or Ships to Load Heavier Cargo

This prioritization assumes all ports have pilots that are more comfortable operating with less under-keel clearance (e.g., lessening restrictions associated with currents, waterway dynamics, and tides, or increasing draft allowance if used with an under-keel clearance system, like at the Port of Long Beach). Precision Navigation will more heavily favor ports where pilots choose to operate with less under-keel clearance and where ships can either add more tonnage or be replaced with larger ships with lower operating costs. We did not have the resources in this project to perform that type of analysis for all ports, but an understanding of this issue could slightly shift the rankings for ports within the top 20.

Limitations in Using MISLE Incident Data as an Indicator to Predict Safety Improvements

ERG used MISLE data (USCG 2015) to determine if safety was a concern at a specific port. While allisions, collisions, and groundings within 3 km of port for the period from 2002 to 2013 provides a consistent indicator for the potential to improve safety, specific ports may vary in how many improvements they have made to ensure safe navigation for pilots through technological changes (acknowledged in the port profiles) and changes to port infrastructure. Additionally, certain ports may have incidents that inherently cause more substantial damage or delays from port closures. ERG did not have the data or resources to comparatively explore which ports may have more substantial incidents, which would certainly be another indicator of the value Precision Navigation could bring to the port.

ERG Only Used 2017 Data for Many Metrics

While an analysis of how a port’s tonnage, cargo value, and vessel calls change over time may have given a better picture of trends over time at specific ports, ERG focused its analysis on a single year of data due to data availability and resource limitations. Additionally, at the time of analysis, 2017 was the most recent year where complete data for most metrics were available.

4. Benefit Valuation Methodology

This section describes two methods for quantifying the benefits associated with implementing Precision Navigation at a specific port. These two methodologies are meant to be generic, so they can be applied to any port. However, when we implemented the methodologies for the two case studies in Section 5 of this report, we gained an additional understanding of how Precision Navigation will affect those specific ports, as the technology's impact will not be uniform among all ports. Accordingly, this methodology may be viewed more accurately as a framework for quantifying associated benefits of Precision Navigation. We considered other benefits quantitatively and qualitatively for the case studies in Section 5 based on site-specific operations that are related to these two methods.

4.1 Value of Decreased Operating Costs from Additional Cargo

This methodology outlines the steps to quantify the increase in cargo and subsequent decrease in operating costs per ton of cargo that will result from increasing a vessel's draft by 1 foot. This is not necessarily the value of Precision Navigation, as implementation of the technology may not directly result in a 1-foot draft allowance increase. Like the Port of Long Beach, it could result in an increased draft when used with an under-keel clearance system. Or, it could help reduce restrictions due to tides, weather, or waterway dynamics, which would be equivalent to a draft allowance increase in these certain situations. Thus, this method along with some additional context can help us start to determine Precision Navigation's contribution to this benefit. For example, vessels may potentially load to the same weight as without Precision Navigation but experience reduced delays when entering and exiting a port because of tide restrictions. This methodology assumes that vessels will use an additional foot of draft; however, if ships continue to load to the same tonnage, ports will only realize some portion of this benefit in the form of reduced delays (but counting both would be double counting the potential benefit).

This calculation of decreased operating costs assumes that vessels can load more tonnage or be replaced by bigger ships over time to take advantage of the decreased operating costs per ton. Realizing this benefit could take some time as shipping companies adapt to behavior changes from pilots using Precision Navigation.

The calculation of decreased operating costs is not connected to the value of the commodities that the vessel carries (i.e., operating costs to move a ton of cheaper goods are comparable to moving a ton of more expensive commodities if the same vessel type is used). While the value of the commodities themselves do not influence the vessel operating costs, downstream economic impacts are associated with the value of the goods. For example, a vessel full of technology-related goods may support more jobs than a vessel full of agricultural products. However, increasing the commodity amount on a ship may not necessarily provide an additional benefit (outside of reduced operating costs), as the same value could just be shipped as part of additional vessel calls. That is, if there are 100,000 tons of soybeans to ship, one can only ship 100,000 tons whether they are part of one or multiple shipments. This impacts the operating costs but ultimately does not impact the jobs supported to produce 100,000 tons of soybeans.

4.1.1 Value Chain for Decreased Operating Costs

Below, ERG has described the value chain associated with vessels being able to utilize an extra foot of draft, leading to more fully loaded ships and decreased operating costs.

NOAA's Precision Navigation program provides information that allows pilots to navigate ships with more certainty, efficiency, and safety. Precision Navigation is an integrated data source that includes multilayer bathymetric charts and both forecasted and real-time environmental conditions at the port, which gives pilots more confidence to navigate ships with greater drafts and less under-keel clearance. Thus, shipping companies and vessel captains may decide to load more cargo onto each shipment or use larger ships over time, leading to reduced operating costs and overall cost savings per ton of cargo shipped.

4.1.2 Step-by-Step Methodology for Decreased Operating Costs

Our cost savings estimate is a range that varies by port implementation depending on data availability. The main premise of our estimate is as follows: We aim to estimate an annual reduced operating cost at a port. ERG starts by estimating the **number of vessel calls at a port in a given year**. Then, ERG estimates how much **additional tonnage can be loaded onto each vessel call** as a result of an additional foot of draft. Next, ERG **estimates vessel transit length and speed.** Finally, ERG estimates vessel hourly operating costs to derive an annual dollar savings using one of two methods, each of which results in exactly the same savings amount:

1. Assume that tonnage will remain constant, and the added loading due to Precision Navigation will result in fewer annual vessel calls and overall decreased operating costs because of fewer trips.
2. Assume that tonnage to a port can increase, and the added loading due to Precision Navigation will result in lower unit operating costs, meaning the baseline tonnage will be shipped at a lower overall cost. Additionally, other benefits are associated with additional economic activity at a port, but we have not quantified those in this methodology.

Step 1: Estimate the Number of Vessel Calls That Will Increase Their Load If Draft Allowance Increases

ERG pulled the number of vessel calls by draft from the entrance and clearance data set (WCSC 2017). We then used this information to estimate the number of annual vessel calls at each port that will be affected by an increase in draft allowance, analyzing the vessel call data by draft feet. See Figure 1 (on page 19), which shows the number of each vessel call by draft for the Port of New Orleans in 2017.

Assumptions:

- ERG's lower bound estimate assumes that ships well below the maximum draft would not change their behavior by adding more cargo because of Precision Navigation. For this estimate, ERG assumes ships are loading to drafts of less than 37 feet based on a different constraint than the draft allowance of that port. We based the 37-foot cutoff on conversations with several contacts from the Port of New York/New Jersey and the Ports of the Lower Mississippi River and their understanding of the vessels that Precision Navigation would impact the most. These contacts indicated there was an existing reason (i.e., under-keel clearance, waiting for tides) that vessels were not loading heavier cargo given the current state of the port. This could mean those larger ships increase their tonnage or are replaced by even larger ships over time, so the benefit may not be immediately realized.

- ERG's upper bound estimate assumes that all ships will change their behavior by adding more cargo because of Precision Navigation. This generally follows the principles used in the USACE economic analyses for channel improvement projects. USACE typically performs these studies over a 50-year project lifespan, with many assumptions for how the fleet will change over time. For example, the Brazos Island Harbor study (USACE 2013) assumes ships of all sizes will increase in size and draft over time based on the increased draft allowance.

Step 2: Estimate the Number of Tons That Could Be Added If the Draft Allowance Increases

ERG used the number of vessel calls from Step 1, as well as the amount of additional tonnage that can be loaded onto vessels (based on data from the USACE [1996] Charleston Harbor Study), to estimate a range for the number of additional tons that could be added to vessels when pilots are able to utilize an additional 1 foot of under-keel clearance.[2]

The Charleston Harbor Study contains data on vessel deadweight tonnage (DWT) at each draft level for various vessel types. Using this information, we can aggregate the DWT for each draft level and estimate the additional DWT for vessels given an extra foot of draft. Combining this with the data from Step 1—which provides the number of vessel calls made at each draft level for each port—provides a means to estimate the average DWT for vessels and the average additional DWT per vessel given an extra foot of draft. Table B-2 and Table B-3 in Appendix B present the calculations for the Port of New York/New Jersey as an implementation example for this method.

Note that the upper and lower bounds for average and additional DWT are determined based on the upper and lower bounds for annual vessel calls in Step 1. For instance, if the upper bound for vessel calls is all the vessel calls, the upper bound average DWT will be determined by considering average DWT for all vessel calls; if the lower bound for vessel calls only considers vessels above 37 feet, the lower bound average DWT will be determined by considering only the DWT for vessel calls above 37 feet. This may result in counterintuitive ranges—with the data showing that average DWT for all vessel calls (used for the upper bound) may be lower than the average DWT for vessel calls above 37 feet (used for the lower bound), as vessel calls with more draft have more DWT on average. We have thus used the language "if all ships add more tonnage" to reflect the upper bound and "if only larger ships add more tonnage" to reflect the lower bound in this Section 4 methodology and the Section 5 case studies to make this more intuitive.

[2] While this is an older study, we were not able to find more recent data; however, we believe these estimates for incremental DWT are reasonable given that many of these ships are still in use and the incremental tonnage per increase in a foot of draft has likely not changed enough to meaningfully impact our estimate.

Step 3: Estimate the Number of Miles (and Subsequently Hours) Vessels Traveled During Transit

The next step estimates miles and hours that vessels traveled during transit. First, we estimate transit length at the specific port of interest and vessel speed at sea. The estimates are calculated based on data from a Charleston Harbor Study that used National Imagery and Mapping Agency data[3] and provides transit lengths from one region to another for most shipping regions around the world. We converted speeds given in knots to miles for this study.

Below, Table 3 shows minimum, average, and maximum vessel speeds at sea based on vessel type. ERG developed these ranges from a study of the Port of Charleston, South Carolina (USACE 1996).

Table 3. Vessel speed by vessel type.

Description	Vessel Speed at Sea, Min (Knots)	Vessel Speed at Sea, Most Likely (Knots)	Vessel Speed at Sea, Max (Knots)
General cargo	15	17	20
Large bulker	15	17	20
Large dry cargo	15	17	20
Large passenger	15	17	20
Large ro-ro	15	17	20
Large tanker	15	17	20
Liquid barge	15	17	20
Medium tanker	15	17	20
Offshore	15	17	20
Panamax	16	20	23
PPX1	16	20	25
PPX2	17	22	26
PPX3	18	23	27
Small tanker	15	17	20
Small bulker	15	17	20
Small dry cargo	15	17	20
Small passenger	15	17	20

[3] The National Imagery and Mapping Agency was renamed the National Geospatial-Intelligence Agency in 2003; however, the data that ERG analyzed for this study was from before 2003.

Description	Vessel Speed at Sea, Min (Knots)	Vessel Speed at Sea, Most Likely (Knots)	Vessel Speed at Sea, Max (Knots)
Small ro-ro	15	17	20
Sub-Panamax	15	18	21

Below is a table for average transit length from the United States to various destinations across the world (USACE 1996).

Table 4. Transit length by port origin and destination.

Origin Port	Destination Port	Distance (Nautical Miles)	Distance (Miles)
U.S. East Coast	West Coast South America	3,643	4,192
U.S. East Coast	Iceland / Greenland	1,781	2,050
U.S. East Coast	U.S. Gulf Coast	3,449	3,969
U.S. East Coast	U.S. West Coast	4,901	5,640
U.S. Gulf Coast	West Coast South America	3,431	3,948
U.S. Gulf Coast	Iceland / Greenland	3,449	3,969
U.S. Gulf Coast	U.S. West Coast	4,689	5,396
U.S. West Coast	West Coast South America	4,620	5,317
U.S. West Coast	Iceland / Greenland	6,803	7,829

Limitation: We acknowledge that transit length and vessel speed will vary depending on factors such as ship size, cargo type, port origin, and destination.

Step 4: Estimate Vessel Hourly Operating Costs

This step uses estimates for at-sea operating costs from the Charleston Harbor Study. Like the data described in Step 2, the Charleston Harbor study provides hourly vessel operating costs at sea for different vessel types at each draft level. By combining the estimates for each vessel type, we calculate an aggregated average hourly vessel cost at sea for each draft level. Then, using the data from Step 1 on the number of vessel calls made at each draft level for each port, we calculate each individual port's average hourly vessel operating costs. Table B-2 and Table B-3 in Appendix B present these calculations for the Port of New York/New Jersey as an example.

Step 5: Estimate Annual Cost Savings

This step takes information from Step 1 through Step 4 to calculate annual cost savings at a port using two methods of computation, each producing the same cost savings estimate.

Method 1:

Assume that tonnage will remain constant, and the added loading due to Precision Navigation will result in fewer annual vessel calls. We estimate this in the following way:

- Estimate the annual vessel calls choosing to load more due to Precision Navigation (from Step 1).
- Estimate the additional tons added per vessel call (from Step 2).
- Calculate the number of transits reduced (from Step 1 and Step 2).
- Calculate the total number of hours reduced (from Step 2 and Step 3).
- Calculate annual savings (from Step 4).

Method 2:

Assume that tonnage can increase, and the added loading due to Precision Navigation will result in lower unit operating costs. We estimate this in the following way:

- Estimate annual vessel calls choosing to load more due to Precision Navigation (from Step 1).
- Estimate additional tons added per vessel call (from Step 2).
- Estimate the total tonnage both before and after Precision Navigation implementation (from Step 1 and Step 2).
- Estimate the average tons per vessel call (from Step 1 and Step 2).
- Calculate the unit operating costs per ton per vessel call both before and after Precision Navigation implementation (from Step 1, Step 3, and Step 4).
- Calculate the old and new total operating costs (from Step 1, Step 3, and Step 4).
- Calculate the annual savings by finding the difference between the old and new total operating costs, which account for the total tonnage amounts.

4.1.3 Example Calculation from Implementing the Decreased Operating Cost Methodology

Table 5 presents the inputs for each step of our methodology for the Port of Baton Rouge assuming all ships increase tonnage and only larger ships increase tonnage. Below the table, ERG presents the calculations for performing each step of the methodology.

Table 5. Inputs and calculations of reducing vessel operating costs for the Port of Baton Rouge, Louisiana.

Methodology Step	Data Category	If Only Larger Ships (>37-foot draft) Increase Tonnage	If All Ships Increase Tonnage
Step 1	Number of vessel transits that will increase load due to Precision Navigation[a]	397	1333
Step 2	Average tonnage per vessel[b]	51,061	27,827
Step 2	Annual total tonnage[ab]	20,271,217	37,093,391
Step 2	Amount of additional tonnage per vessel due to foot increase in draft[c]	4,199 tons	2,524 tons
Step 3	Transit lengths in miles[d]	7,097	7,097
Step 3	Vessel speed[e]	15.5 mph	15.5 mph
Step 3	Hours per transit[f]	457	457
Step 4	Hourly operating costs[g]	$1,554	$1,029
Step 5	Annual savings due to Precision Navigation[h]	$21,379,011	$52,068,184

[a] Values obtained from entrance and clearance (WCSC 2017) data and analysis of vessels close to maximum draft allowance.

[b, c] Values calculated from data obtained in Charleston study (USACE 1996).

[a, b] Values calculated by multiplying the values in the previous two columns.

[d] Values obtained from National Imagery and Mapping Agency and input from experts.

[e] Values obtained from Charleston feasibility study and input from experts (USACE 1996).

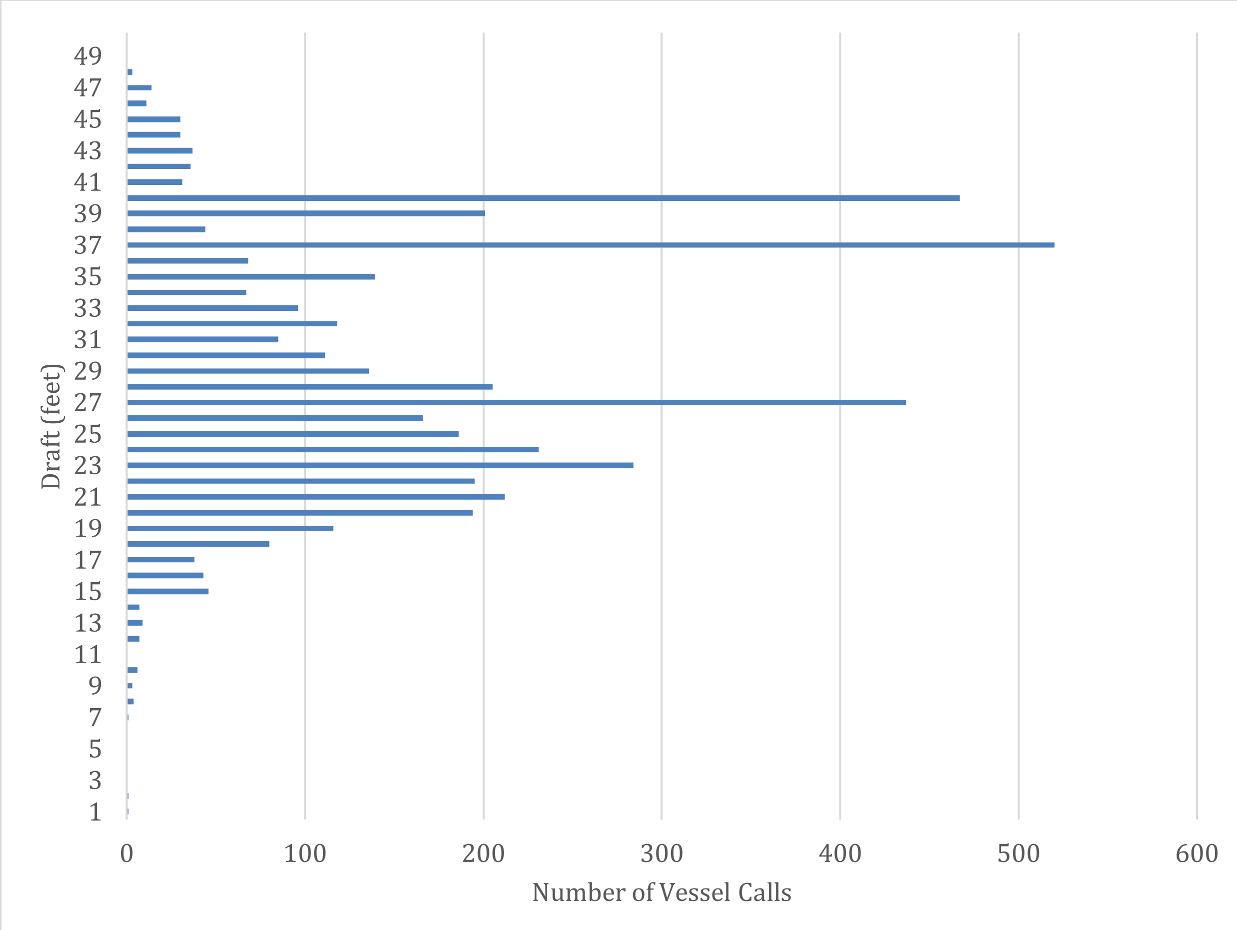
[f] Values calculated by dividing the values in the previous two columns.

[g] Values calculated from data obtained in Charleston study (USACE 1996).

[h] Values calculated using the methods outlined in Step 5. Below are formulas that show how the calculations are executed:

Savings = (A = operating costs per hour) x (B = transit length (in hours)) x (C = # vessel calls that decide to increase load due to Precision Navigation) x (D = additional tons added per vessel call) / (E = total tons per vessel call)

Figure 1. Vessel calls by draft feel for the Port of New Orleans, 2017.



4.2 The Value of Increased Safety from Precision Navigation

In this section, we describe our approach to measuring the economic benefit Precision Navigation will have by decreasing the likelihood of allisions, collisions, groundings, and avoiding the costs associated with these incidents. We outline our plan to estimate this benefit using existing resources and potential data gathered from individual ports.

ERG had limited data on the effectiveness of Precision Navigation in reducing incidents, as it has only been implemented at the Port of Long Beach for oil tankers. Precision Navigation incorporates the data from PORTS®[4]—for which incident reductions have been studied (Wolfe and Mitchell 2018)—with

[4] PORTS® is an integrated system of oceanographic and meteorological sensors that can provide access to observations and real-time information of water levels, currents, waves, salinity, water temperature, bridge heights, winds, visibility, atmospheric pressure, and air temperature. It integrates air gap sensors to help vessels navigate bridges, and it enables mariners to safely use every inch of available channel depth, thereby increasing the amount of cargo moved per transit.

additional information, so we anticipate the impact will be larger than PORTS®; thus, we created ranges of incident reduction to provide a sense of the possible benefits.

4.2.1 Value Chain for Increased Safety

We have developed a representative value chain showing increased safety and decreased losses associated with Precision Navigation implementation as a tool for describing benefits at any port. Because these numbers will vary from port to port, we have left them as placeholders below.

Portable Pilot Units (PPUs) equipped with Precision Navigation are given to several pilots at the [port name], allowing the pilots to more safely navigate rough waterways. Precision Navigation technology gives pilots a streamlined data source that includes multilayer bathymetric charts and various real-time environmental conditions at the port, enabling pilots to more safely navigate through hazardous conditions. Due to Precision Navigation's implementation, there will be approximately a [#] percent decrease in ship [allisions, collisions, or groundings] annually at [port name] from the [average number of groundings before Precision Navigation] ship groundings that occurred on average for the 10 years before implementation. We estimate a reduction of [X#] [allisions, collisions, or groundings] annually resulting in [$XXX] of avoided costs, based on [$X] for an average incident.

4.2.2 Step-by-Step Methodology for Increased Safety

In this section, we present our step-by-step methodology to calculate the avoided cost from reduced allisions, collisions, and groundings due to Precision Navigation. In the following section, we provide an example of how we can perform this calculation in Table 7.

The following is a summary of our approach: We first estimate the number of annual allisions, collisions, and groundings at a port. Then, we estimate the rate of change for allisions, collisions, and groundings after implementing Precision Navigation to determine the number of allisions, collisions, and groundings avoided at a port each year due to Precision Navigation. Finally, we use a cost estimate of the economic loss due to allisions, collisions, and groundings at a port to determine annual cost savings from reduced allisions, collisions, and groundings as a result of Precision Navigation implementation.

Step 1: Estimate a Baseline Number of Allisions, Collisions, and Groundings Before Precision Navigation, Accounting for the PORTS® System

For each port, ERG used data from the U.S. Coast Guard MISLE data set (USCG 2015) to estimate the baseline number of allisions, collisions, and groundings over a period of time preceding Precision Navigation. ERG determined that the period from 2002 to 2013 was a good baseline for incident data. ERG concluded that data before 2002 were not comprehensive; moreover, data after 2013 were underreported and started to include information from after PORTS® was installed in various locations.

After developing a baseline number of annual allisions, collisions, and groundings directly from the MISLE data set, we calculate a new baseline to account for the PORTS® system's impact on allisions, collisions, and groundings. The *PORTS® and Marine Accident Report* estimated reduction rates of 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings (Wolfe and Mitchell 2018). ERG thus multiplied those reductions by the original number of allisions, collisions, and groundings to account for PORTS® in the estimate of incident reductions. We then developed a new baseline before estimating the additional impact from Precision Navigation.

While PORTS® is a specific system that gives mariners easy access to certain data, Precision Navigation encompasses a broader umbrella of data integration and access to information that meets the specific needs of an individual port. While PORTS® and Precision Navigation both help mariners make more efficient decisions by allowing access to data, Precision Navigation's tailored approach to each individual port—integrating all available technologies, including the PORTS® system—will hopefully maximize the benefits that advanced navigational technology has to offer. This will most likely result in a greater reduction of allisions, collisions, and groundings than was found for just the PORTS® system, which we incorporate into the methodology below.

Step 2: Estimate the Change in Allisions, Collisions, and Groundings Due to Precision Navigation

ERG created two scenarios to account for previous technology and the unknown effect that Precision Navigation will have on the rate of allisions, collisions, and groundings. For each scenario, we determined a range of the reduction rate and number of annual reduced allisions, collisions, and groundings. In both scenarios, we calculate benefits for the combination of the port's underlying technological infrastructure (in many cases, the PORTS® system, but other technologies as well) and Precision Navigation itself. To calculate Precision Navigation's impact, we applied the determined reduction percentages to the baseline number of allisions, collisions, and groundings after accounting for the PORTS® system's impact.

- Upper bound estimate: Precision Navigation will have an equal effect on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g., PORTS®)—that is, after developing a new baseline, a reduction rate of another 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings.
- Lower bound estimate: Precision Navigation will have an effect equating to 50 percent of the impact on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g., PORTS® with the added benefit of integrated data and dissemination)—that is, after developing a revised baseline, a reduction rate of 19.7 percent for allisions, 31.4 percent for collisions, and 10.2 percent for groundings.

Step 3: Convert the Reduction in Incidents to an Avoided Cost

In this step, we converted our measurable change in Step 2 to an avoided cost. We can use a handful of values from existing studies to estimate the avoided cost per incident.' They include:

- Facility damage, cargo loss, vessel damage, injury, and deaths due to an allision (see Appendix B, Table B-1, for the breakdown of these losses, which used the national average from over 18,000 incidents from 2005 to 2017) (Wolfe and Pacheco 2019).[5]
    - $217,481 average loss per allision ($2017)
    - $237,518 average loss per collision ($2017)

[5] An updated version of the paper was made available after ERG conducted its analysis. The updated values would slightly change the calculations, but not significantly. The updated estimates are $215,694 average loss per allision ($2017), $237,698 average loss per collision ($2017), and $54,383 average loss per grounding ($2017).

- $55,960 average loss per grounding ($2017)

A more comprehensive accounting of economic loss for an average incident, which includes the following losses: loss of human life and personal injuries, vessel hull damage, cargo loss and damage, economic cost of the vessel being out of service, spill cleanup costs, losses in tourism and recreation, losses in commercial fish species, impacts on marine birds and mammals, losses due to liquefied petroleum gas (LPG)/LNG fires and explosions, and bridge and navigational aids damage. Table 6 presents these more comprehensive losses, which ERG converted from $1993 in the original study to $2017.[6]

Table 6. Economic loss by grounding for four ports (millions of $2017).

Port	Tanker Grounding	Dry Cargo Ship Grounding
New York	$2.7	$0.8
Tampa	$1.6	$0.6
Houston	$3.8	$0.8
San Francisco	$2.0	$0.6

Source: MIT 1998

Assumption: In the absence of port-specific data, ERG assumed that the national averages will reflect what would happen at any given port. This could vary based on any different or unique conditions at a given port that would make the cost per incident inherently much higher or much lower than the average across all ports.

4.2.3 Example Calculation from Implementing the Increased Safety Methodology

This example shows how we implemented the above steps to estimate the avoided losses from allisions, collisions, and groundings at the Port of Baton Rouge, Louisiana. Note, in this sample calculation, ERG applied the values from Wolfe and Pacheco (2019) to calculate the physical damage; however, one could also use the values from MIT (1998) to capture a more comprehensive economic loss as well.

[6] ERG converted the original values in the study using the Bureau of Economic Analysis' "Table 1.1.4. Price Indexes for Gross Domestic Product," which was 68.917 for 1993 and 107.795 for 2017 (BEA 2019).

Table 7. Example calculation for implementing increased safety methodology.

Method Step	Description of Step	Allisions	Collisions	Groundings
1	Number of accidents that occurred between 2002 and 2013 (baseline prior to PORTS® system) (USCG 2015)	61	20	59
1	Average number of accidents occurring annually (row above divided by 12)	5.1	1.7	4.9
1	Revised baseline number of incidents after accounting for PORTS® system[a]	3.1	0.6	3.9
2	Lower bound of effectiveness: % change in the rate of accidents from Precision Navigation is 50% of the PORTS® system	-19.7%	-31.3%	-10.2%
2	Upper bound of effectiveness: % change in the rate of accidents from Precision Navigation is equal to the PORTS® system	-39.4%	-62.6%	-20.3%
2	Lower bound of annual number of accidents reduced due to Precision Navigation[b]	0.6	0.2	0.4
2	Upper bound of annual number of accidents reduced due to Precision Navigation[b]	1.2	0.4	0.8
3	Annual savings (lower bound) (total of $200,000)[c]	$131,530	$46,093	$22,265
3	Annual savings (upper bound) (total of $400,000)[c]	$263,061	$92,185	$44,531

[a] Reduction amounts obtained from the *PORTS® and Marine Accident Reduction Report* (Wolfe and Mitchell 2018) and detailed in Step 2 of this method.

[b] Calculation is revised baseline x % change in the rate of accidents.

[c] Calculation is number of accidents reduced x the loss associated with the accident.

5. Case Studies for the Ports of the Lower Mississippi River and the Port of New York/New Jersey

This section presents case studies for monetizing, quantifying, and describing the benefits associated with implementing Precision Navigation at two major ports: the Ports of the Lower Mississippi River and the Port of New York/New Jersey. The studies use data obtained for the port prioritization analysis, the previously created methodology document guiding the calculations, and port-specific data and information obtained from conversations with experts familiar with each port to tailor each case study to the specific port of interest.

5.1 Case Study Description

Each case study consists of both a results section and methodology implementation section:

- The results section presents a table of the benefits and impacts related to Precision Navigation along with the context of those benefits and impacts.
- The methodology implementation section details the inputs that ERG used to implement the methodology for increased safety and increased cargo/decreased operating costs at each port. It also provides internal links to the related methodology step in Section 4 of this report.

5.2 Case Study for the Ports of the Lower Mississippi River

The Ports of the Lower Mississippi River together were the highest-ranked port system in the port prioritization analysis (see Appendix A for the port profile). Based on the safety concerns along the river and the high volume of cargo transported up and down the river every year, Precision Navigation would offer many benefits to the Ports of the Lower Mississippi River; moreover, daily operations at the port system would improve due to improved navigational technology. For our estimates, ERG calculated the combined benefits for the Port of New Orleans, Port of South Louisiana, Port of Plaquemines, and Port of Baton Rouge, and we provide some more granular information in footnotes.[7]

5.2.1 Results

Table 8 presents the estimated benefits and impacts of Precision Navigation at the Ports of the Lower Mississippi River, including the Port of New Orleans, Port of South Louisiana, Port of Plaquemines, Port of St. Bernard, and Port of Baton Rouge.[8] ERG has not summed up the individual benefits as they often benefit different stakeholders; some are economic benefits while others are economic impacts; and, in some cases, only a portion of the benefits are attributable to Precision Navigation. Each row in Table 8 presents these benefits as a value chain, beginning with what Precision Navigation impacts, the associated change of that impact, and the benefit and value of that impact. ERG has provided additional

[7] We had originally planned to include the Port of St. Bernard as its own port for the study, but data for the Port of St. Bernard may have data rolled into the Port of New Orleans in some of the data sets, because no data was available specifically for the Port of St. Bernard.

[8] The Port of St. Bernard data set was subsumed by another Lower Mississippi River port—the Port of New Orleans—in most data sets, most likely due to geography, but was included as one of the five ports in our analysis.

context and assumptions for each benefit following Table 8, which is important to understand how Precision Navigation may contribute to a benefit.

Table 8. Summary of benefits from Precision Navigation for the Ports of the Lower Mississippi.

Impact Description	Change	Benefit and Value ($) (See context and assumptions for each benefit below this table)
Pilots are more comfortable operating with less under-keel clearance.	Ships can load more cargo or wait less time and reduce operating costs.	**Benefit 1:** Utilization of an additional foot of draft could lead ships to save about **$200 million to $440 million per year in** operating costs. Precision Navigation could help ships capture a small portion of this benefit as pilots are more comfortable operating with less under-keel clearance than without Precision Navigation. This may be particularly true on days with inclement weather or conditions. *"One of the biggest issues facing pilots is accurate determination of under-keel clearance. Maximizing vessel draft has a very significant impact on commerce."* *– Captain John Betz, Port of Los Angeles*
Pilots use the real-time data from Precision Navigation to operate more safely.	Ships experience fewer allisions, collisions, and groundings.	**Benefit 2:** Precision Navigation could help decrease costs to ships and insurance companies associated with vessel, cargo, and facility damages, as well as injuries/death, by approximately **$515,000 to $1,030,000 per year.** After accounting for more comprehensive economic loss, including environmental damage and waiting time from shutting down waterways, reduced incidents as a result of Precision Navigation could save approximately **$3.7 to $9.8 million per year** in associated economic losses. Taken one step further, the value of goods going through the ports is around **$590 million** per day and the economic impact of a day-long closure is likely well over a $1 billion loss when considering the ripple effect on the economy and impact on the supply chain (Burkley 2019). If Precision Navigation can help avoid one accident that would shut down the port, it would contribute to a huge economic impact.
Pilots can better time and work around weather events.	Fewer ships are delayed by weather-related events.	**Benefit 3:** Precision Navigation will help lessen the operating costs for ships associated with delays from weather closures or tide restrictions. *"Having all weather information in one central location would have a huge benefit to pilots. When a weather event is imminent, such as fog, having access to all the available information has a huge impact on decisions and efficiency."* *– Pilot from Port of Tampa Bay*

Benefit 1 context and assumptions: Pilots would be more comfortable operating with less under-keel clearance using data provided by Precision Navigation. This benefit may only be realized if Precision Navigation is combined with an under-keel clearance system such as at the Port of Long Beach, where the draft was increased by several feet. It is unclear whether the Ports of the Lower Mississippi would be able to increase their declared draft, but Precision Navigation may make pilots more comfortable operating with less under-keel clearance, which means that pilots may not need to reduce the draft as much for adverse conditions (e.g., fog, accretion, high flow, low water levels). We were not able to consider whether all ships were physically able to add more cargo, but this assumes that over the long term, larger ships may come in with lower operating costs per ton of cargo to optimize this benefit.

Benefit 2 context and assumptions: There are specific challenges to navigation along the Mississippi River, including flocculation (which in this context refers to the clumping of silt on a riverbed), fog blackouts that affect vessel operations and dredging, and immense flooding. In 2019, more flooding and fog occurred than usual, causing many instances of lost draft overnight. The allisions, collisions, and groundings that occur at the port occur in large part due to those specific, previously mentioned challenges navigating the river.

Precision Navigation provides all of the data in PORTS® in addition to a broader umbrella of real-time data. The lower bound assumes Precision Navigation reduces the number of incidents by about 50 percent of what PORTS® accomplished, while the upper hound estimates that Precision Navigation reduces the number of incidents by the same percent as PORTS® (after accounting for the improvement in PORTS®). There are no data on the efficacy of Precision Navigation to estimate this upper bound, so it is an estimate to provide a sense of what the reduced damage may be. The initial $515,000 to $1,030,000 per year estimate only includes physical damage and loss from injuries and death, while the more comprehensive benefit estimate of $3.7 to $9.8 million per year includes the avoided economic cost of the vessel being out of service, spill cleanup costs, losses in tourism and recreation, losses in commercial fish species, impacts on marine birds and mammals, losses due to LPG/LNG fires and explosions, and bridge and navigational aids damage. We also assumed the comprehensive economic loss for groundings would be similar to allisions and collisions (for which we do not have an estimate for a more comprehensive economic loss per incident). This does not consider that larger ships may be coming into the port over time with less clearance and potentially less room for error.

Precision Navigation will help decrease the risks involved with larger vessels transiting through the port in the future. The $1 billion estimate for the ripple effect on the economy comes from a study that cited a $590 million loss in cargo freight alone for each day that the Ports of the Lower Mississippi are shut down and an overall economic impact likely in the billions when considering the impact on the supply chain (Burkley 2019). The actual impact depends on the sensitivity of the timing associated with delivering the goods, which is a complex analysis and beyond the scope of our study.

Benefit 3 context and assumptions: Access to additional data from Precision Navigation will allow pilots to better anticipate future weather conditions and better deal with current weather to minimize the delays caused by safety incidents or by high wind events, tide restrictions, and dense fog. Precision Navigation helps pilots make safer decisions when navigating through a port. Safer decision-making reduces the number of annual allisions, collisions, and groundings that occur at the port, which delay other vessels. By reducing the number of annual incidents, Precision Navigation also saves costs associated with delays caused by safety incidents. In addition, pilots and the port authority may over time gain confidence in the vessels' ability to navigate with less under-keel clearance, thus lowering or eliminating tide restrictions and decreasing overall delays at the port.

Enough data were not available to provide an accurate quantitative estimate for this benefit. However, we can assume that the total value saved from this benefit will be of a smaller magnitude than benefit 1 and closer to the first quantitative estimate of benefit 2, because the delays do not affect every vessel call at a port. Moreover, the vessel calls that are affected will have a relatively small economic impact unless delays last for a very significant number of hours, which we assume does not happen in most cases.

Additional consideration—future developments at the port:
"Having integrated data and more accurate weather conditions will increase the size of the largest vessel able to navigate the port."

—Capt. Stephen Roberts
Pilots' Association for the Bay & River Delaware

Precision Navigation will improve pilots' ability to more safely navigate through the port. This will potentially lead to vessels being able to operate more confidently at higher draft levels and with less under-keel clearance. Those two occurrences will enable vessels with larger widths and TEU (twenty-foot equivalent unit) capacities to enter the port more easily—which is predicted to occur in the coming years—as long as ports are capable of handling the changes. The larger vessels need more draft to enter the port. Larger vessels are also more difficult to operate and will have to be navigated in tighter spaces than usual—a process that Precision Navigation will aid. Without Precision Navigation, larger vessels may 1) cause an increase in safety incidents at the port, or 2) decide to omit the port entirely and only travel to ports that allow them to properly navigate without increased risks of safety incidents—this would be an enormous economic loss depending on the number of vessels calls decreased.

5.2.2 Methodology Implementation

We implemented the methodologies from Section 4 for the Ports of the Lower Mississippi River, calculating an annual dollar estimate for the benefits of Precision Navigation. The following section presents the inputs used to arrive at the final estimates for economic benefit from reduced allisions, collisions, and groundings, as well as the increased cargo/decreased operating costs due to vessels utilizing 1 additional foot of draft for each vessel call. To reduce redundancy in the report, ERG does not detail the methodology in this section as well. We instead link internally to the applicable Section 4 methodology step.

Increased Safety

ERG procured data from the U.S. Coast Guard's MISLE data set (USCG 2015) and a study on increased safety from the PORTS® system (Wolfe and Mitchell 2018).

Step 1: A total of 171 allisions, 49 collisions, and 141 groundings occurred from 2002 to 2013 within 10 km of the Port of New Orleans, 10 km of the Port of South Louisiana, 10 km of the Port of Plaquemines, and 10 km of the Port of Baton Rouge (USCG 2015).[9] This breaks down to about 14 allisions, 4 collisions,

[9] By individual port, this comes out to the following—Port of New Orleans: 52 allisions, 12 collisions, and 11 groundings within 10 km of the port. Port of South Louisiana: 24 allisions, 4 collisions, and 12 groundings within 10 km of the port. Port of Plaquemines: 1 allision, 5 collisions, and 6 groundings within 10 km of the port. Port of Baton Rouge: 84 allisions, 28 collisions, and 112 groundings within 10 km of the port.

and 12 groundings per year before considering the impact of either the PORTS® system or Precision Navigation.

ERG developed a revised baseline to calculate approximately what would be expected after the implementation of the PORTS® system. ERG multiplied the baseline number of incidents by the estimated reduction rates of 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings found in the *PORTS® and Marine Accident Report* (Wolfe and Mitchell 2018). After accounting for this reduction, our new baseline—considering the impact of the PORTS® system—is about 8 allisions, 1.5 collisions, and 9 groundings per year.[10]

Step 2: The range for the annual decrease in allisions, collisions, and groundings due to Precision Navigation for each port is 1.6 to 3.2 allisions per year, 0.5 to 1.0 collisions per year, and 1.0 to 1.9 groundings per year.[11,12] This is above and beyond the revised baseline in Step 1, which accounted for the estimated reduction from the PORTS® system. As outlined in Section 4, this estimate assumes the following for an upper and lower bound:

- Upper bound: Precision Navigation will have an equal effect on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g., PORTS®)—that is, after developing a new baseline, a reduction rate of another 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings.
- Lower bound: Precision Navigation will have an effect equating to 50 percent of the impact on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g., PORTS® with the added benefit of integrated data and dissemination)—that is, after developing a revised baseline, a reduction rate of 19.7 percent for allisions, 31.4 percent for collisions, and 10.2 percent for groundings.[13]

Step 3: As outlined in the Section 4 methodology, the *PORTS® and Marine Accident Report* (Wolfe and Mitchell 2018) estimates the average cost of an allision, collision, and grounding, which ERG applied to the annual average expectation for the number of reduced incidents in the previous step. Table 9 shows the lower and upper bound for the avoided costs attributable to Precision Navigation across the Ports of the Lower Mississippi. The second column presents total avoided losses, and the subsequent columns to

[10] By individual port, this comes out to the following revised baseline on an average number of incidents per year—Port of New Orleans: 2.6 allisions, 0.4 collisions, and 0.7 groundings. Port of South Louisiana: 1.2 allisions, 0.1 collisions, and 0.8 groundings. Port of Plaquemines: 0.05 allisions, 0.16 collisions, and 0.4 groundings. Port of Baton Rouge: 4.2 allisions, 0.9 collisions, and 7.4 groundings.

[11] By individual port this comes out to the following range of reductions annually—Port of New Orleans: 0.52–1.03 allisions, 0.12–0.23 collisions, and 0.07–0.15 groundings. Port of South Louisiana: 0.24–0.48 allisions, 0.04–0.08 collisions, and 0.08–0.16 groundings. Port of Plaquemines: 0.01–0.02 allisions, 0.05–0.10 collisions, and 0.04–0.08 groundings. Port of Baton Rouge: 0.84–1.67 allisions, 0.27–0.55 collisions, and 0.76–1.51 groundings.

[12] We have annualized incident reductions to develop annual averages for avoided costs. Even though 0.5 reductions are hard to conceptualize, another way to think about this is one reduction every two years.

[13] These upper and lower bounds are estimates, as no study has measured the increased safety associated with Precision Navigation to date.

the right break down the losses included in this estimate. Across all incidents, ERG expects an annual reduction in damage, injuries, and deaths ranging from about $500,000 to $1 million.[14]

Table 9. Annual dollars saved for increased safety due to Precision Navigation for the Ports of the Lower Mississippi River ($2017).

Incident Type	Total Avoided Losses	Deaths & Missing Persons	Injuries	Vessel Losses	Cargo Losses	Facility Losses	Other Losses
Allisions lower bound	**$348,341**	$20,900	$90,569	$45,284	$3,483	$94,052	$97,536
Allisions upper bound	**$696,682**	$41,801	$181,137	$90,569	$6,967	$188,104	$195,071
Collisions lower bound	**$113,534**	$59,038	$32,925	$17,030	$0	$2,271	$2,271
Collisions upper bound	**$227,069**	$118,076	$65,850	$34,060	$0	$4,541	$4,541
Groundings lower bound	**$53,191**	$4,787	$15,957	$30,851	$532	$532	$532
Groundings upper bound	**$106,382**	$9,574	$31,915	$61,702	$1,064	$1,064	$1,064
All incidents lower bound	**$515,066**	$84,725	$139,451	$93,165	$4,015	$96,855	$100,339
All incidents upper bound	**$1,030,133**	$169,451	$278,902	$186,331	$8,031	$193,709	$200,676

There are substantial economic losses from incidents that are not captured in Table 9. Below, ERG estimates approximately how much Precision Navigation can contribute to prevent these economic losses. As shown in Table 6 of Section 4 of this report, the total average economic loss for a dry cargo ship grounding ranged from $0.6 million (Tampa, Florida, and San Francisco, California) to $0.8 million (New York and Houston, Texas) across the four ports studied. For oil tankers, the total economic loss per grounding was $1.6 in Tampa, $2.0 million in San Francisco, $2.7 million in New York, and $3.8 million in Houston (for an average of $1.6 million across all four ports, assuming half tankers and half cargo ships). In addition to the costs covered in Table 9, these more comprehensive economic losses include the economic cost of the vessel being out of service, spill cleanup costs, losses in tourism and recreation, losses in commercial fish species, impacts on marine birds and mammals, losses due to LPG/LNG fires and explosions, and bridge and navigational aids damage.

Table 10 presents the estimated (more comprehensive) economic loss avoided by implementing Precision Navigation. It shows that after factoring in the more comprehensive cleanup costs, costs of being out of service, and other costs discussed above, Precision Navigation could avoid approximately $3.7 to $9.8 million from reduced incidents. It also assumes we apply the loss for groundings to allisions

[14] By individual port, this comes out to the following—Port of New Orleans: $144,462 to $288,923. Port of South Louisiana: $65,722 to $131,443. Port of Plaquemines: $16,012 to $32,024. Port of Baton Rouge: $288,871 to $577,742.

and collisions (for which we do not have an estimate for a more comprehensive economic loss per incident).

Table 10. Annual savings for more comprehensive economic loss avoided from increased safety.

Incident Type	Lower Bound # Incidents Reduced (from Step 2 Above)	Upper Bound # Incidents Reduced (from Step 2 Above)	Lower Bound Annual Avoided Loss (Millions of $2017)[a]	Upper Bound Annual Avoided Loss (Millions of $2017)[b]
Allisions	1.6	3.2	$1.9	$5.1
Collisions	0.5	1	$0.6	$1.6
Groundings	1	1.9	$1.2	$3.0
All incidents	3.1	6.1	**$3.7**	**$9.8**

[a] Calculated from reduced number of incidents x $1.2 million per incident [based on weighted average of loss of $0.7 million per cargo ship incident across the four ports in the MIT study and $2.5 million per tanker incident and a lower bound estimate of a 25:75 split of tankers and cargo ships] (MIT 1998).

[b] Calculated from reduced number of incidents x $1.6 million per incident [based on weighted average of loss of $0.7 million per cargo ship incident across the four ports in the MIT study and $2.5 million per tanker incident and an upper bound estimate of a 50:50 split of tankers and cargo ships] (MIT 1998). The MISLE 2002–2013 data set included about 26 percent of incidents as tanker ships or tanker barges (USCG 2015); thus, we used 25 to 50 percent as the range.

Increased Cargo/Decreased Operating Costs

ERG procured data for this method from the WCSC (2017) and the Charleston Harbor Study (USACE 1996).

Step 1: The following are the ranges for annual vessel calls that will load to 1 more foot of draft (WCSC 2017). The upper bound assumes all vessel calls will behave that way. The lower bound assumes ships that had a draft of 37 feet or more would load to 1 more foot of draft. The rationale for this is explained in Section 4.1 of this report.

- Port of New Orleans: lower bound of 1,424 vessel calls; upper bound of 4,716 vessel calls.
- Port of South Louisiana: lower bound of 1,572 vessel calls; upper bound of 4,437 vessel calls.
- Port of Plaquemines: lower bound of 316 vessel calls; upper bound of 1,753 vessel calls.
- Port of Baton Rouge: lower bound of 397 vessel calls; upper bound of 1,333 vessel calls.

Step 2: ERG used the ranges below for average DWT per vessel, as well as average additional DWT per vessel for each added foot of draft.

Average DWT per vessel (in short tons):

- Port of New Orleans: if only larger ships add more tonnage—46,804; if all ships add more tonnage—23,472.
- Port of South Louisiana: if only larger ships add more tonnage—55,186; if all ships add more tonnage—30,935.

- Port of Plaquemines: if only larger ships add more tonnage—53,481; if all ships add more tonnage—20,611.
- Port of Baton Rouge: if only larger ships add more tonnage—51,167; if all ships add more tonnage—27,858.
- Average additional DWT per vessel for each added foot of draft (in short tons):
- Port of New Orleans: if only larger ships add more tonnage—3,969; if all ships add more tonnage—2,093.
- Port of South Louisiana: if only larger ships add more tonnage—4,420; if all ships add more tonnage—2,700.
- Port of Plaquemines: if only larger ships add more tonnage—4,333; if all ships add more tonnage—1,791.
- Port of Baton Rouge: if only larger ships add more tonnage—4,199; if all ships add more tonnage—2,524.

Step 3: ERG used the following inputs to estimate the average transit length (in hours) for all four ports:

- Average transit length (in miles): 7,097 miles.
- Average vessel speed at sea (in mph): 15.5 mph.
- Average length of each transit (hours): 457 hours.

Step 4: ERG used the following inputs to determine average hourly at-sea operating costs per vessel:

- Port of New Orleans: if only larger ships add more tonnage—$1,494; if all ships add more tonnage—$903.
- Port of South Louisiana: if only larger ships add more tonnage—$1,607; if all ships add more tonnage—$1,083.
- Port of Plaquemines: if only larger ships add more tonnage—$1,585; if all ships add more tonnage—$814.
- Port of Baton Rouge: if only larger ships add more tonnage—$1,554; if all ships add more tonnage—$1,029.

5.3 Case Study for the Port of New York/New Jersey

The Port of New York/New Jersey ranked high in the port prioritization for several metrics, especially total annual tonnage and total annual cargo value. Thus, ERG decided that the Port of New York/New Jersey would be an excellent candidate for Precision Navigation. Daily operations at the port would improve due to enhanced access to navigational information, as a higher volume of cargo would lead to greater potential savings from decreased operating costs. Below is an estimate of the annual economic benefit for the port due to Precision Navigation. ERG based this on conversations with key stakeholders at the port and data gathered during the port prioritization analysis. ERG held a discussion on October 8, 2019, with the following groups: U.S. Coast Guard Vessel Traffic Service, Sandy Hook Pilots, and Tug and Barge Committee. ERG also discussed additional qualitative benefits that Precision Navigation may bring to the port that are more challenging to monetize.

5.3.1 Results

Table 11 presents the estimated benefits and impacts of Precision Navigation at the Port of New York/New Jersey. ERG has not summed up the individual benefits as they often benefit different stakeholders; some are economic benefits compared to economic impacts; and, in some cases, only a portion of the benefits are attributable to Precision Navigation. Each row in Table 11 presents these benefits as a value chain, beginning with what Precision Navigation impacts, the associated change of that impact, and the benefit and value of that impact. ERG has provided additional context and assumptions for each benefit following Table 11, which is important to understand how Precision Navigation may contribute to a benefit.

Table 11. Summary of benefits from Precision Navigation for the Port of New York/New Jersey.

Impact Description	Change	Benefit and Value ($) (See context and assumptions for each benefit below this table)
Pilots are more comfortable operating with less under-keel clearance.	Ships can load more cargo or wait less time and reduce operating costs.	**Benefit 1:** An additional foot of draft could lead ships to save about **$216 million to $472 million per year in** operating costs. Precision Navigation could help ships capture a small portion of this benefit as pilots are more comfortable operating with less under-keel clearance than without Precision Navigation. This may be particularly true on days with inclement weather or conditions. *"One of the biggest issues facing pilots is accurate determination of under-keel clearance. Maximizing vessel draft has a very significant impact on commerce."* *– Captain John Betz, Port of Los Angeles*
Pilots use the real-time data from Precision Navigation to operate more safely.	Ships experience fewer allisions, collisions, and groundings.	**Benefit 2**: Precision Navigation can help decrease costs to ships and insurance companies associated with vessel, cargo, and facility damages, as well as injuries/death, by approximately **$176,000 to $351,000 per year.** After accounting for more comprehensive economic loss, including environmental damage and waiting time from shutting down waterways, reduced incidents from Precision Navigation could save approximately **$1.2 to $3.3 million per year** in associated economic losses. Taken one step further, the amount of goods that move through the port is worth over **$500 million daily** (Census 2017). Therefore, the economic impact of a day-long closure is likely well over a **$1 billion** loss when considering the ripple effect on the economy and impact on the supply chain. If Precision Navigation can help avoid one accident that would shut down the port, it would contribute a huge economic impact.
Pilots can better time and work around weather events.	Fewer ships are delayed by weather-related events.	**Benefit 3:** Precision Navigation will help lessen the operating costs for ships associated with delays from weather closures or tide restrictions. *"Having all weather information in one central location would have a huge benefit to pilots. When a weather event is imminent, such as fog, having access to all the available information has a huge impact on decisions and efficiency."* *– Pilot from Port of Tampa Bay*

Benefit 1 context and assumptions: Pilots would be more comfortable operating with less under-keel clearance using data provided by Precision Navigation. This benefit may only be realized if Precision Navigation is combined with an under-keel clearance system such as at the Port of Long Beach, where the draft was increased by several feet. The Port of New York/New Jersey may not be able to increase its declared draft, but Precision Navigation may make pilots more comfortable operating with less under-keel clearance, which means that pilots may not need to reduce the draft as much for adverse conditions (e.g., fog, accretion, high flow, low water levels). We were not able to consider whether all ships were physically able to add more cargo, but this assumes that over the long term, larger ships may come in with lower operating costs per ton of cargo to optimize this benefit.

Benefit 2 context and assumptions: Stakeholders at the Port of New York/New Jersey mentioned a few specific areas where improved technology would increase the safety of navigation in and around the port. Improved weather predictions for wind, fog, and currents would allow for safer navigation under the Verrazano Bridge (NY/NJ Stakeholder Call 2019). This would allow not just for a reduction of major incidents, but also for more efficient navigation and the ability to reduce wait time around the port. With the improved data of Precision Navigation, stakeholders hope to make timing decisions three hours earlier than current capabilities. These changes would result in an economic benefit higher than the above reported value.

Precision Navigation provides all the data in PORTS® in addition to a broader umbrella of real-time data. The lower bound estimates that Precision Navigation reduces the number of incidents by about 50 percent of what PORTS® accomplished, while the upper bound estimates that Precision Navigation reduces the number of incidents by the same percent as PORTS® (after accounting for the improvement in PORTS®). There are no data on the efficacy of Precision Navigation to estimate this upper bound, so it is an estimate to provide a sense of what the reduced damage may be. The initial estimate of $176,000 to $351,000 per year only includes physical damage and loss from injuries and death, while the more comprehensive benefit estimate of $1.7 to $3.3 million per year includes the avoided economic cost of the vessel being out of service, spill cleanup costs, losses in tourism and recreation, losses in commercial fish species, impacts on marine birds and mammals, losses due to LPG/LNG fires and explosions, and bridge and navigational aids damage. We also assumed the comprehensive economic loss for groundings would be similar to allisions and collisions (for which we do not have an estimate for a more comprehensive economic loss per incident). This does not consider that larger ships may be coming into the port over time with less clearance and potentially less room for error.

Precision Navigation will help decrease the risks involved with larger vessels transiting through the port in the future. The Port of New York/New Jersey moved over $500 million worth of goods every day in 2017 (Census 2017); thus, the economic impact from shutting down the Port of New York/New Jersey could possibly be over $1 billion per day (as referenced by Burkley [2019] for the Ports of the Lower Mississippi). The actual impact depends on the sensitivity of the timing associated with delivering the goods, which is a complex analysis and beyond the scope of our study.

Benefit 3 context and assumptions: Access to additional data from Precision Navigation will allow pilots to better anticipate future weather conditions and better deal with current weather to minimize the delays caused by safety incidents or by high wind events, tide restrictions, and dense fog. Precision Navigation helps pilots make safer decisions when navigating through a port. Safer decision-making reduces the number of annual allisions, collisions, and groundings that occur at the port, which delay other vessels. By reducing the number of annual incidents occur, Precision Navigation also saves costs associated with delays caused by safety incidents. In addition, pilots and the port authority may over time gain confidence in the vessels' ability to navigate with less under-keel clearance, thus lowering or eliminating tide restrictions and decreasing overall delays at the port.

Enough data were not available to provide an accurate quantitative estimate for this benefit. However, we can assume that the $ value saved from this benefit will be of a smaller magnitude than benefit 1 and closer to the first quantitative estimate of benefit 2, because the delays do not affect every vessel call at a port. Moreover, the vessel calls that are affected will have a relatively small economic impact unless delays last for a very significant number of hours, which we assume does not happen in most cases.

> **Additional consideration—future developments at the port**:
>
> ***"Having integrated data and more accurate weather conditions will increase the size of the largest vessel able to navigate the port."***
>
> **—Capt. Stephen Roberts, Pilots' Association for the Bay & River Delaware**

Precision Navigation will improve pilots' ability to more safely navigate through the port. This will potentially lead to vessels being able to operate more confidently at higher draft levels and with less under-keel clearance. Those two occurrences will enable vessels with larger widths and TEU capacities to enter the port more easily—which is predicted to occur in the coming years—as long as ports are capable of handling the changes. The larger vessels need more draft to enter the port. Larger vessels are also more difficult to operate and will have to be navigated in tighter spaces than usual—a process that Precision Navigation will aid. Currently, vessels enter the port at a maximum of 50 feet of draft and at most carry 18,000 TEU; they also have width restrictions, such as 160 feet for tankers and 215 feet for passenger vessels (NY/NJ Stakeholder Call 2019). The ability to not only add more cargo onto vessels, but to alter the types of vessels capable of traversing the port, has economic benefits not captured in the above estimate. Without Precision Navigation, larger vessels may 1) cause an increase in safety incidents at the port, or 2) decide to omit the port entirely and only travel to ports that allow them to properly navigate without increased risks of safety incidents—this would be an enormous economic loss depending on the number of vessels calls decreased.

5.3.2 Methodology Implementation

The following subsections present the inputs ERG used to calculate the economic benefit from reduced allisions, collisions, and groundings, as well as increased cargo/decreased operating costs from using 1 additional foot of draft. To reduce redundancy in the report, ERG does not detail the methodology in this section. ERG instead provides internal links to the applicable Section 4 methodology steps.

Increased Safety

ERG procured data for this method from the USCG MISLE data set (USCG 2015) and a study on increased safety from the PORTS® system (Wolfe and Mitchell 2018).

Step 1: From 2002 to 2013, 72 allisions, 5 collisions, and 22 groundings occurred within 10 km of the Port of New York/New Jersey (USCG 2015). This equates to an annual average of 6 allisions, 0.4 collisions, and 1.8 groundings before considering the impact of either the PORTS® system or Precision Navigation.[15]

ERG developed a revised baseline to calculate approximately what would be expected after the implementation of the PORTS® system. We multiplied the baseline number of incidents by the estimated reduction rates of 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings found in the *PORTS® and Marine Accident Report* (Wolfe and Mitchell 2018). After accounting for this reduction, our new baseline—considering the impact of the PORTS® system—is about 3.6 allisions, 0.2 collisions, and 1.5 groundings each year (i.e., 36 allisions, 2 collisions, and 15 groundings over a 10-year period).

Step 2: The range for the annual decrease in allisions, collisions, and groundings due to Precision Navigation is 0.7 to 1.4 allisions, 0.05 to 0.10 collisions, and 0.15 to 0.30 groundings. This is above and beyond the revised baseline in Step 1, which accounted for the estimated reduction from the PORTS® system.[16] As outlined in Section 4, this assumes the following for an upper and lower bound:

- Upper bound: Precision Navigation will have an equal effect on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g., PORTS®)—that is, after developing a new baseline, a reduction rate of another 39.4 percent for allisions, 62.6 percent for collisions, and 20.3 percent for groundings.
- Lower bound: Precision Navigation will have an effect equating to 50 percent of the impact on the rate of allisions, collisions, and groundings as the underlying technological infrastructure (e.g. PORTS® with the added benefit of integrated data and dissemination)—that is, after developing a revised baseline, a reduction rate of 19.7 percent for allisions, 31.4 percent for collisions, and 10.2 percent for groundings).[17]

Step 3: The PORTS® study (Wolfe and Pachacho 2019) provides estimates for the dollar losses for each allision, collision, and grounding based on MISLE data from 2005 to 2017 for all incidents in the United States. We applied those estimates to the average annual decrease found above. Table 12 presents the total avoided costs for each incident, and subsequent columns to the right show the breakdown of how these damages and injuries contribute to the avoided costs to ships.

[15] We have annualized incident reductions to develop annual averages for avoided costs. Even though 0.4 incidents per year is hard to conceptualize, as you can only have a whole number of incidents in a given year, another way to think about this is four reductions every 10 years. We estimate this as 0.4 incidents so we can take the annual average.

[16] While there cannot be 0.05 incidents in a year, when we perform our calculation, this would be the equivalent of stating we reduced one incident every 20 years, calculating the value over the 20-year period and an annual savings that is 5 percent of the total.

[17] These upper and lower bounds are estimates, as no study has measured the increased safety associated with Precision Navigation to date.

Table 12. Annual dollars saved for increased safety due to Precision Navigation for the Port of New York/New Jersey ($2017).

Incident Type	Total Avoided Costs	Deaths & Missing Persons	Injuries	Vessel Losses	Cargo Losses	Facility Losses	Other Losses
Allisions lower bound	**$155,780**	$9,347	$40,503	$20,251	$1,558	$42,061	$43,618
Allisions upper bound	**$311,560**	$18,694	$81,006	$40,503	$3,116	$84,121	$87,237
Collisions lower bound	**$11,585**	$6,024	$3,360	$1,738	$0	$232	$232
Collisions upper bound	**$23,170**	$12,049	$6,719	$3,476	$0	$463	$463
Groundings lower bound	**$8,299**	$747	$2,490	$4,814	$83	$83	$83
Groundings upper bound	**$16,599**	$1,494	$4,980	$9,627	$166	$166	$166
All incidents lower bound	**$175,664**	$16,118	$46,353	$26,803	$1,641	$42,376	$43,933
All incidents upper bound	**$351,329**	$32,237	$92,705	$53,606	$3,282	$84,750	$87,866

There are substantial economic losses from incidents that are not captured in Table 12. Below, ERG estimates approximately how much Precision Navigation can help prevent these economic losses. As shown in Table 6 of Section 4 of this report, the total average economic loss for a dry cargo ship grounding was $0.8 million in New York (after converting to $2017). For oil tankers, the total economic loss per grounding was $2.7 million in New York (after converting to $2017). In addition to the costs covered in Table 12, these more comprehensive economic losses include the economic cost of the vessel being out of service, spill cleanup costs, losses in tourism and recreation, losses in commercial fish species, impacts on marine birds and mammals, losses due to LPG/LNG fires and explosions, and bridge and navigational aids damage.

Table 13 presents the estimated (more comprehensive) economic loss avoided by implementing Precision Navigation. It shows that after factoring in the more comprehensive cleanup costs, costs of being out of service, and other costs discussed above, Precision Navigation could prevent approximately $1.2 to $3.3 million each year from reduced incidents. This assumes ERG applies the loss for groundings to allisions and collisions (for which we do not have an estimate for a more comprehensive economic loss per incident).

Table 13. Annual savings for more comprehensive economic loss avoided from increased safety.

Incident Type	Lower Bound # Incidents Reduced (from Step 2 Above)	Upper Bound # Incidents Reduced (from Step 2 Above)	Lower Bound Annual Avoided Loss (Millions of $2017)[a]	Upper Bound Annual Avoided Loss (Millions of $2017)[b]
Allisions	0.72	1.43	$0.9	$2.6
Collisions	0.05	0.1	$0.1	$0.2
Groundings	0.15	0.3	$0.2	$0.5
All incidents	0.92	1.83	$1.2	$3.3

[a] Calculated from reduced number of incidents x $1.3 million per incident [based on weighted average of loss of $0.8 million per cargo ship incident and $2.7 million per tanker incident and a lower bound estimate of a 25:75 split of tankers and cargo ships] (MIT 1998).

[b] Calculated from reduced number of incidents x $1.8 million per incident [based on weighted average of loss of $0.8 million per cargo ship incident and $2.7 million per tanker incident and an upper bound estimate of a 50:50 split of tankers and cargo ships] (MIT 1998). The MISLE 2002–2013 data set included about 40 percent of incidents as tanker ships or tanker barges (USCG 2015); thus, we used 25 to 50 percent as the range.

Increased Cargo/Decreased Operating Costs

ERG procured data for this method from the WCSC (2017) and the Charleston Harbor Study (USACE 1996).

Step 1: The following are the ranges for annual vessel calls that will load to 1 more foot of draft (WCSC 2017). The upper bound assumes all vessel calls will behave that way. The lower bound assumes ships that had a draft of 37 feet or more would load to 1 more foot of draft. The rationale for this is explained in Section 4.1 of this report. The lower bound is 2,666 vessel calls. The upper bound is 7,751 vessel calls.

Step 2: ERG used the following ranges for average DWT per vessel, as well as average additional DWT per vessel for each added foot of draft:

- Average DWT per vessel: if only larger ships add more tonnage—52,567 short tons; if all ships add more tonnage—30,100 short tons.
- Average additional DWT per vessel for each added foot of draft: if only larger ships add more tonnage—4,289 short tons; if all ships add more tonnage—2,730 short tons.

Step 3: ERG used the following inputs to estimate the average transit length (in hours):

- Average transit length (in miles): 8,598 miles.
- Average vessel speed at sea (in mph): 12.7 mph.
- Average length of each transit (hours): 679.2 hours.

Step 4: ERG used the following inputs to estimate average hourly at-sea operating costs per vessel:

- Average hourly at-sea operating costs per vessel: if only larger ships add more tonnage—$1,585; if all ships add more tonnage—$1,079.

5.4 Costs of Implementation

ERG spoke with several people involved in implementing the pilot study for Precision Navigation in Long Beach, California (Captain James Haley, Jacobsen Pilot Service, December 21, 2018; Captain Kip Louttit, Marine Exchange of Southern California, April 11, 2019; and Karsten Uil, Charta Software [creators of ProTide], January 16, 2020). A common theme emerged from these conversations: Precision Navigation offers a tremendous opportunity for any port willing to put in the effort to increase the technology available to pilots and the port. This effort includes coordination between private stakeholders at the port and public groups alike.

Based on our conversations, ports may pay around $200,000 to $500,000 annually for their PPUs and sensors depending on the number of sensors needed for that particular port. Based on the benefits outlined earlier in this section—which were in the millions, if not tens of millions or more each year—the return on investment is quite favorable. This cost does not include the cost for NOAA to develop the data sets that support Precision Navigation. While the return on investment is clearly favorable, the question of who pays compared to who benefits could lead to some challenges. The benefits are dispersed across a number of beneficiaries (i.e., ship owners, insurance companies, pilots, the port), but often the payee may be an entity only receiving a portion of the overall benefit. Thus, collaborations among beneficiaries like those at the Port of Long Beach, California, can be an effective way to align the payment with who is benefitting.

6. Recommendations to Agency

ERG performed the prioritization and economic analyses with limited data on the effectiveness of Precision Navigation, as the technology has only been implemented for oil tankers at the Port of Long Beach to date. In valuing the many benefits of Precision Navigation, ERG relied on feedback from pilots who might implement the technology and data from similar systems (e.g., PORTS®) that have generated benefits like those expected from Precision Navigation. ERG estimated ranges and approximated values that could be further studied once more ports implement Precision Navigation. ERG recommends the following future studies to improve the results of this study.

Study Precision Navigation's effectiveness in reducing incidents after implementing the technology for several years. ERG based the effectiveness in reducing allisions, collisions, and groundings on PORTS®, which is incorporated into Precision Navigation but is not the only data used to increase safety. After collecting several years of data at a handful of ports, this information could help establish a defensible estimate of the expected reduction of incidents resulting from Precision Navigation. This would help estimate reduced damage, as well as the reduced number of events that might shut down a waterway and cause significant impacts due to ships not delivering commodities on time.

Interview more pilots after implementing Precision Navigation to better understand associated behavior changes. As part of this study, ERG interviewed pilots at the Port of Long Beach, California, who used Precision Navigation to help bring in oil tankers. The pilots integrated Precision Navigation with an under-keel clearance system, which increased the declared draft allowance by a few feet. It is unclear from this study alone how much Precision Navigation and the under-keel clearance system each contributed to this declared draft increase. The pilots ERG interviewed at the Ports of New York/New Jersey and the Lower Mississippi River agreed that Precision Navigation may help them loosen their restrictions. However, they had a hard time quantifying how much this would help without implementing the technology. Depending on the port and situation, pilots seemed to indicate that Precision Navigation's real-time data could increase their comfort when dealing with less under-keel clearance or adverse conditions, and that the technology could result in a permanent draft increase or a lessening of tide and weather-related restrictions.

Gather more data and interview more pilots to better understand the scope of vessel delays from weather-related events*.* As discussed under benefit 3 in Table ES-1, we have only developed a qualitative estimate for Precision Navigation's impact on weather-related delays, including tide restrictions. To more fully understand Precision Navigation's impact on reducing these delays, more information from pilots and the port is needed to understand how these delays transpire. Additionally, it will be important to gain knowledge about what information/data pilots and ports need to decrease the length and number of delays that occur, and whether Precision Navigation will meet those needs.

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Appendix A: Port Profiles for Top 20 Ports

Appendix A includes port profiles for the top 20 ports that could benefit most from Precision Navigation. Table A-1 lists the seaports from most likely to least likely to benefit from Precision Navigation.

Table A-1. Top 20 Ports that could benefit from Precision Navigation with port profiles.

1) Ports of the Lower Mississippi River	8) Port of Virginia	15) Port of Jacksonville, Florida
2) Ports of Houston/Galveston, Texas	9) Port of Long Beach, California	16) Ports of Corpus Christi, Texas
3) Ports of Beaumont, Texas	10) Ports of Puget Sound, Washington	17) Port Everglades, Florida
4) Port of New York/New Jersey	11) Ports of the San Francisco Bay Area	18) Port of Mobile, Alabama
5) Port of Savannah, Georgia	12) Ports of the Delaware River and Bay	19) Port of Lake Charles, Louisiana
6) Port of Los Angeles, California	13) Port of Charleston, South Carolina	20) Port of Miami, Florida
7) Ports of the Columbia River, Washington	14) Port of Baltimore, Maryland	

In the pages that follow, we present data that helped form the basis of the rankings; a map of the port from BTS (2017) to provide context for the port vicinity and limiting bridges; and maps that ERG developed to show the locations of allisions, collisions, and groundings from 2001 to 2015.

Port Profile (1): Ports of the Lower Mississippi River

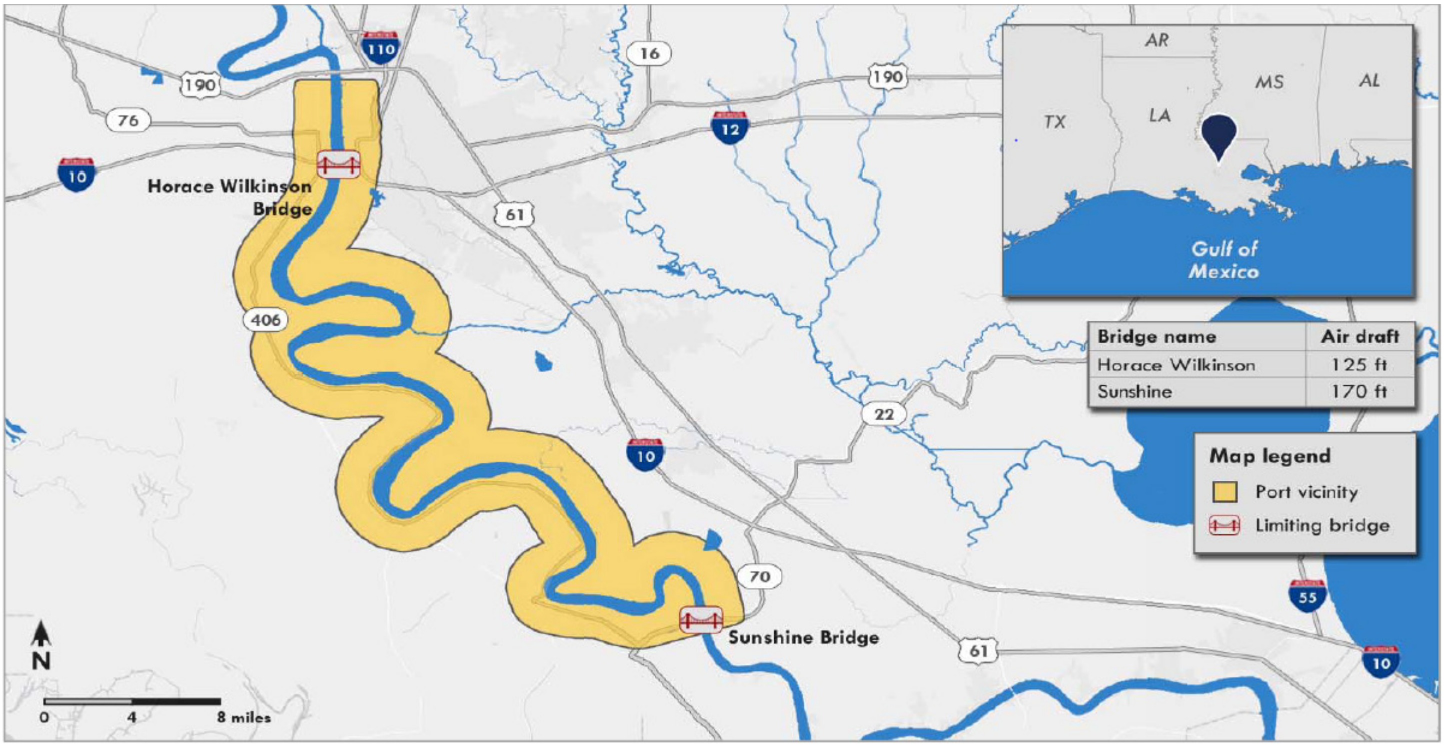

Figure A-1. Port of Baton Rouge, Louisiana, layout (BTS 2017).

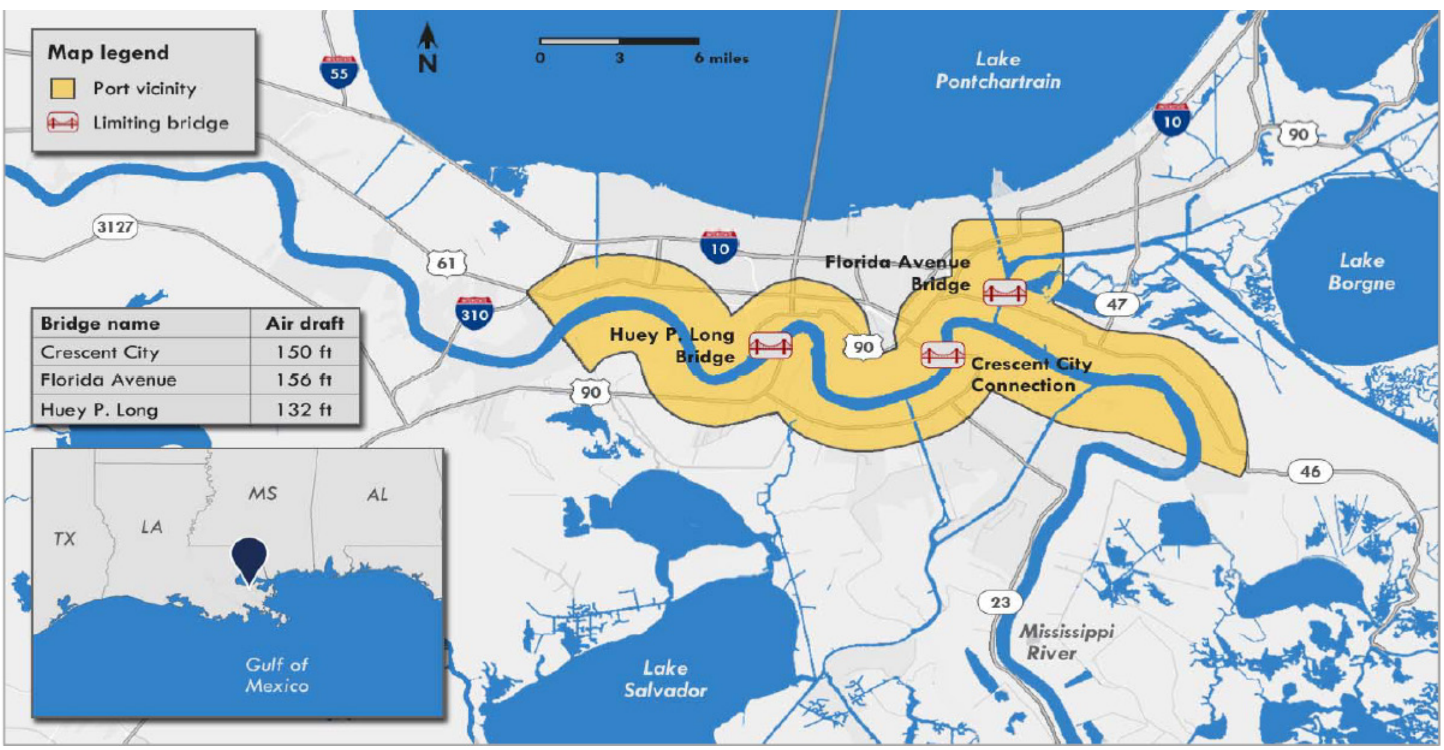

Figure A-2. Port of New Orleans, Louisiana, layout (BTS 2017).

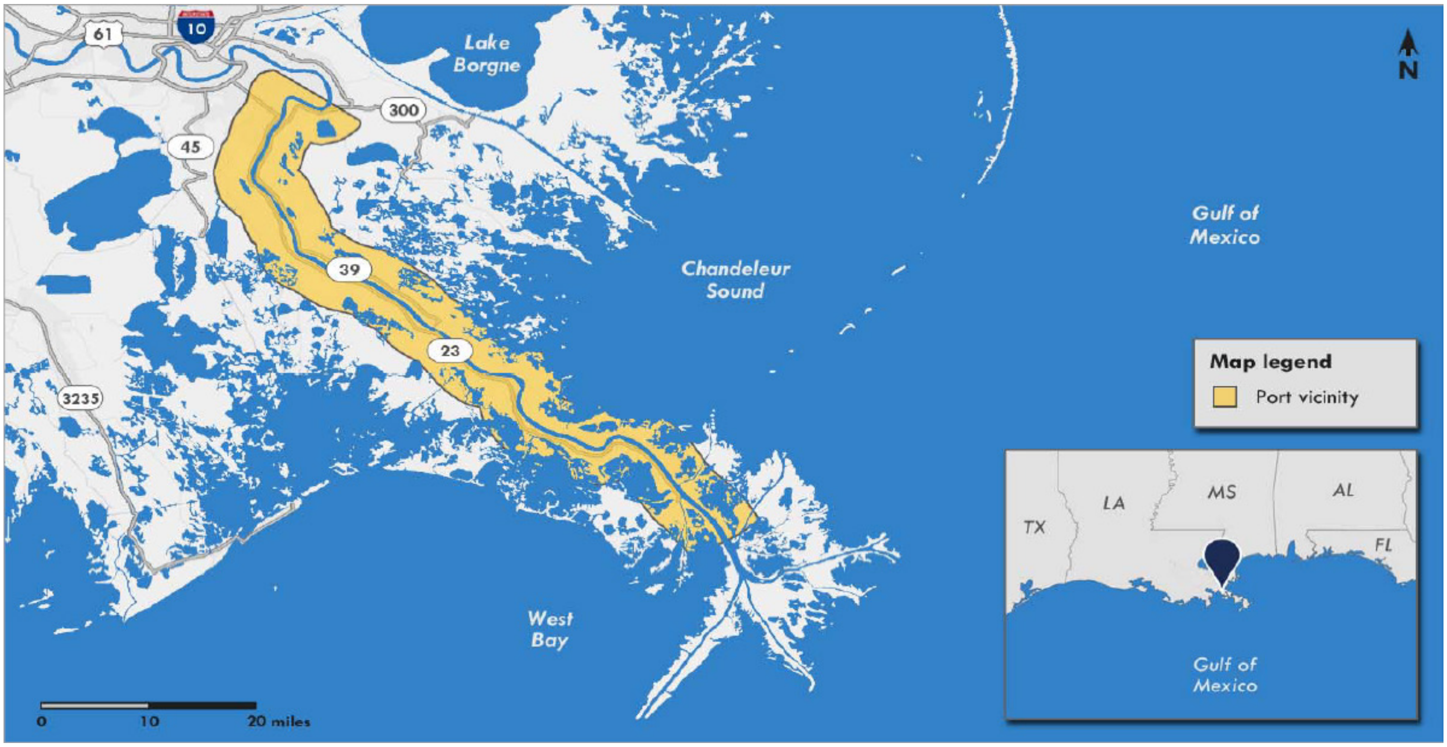

Figure A-3. Port of Plaquemines, Louisiana, layout (BTS 2017).

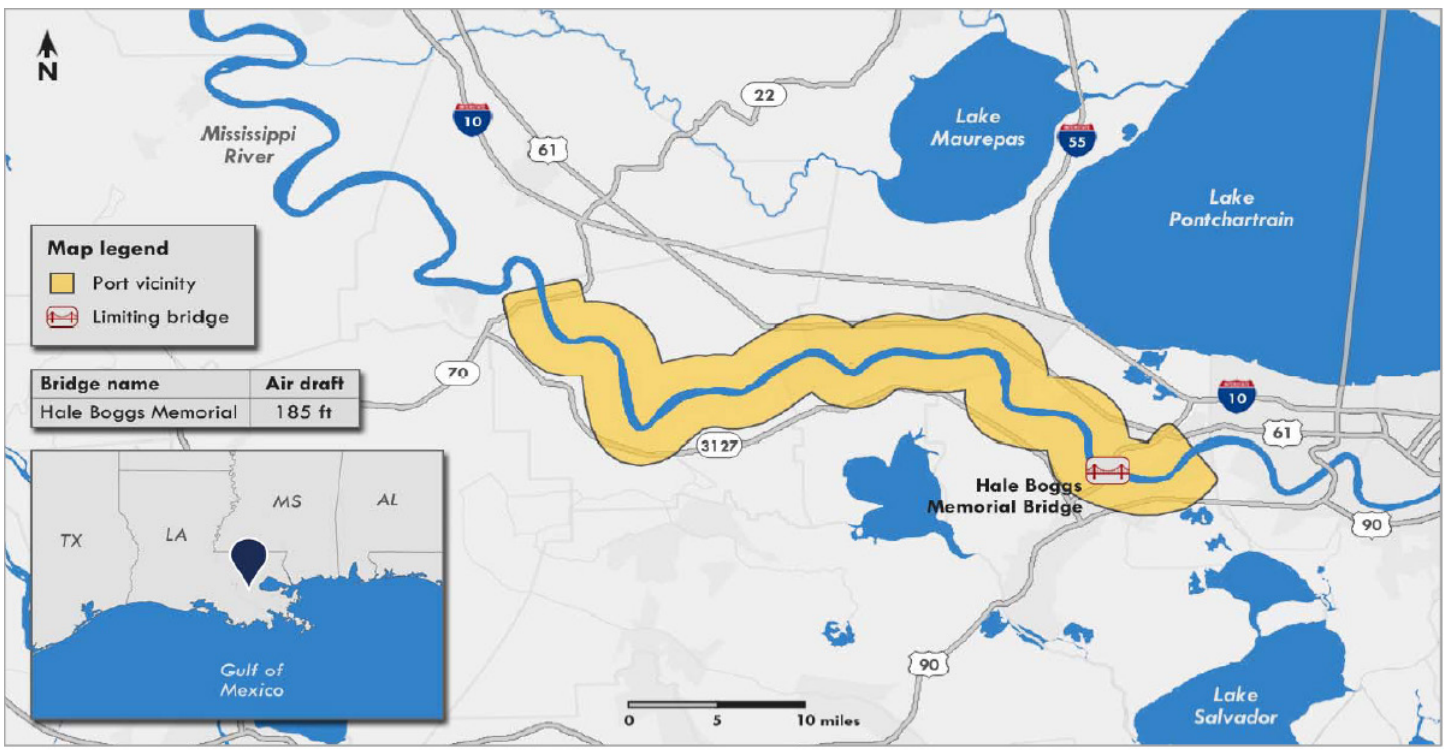

Figure A-4. Port of South Louisiana layout (BTS 2017).

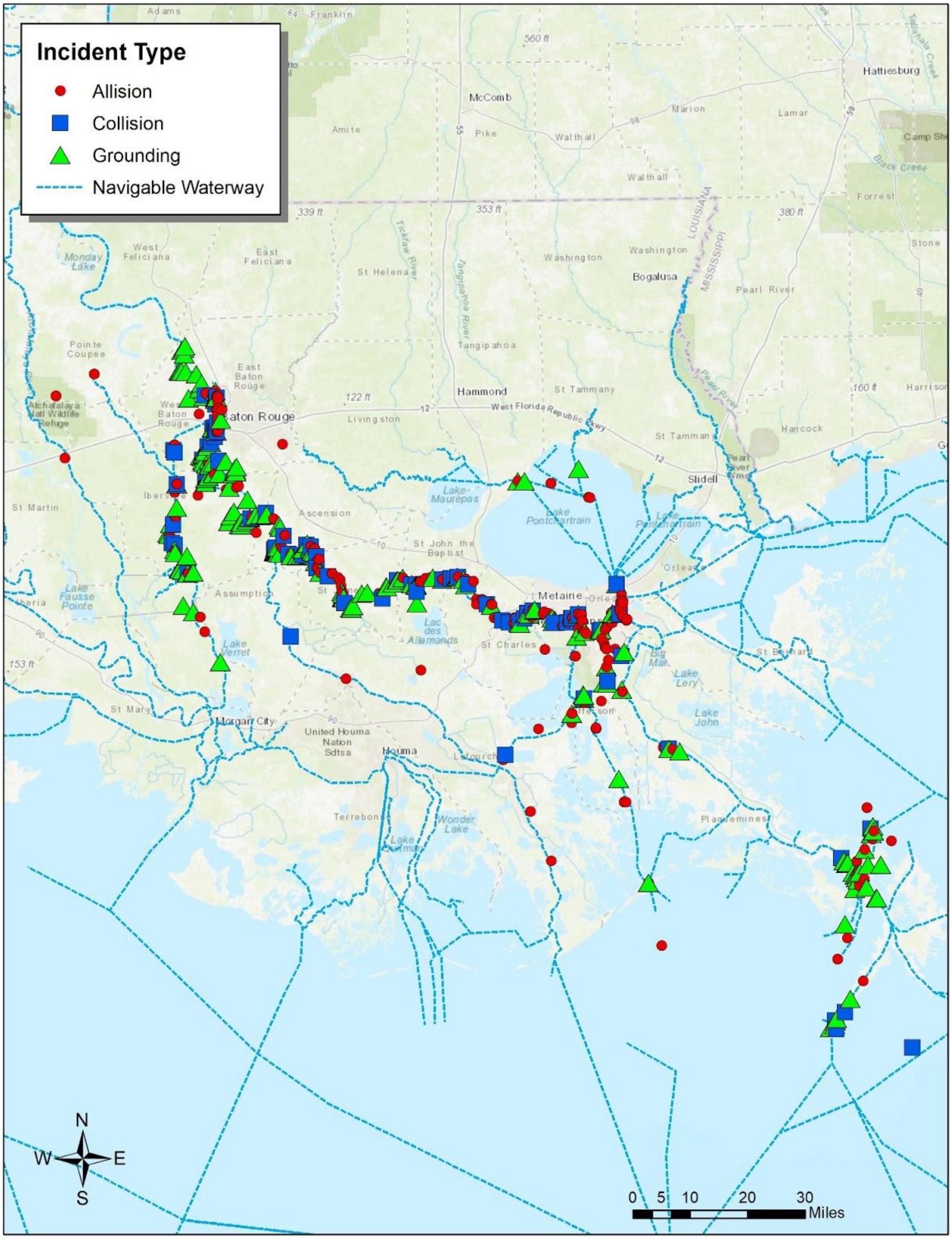

Figure A-5. Accident data for the Ports of the Lower Mississippi River.

Figure A-6. Accident data for the Port of Baton Rouge, Louisiana.

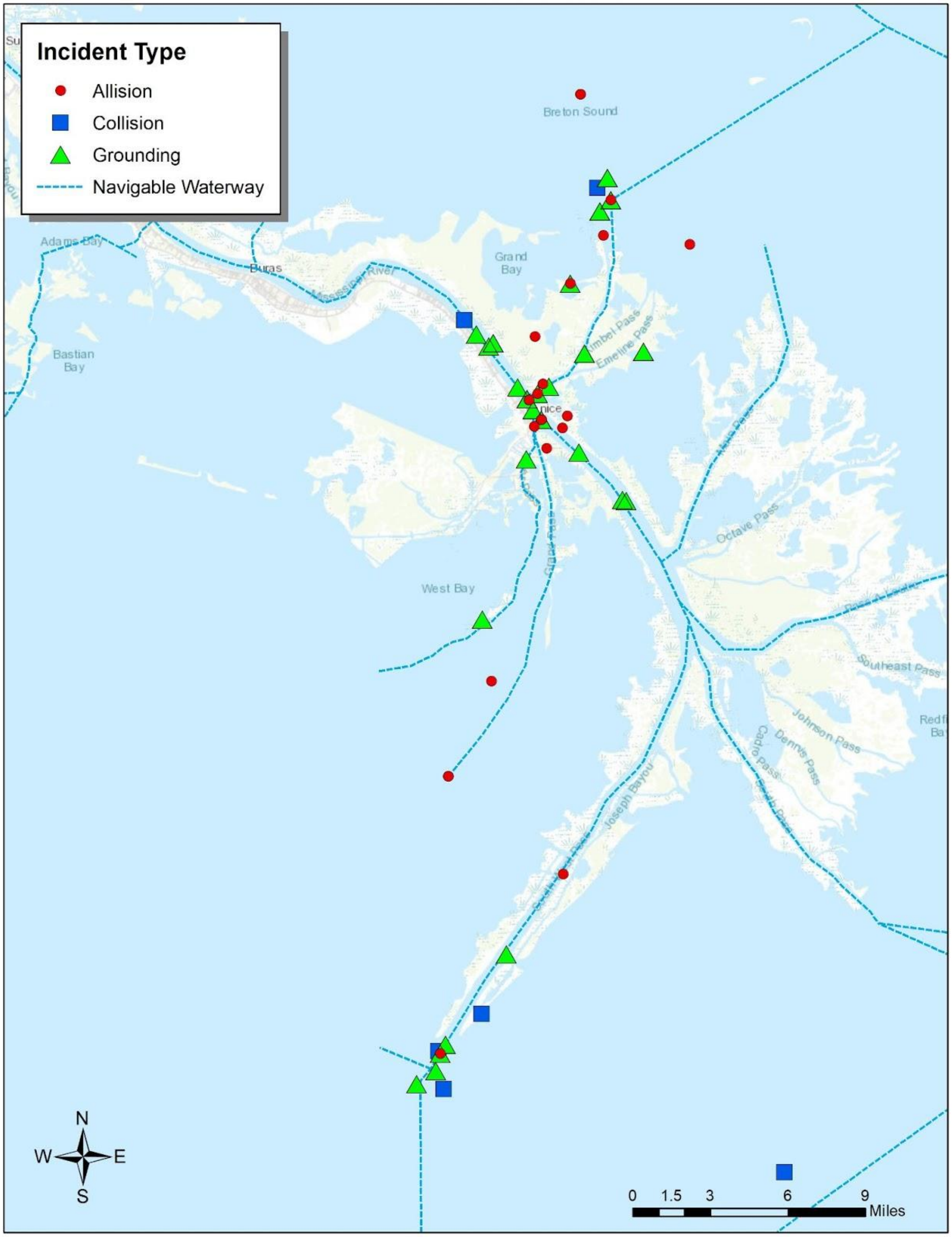

Figure A-7. Accident data for the delta area of the Lower Mississippi River.

Figure A-8. Accident data for inland area of the Lower Mississippi River between Baton Rouge and New Orleans, Louisiana.

Figure A-9. Accident data for the Port of New Orleans, Louisiana.

Table A-2. Data for the Ports of the Lower Mississippi.

Source[18]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (UCSG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[19] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**234,976,899**	**$79,326,656,376**	**222**	**12,239**	**45–47**	**1,791**	**384**
New Orleans, LA	45,655,411	$50,170,665,369	28	4,716	45	631	60
Baton Rouge, LA	31,341,443	$9,930,156,828	140	1,333	45	169	41
Port of South Louisiana	134,871,437	No Data	19	4,437	45	881	265
Plaquemines, LA	23,108,608	No Data	8	1,753	47	110	18
Destrehan, LA	No Data	$222,882	No Data	No Data	No Data	No Data	No Data
Gramercy, LA	No Data	$19,202,721,180	No Data	No Data	No Data	No Data	No Data
Port Sulphur, LA	No Data	$15,292,623	No Data	No Data	No Data	No Data	No Data
St. Rose, LA	No Data	$7,597,494	No Data	No Data	No Data	No Data	No Data
Gulf via Baptiste Collette Bayou	No Data	No Data	24	No Data	No Data	No Data	No Data
Gulf via Bayou Barataria	No Data	No Data	3	No Data	No Data	No Data	No Data

[18] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[19] USACE Channel Project Summary Data used for New Orleans, South Louisiana, and Baton Rouge.

Current Technology and Port Characteristics

The Ports of St. Bernard and Plaquemines are below bridges, and their pilots desire more survey information and channel-related information.

From the Ports of New Orleans to Baton Rouge, there are bridge air gap sensors for three of the six bridges; adding sensors to the remaining three bridges would be an impactful addition of technology. Between these ports, there are issues with the current sensors being struck by objects, needing replacement, or not pointing where they should. Properly functioning sensors are essential to operations due to the immense amount of fog on the river, which led to 19 blackout days in 2019 and affected dredging operations.

The key technologies currently being used by pilots on the Lower Mississippi River include AIS data updated with core surveys and NOAA port sensors.

Challenges that pilots face on the Lower Mississippi River include minimal under-keel clearance with a soft sediment bottom; lightering required, especially recently due to draft restrictions; and sedimentation. Sedimentation occurs in the southwest pass where pilots are required to enter at high tide, and the current survey technology does not help with this issue.

A good candidate for Precision Navigation because:

A high volume and value of cargo is transported through the Ports of the Lower Mississippi River each year, and a high number of vessels travel close to the maximum draft allowance. The Ports of the Lower Mississippi River ranked high in every metric used to measure Precision Navigation’s potential impact, which indicates that Precision Navigation could lead to more cargo transported, safer navigation, and fewer congestion and delays. Specifically, the added technology could alleviate issues arising on the river, including minimal under-keel clearance, lightering, shoaling, and the uncertainty about under-keel clearance with rapid accretion.

Port Profile (2): Ports of Houston/Galveston, Texas

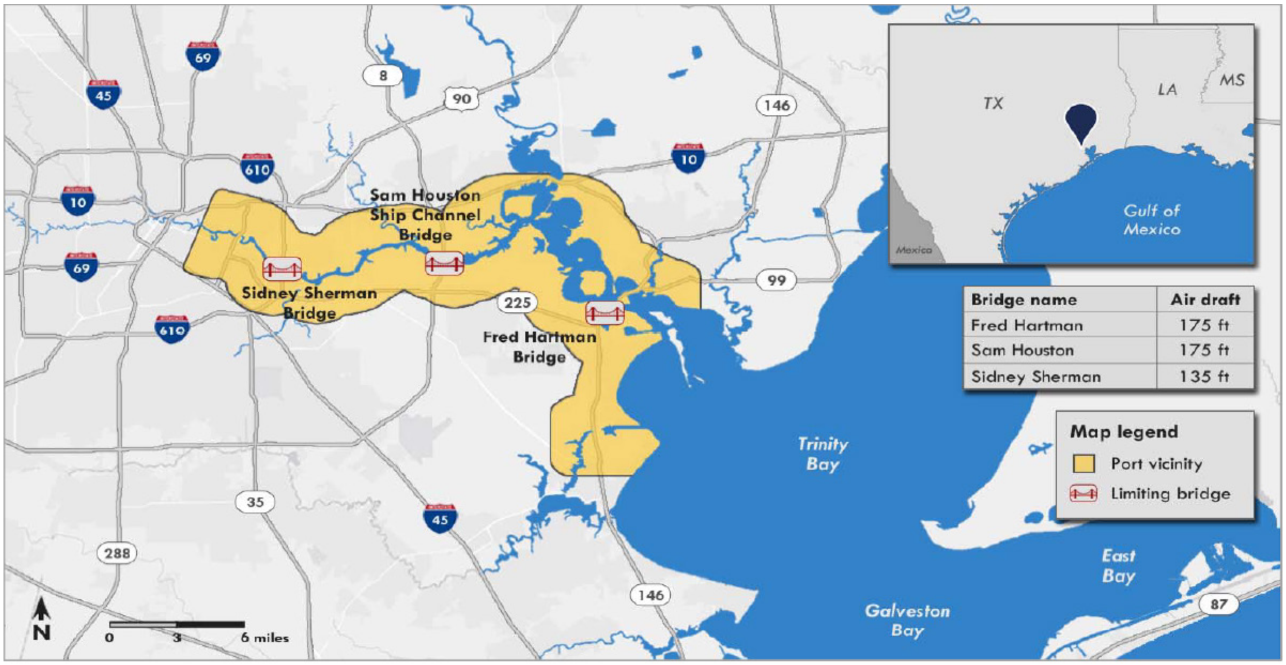

Figure A-10. Port of Houston, Texas, layout (BTS 2017).

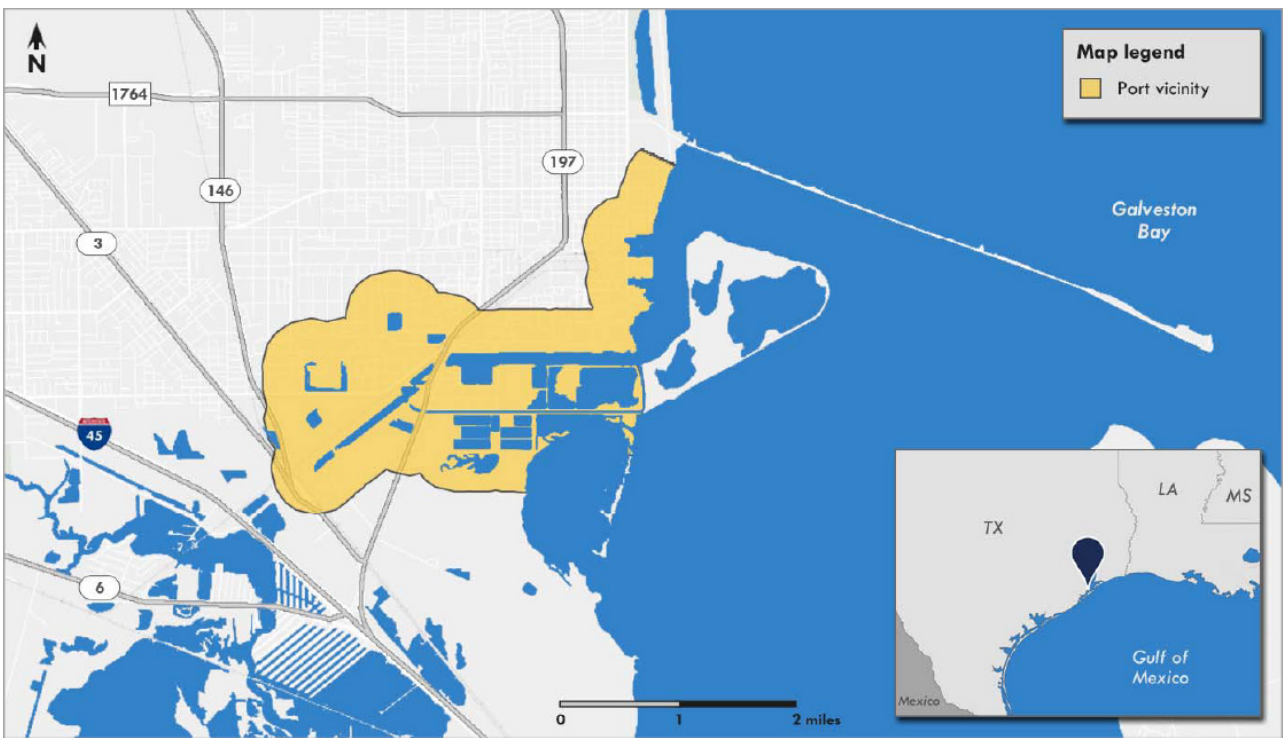

Figure A-11. Port of Texas City, Texas, layout.

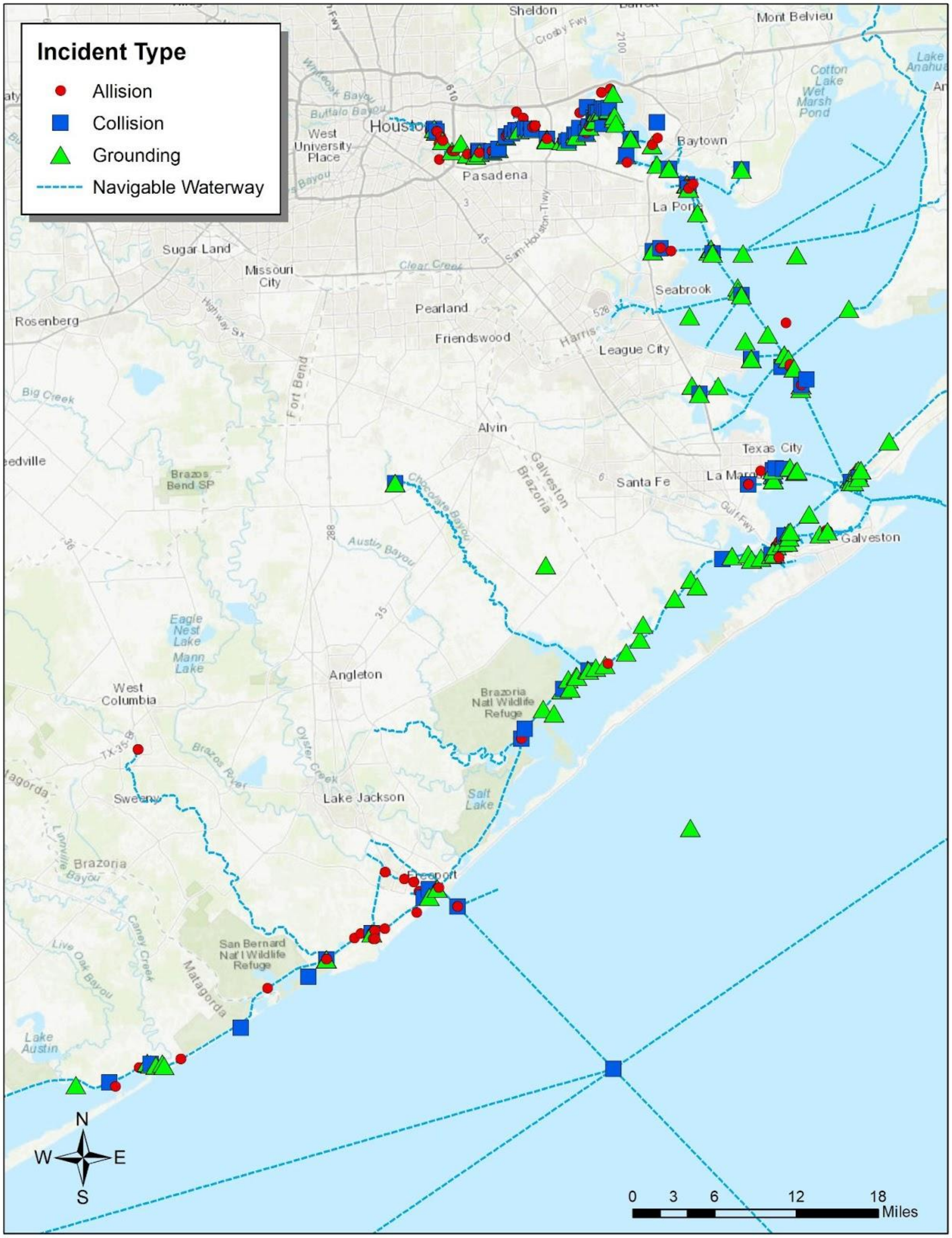

Figure A-12. Accident data for the Ports of Houston/Galveston, Texas.

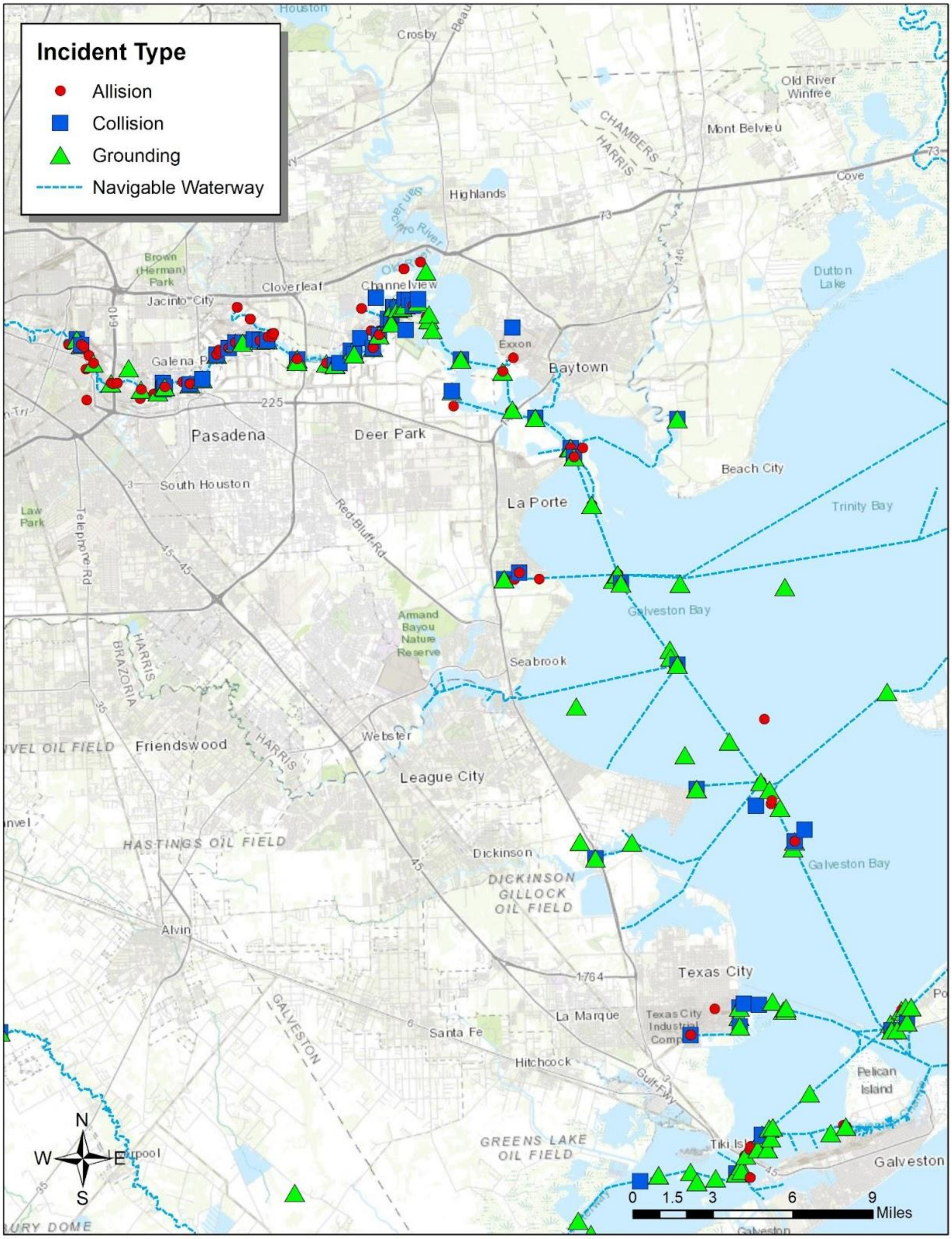

Figure A-13. Accident data for the Ports of Houston/Galveston, Texas (zoomed view 1).

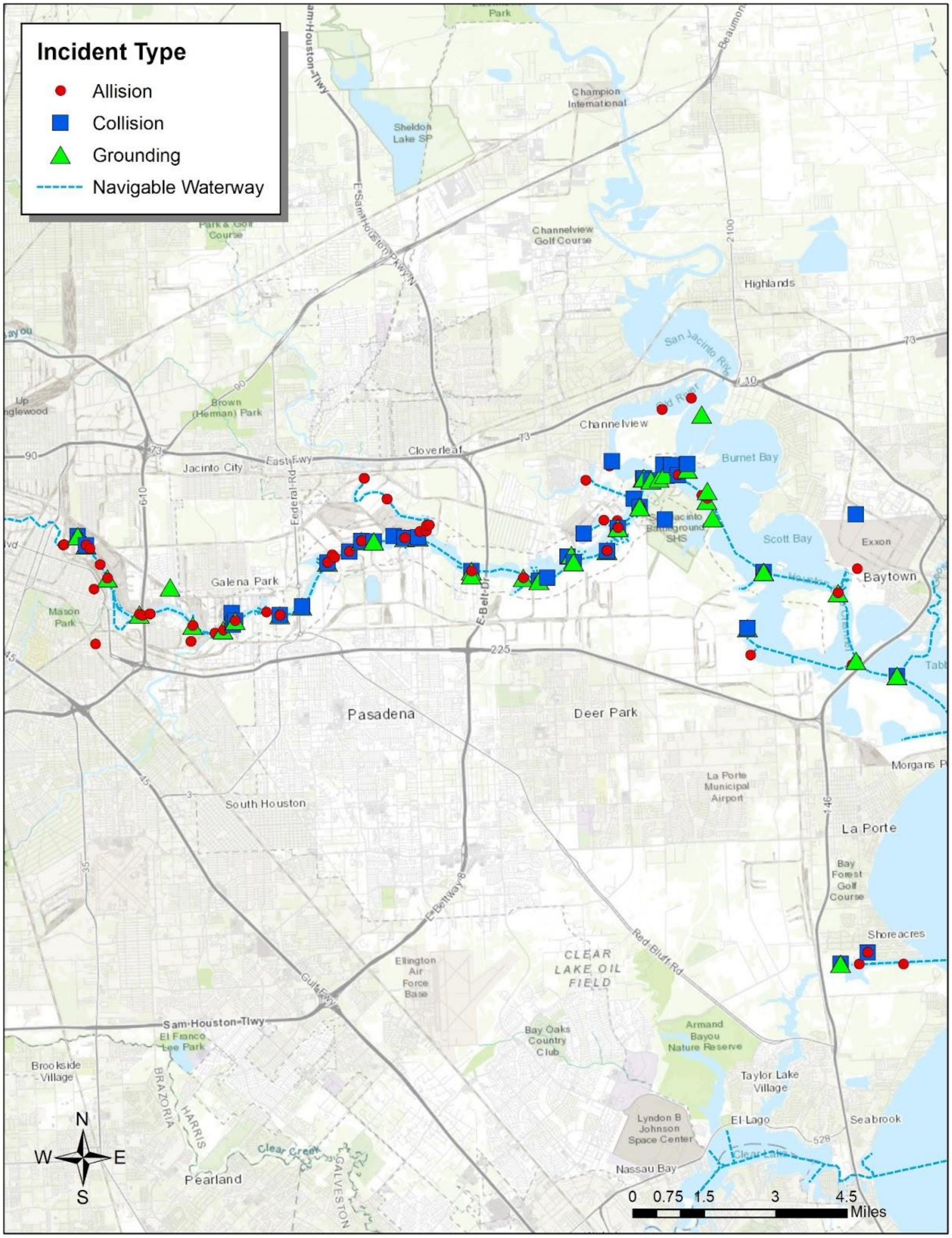

Figure A-13. Accident data for the Ports of Houston/Galveston, Texas (zoomed view 2).

Table A-3. Data for the Ports of Houston/Galveston, Texas.

Source[20]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[21] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total[22]	**218,543,696**	**$153,483,227,170**	**266**	**20,595**	**3–45**	**573**	**59**
Houston, TX	173,210,955	$131,474,342,440	49	12,064	45	464	28
Clear Creek, TX	No Data	No Data	No Data	30	3	No Data	30
Texas City, TX	22,169,173	$8,580,354,197	20	1,129	45	35	1
Freeport, TX	19,355,144	$8,751,127,669	10	1,782	45	72	0
Galveston Bay, TX	3,808,424	$4,677,402,864	146	5,590	45	2	0

A good candidate for Precision Navigation because:

The ports around Houston and Galveston ranked high for number of vessel calls, cargo tonnage and value, and safety incidents. These factors indicate that Precision Navigation could lead to safer navigation and more economic activity at the port from an increased cargo capacity and less congestion.

[20] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[21] USACE Channel Project Summary Data used for Houston, Texas City, Freeport, and Galveston Bay.

[22] Port Bolivar will be included in the analysis for this complex; however, no data from the above sources existed for this port.

Port Profile (3): Ports of Beaumont, Texas

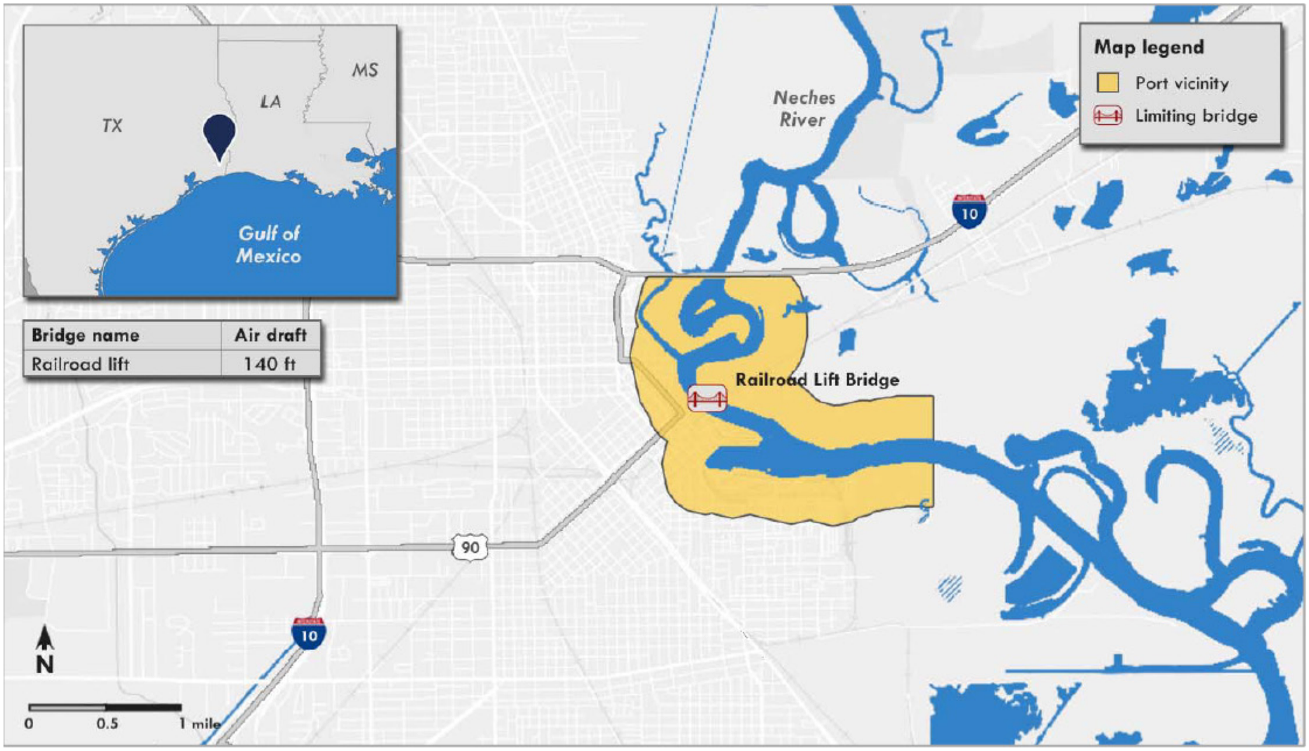

Figure A-14. Port of Beaumont, Texas, layout (BTS 2017).

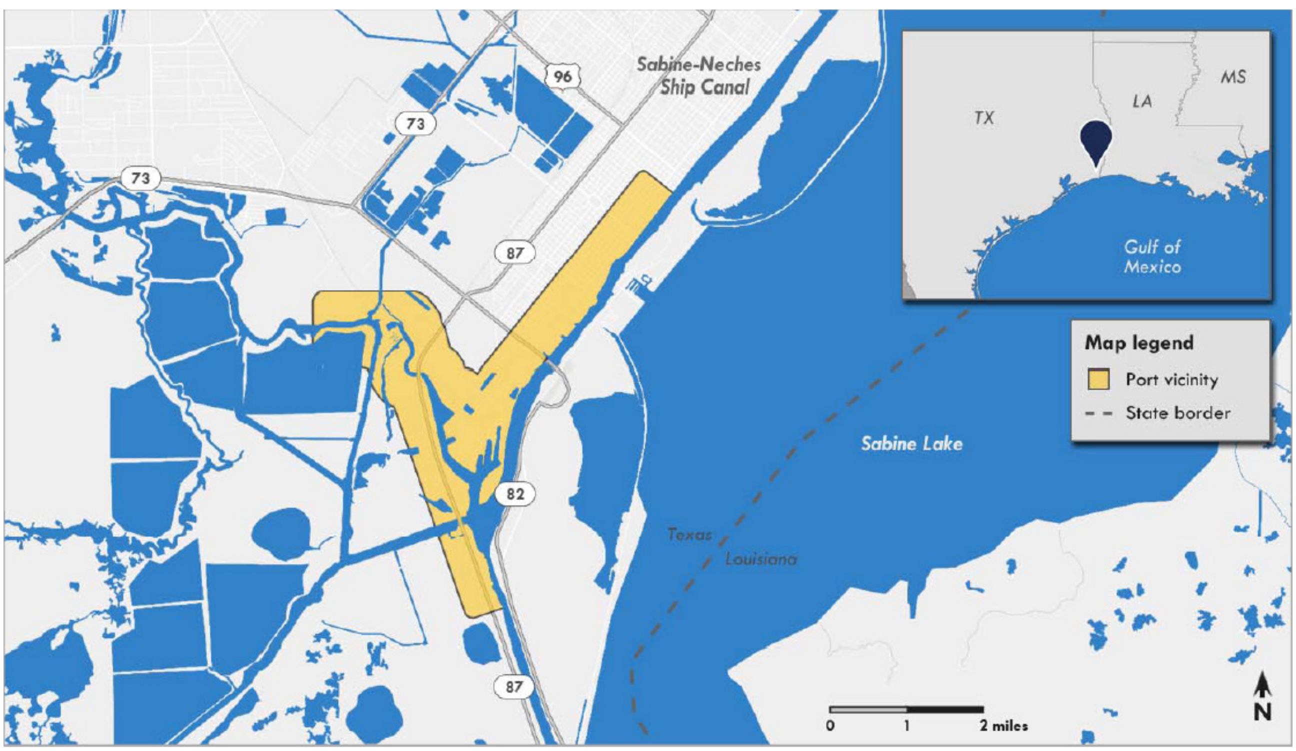

Figure A-15. Port Arthur, Texas, layout (BTS 2017).

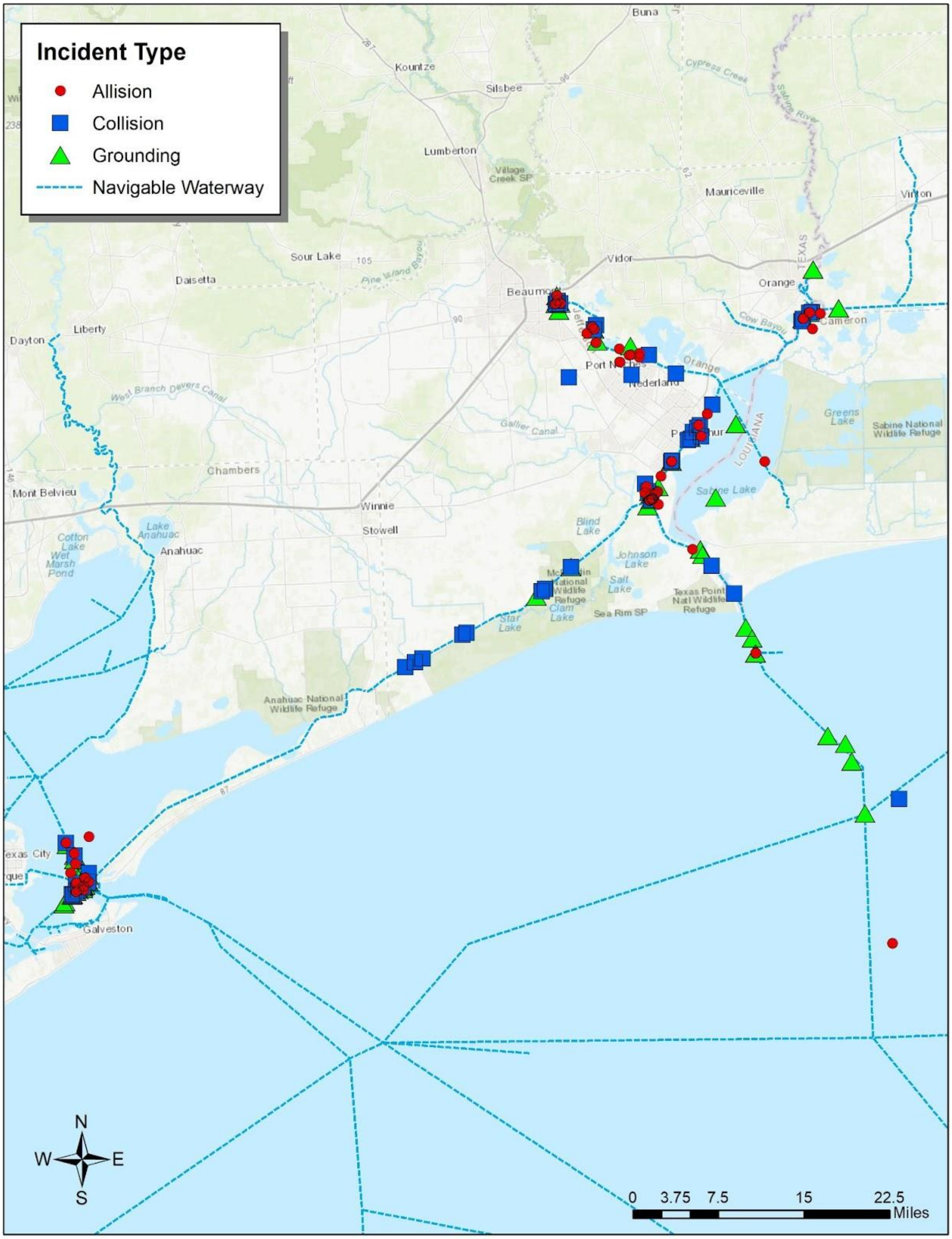

Figure A-16. Accident data for the ports near Beaumont, Texas.

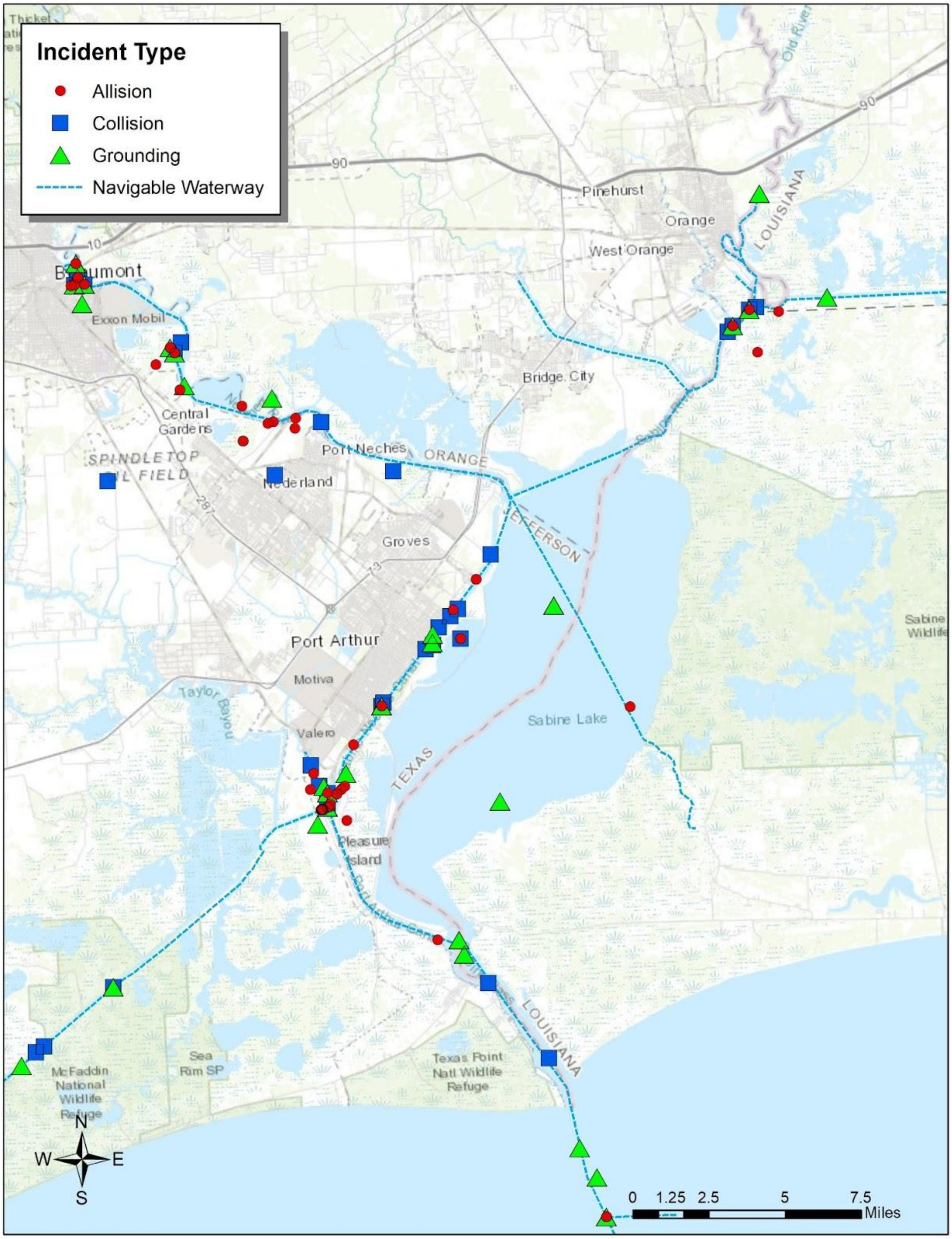

Figure A-17. Accident data for the northeast portion of Port of Beaumont, Texas.

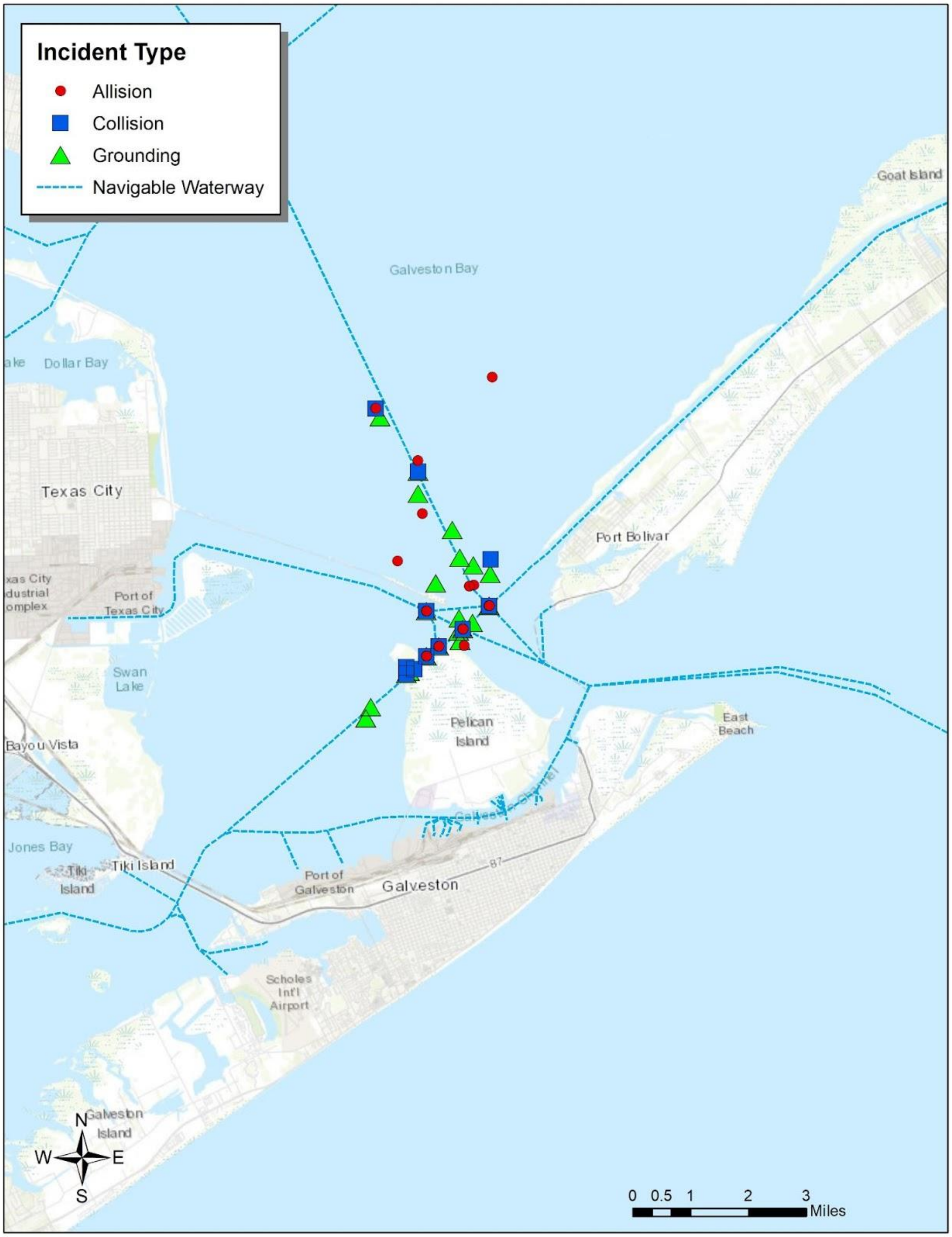

Figure A-18. Accident data for the southwest portion of Port of Beaumont, Texas.

Table A-4. Data for the Ports of Beaumont, Texas.

Source[23]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[24] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCWC 2017)
Total[25]	**83,041,906**	**$29,425,434,935**	**354**	**5,007**	**12–40**	**1,386**	**337**
Special Internal Sabine Neches, TX	No Data	No Data	171	1	12	1	1
Sabine, TX	No Data	$847,454,153	53	685	40	179	27
Beaumont, TX	53,693,826	$13,239,843,573	4	2,727	40	745	173
Gulf via Sabine Pass	No Data	No Data	9	27	23	1	1
Port Arthur, TX	29,348,080	$15,338,137,209	115	1,567	40	460	135

A good candidate for Precision Navigation because:

The Ports of Beaumont ranked especially high for number of vessel calls close to maximum draft and safety incidents. This indicates that Precision Navigation could heavily increase navigational safety at the port, and an increase in draft allowance would lead to a high rate of increased cargo capacity and therefore economic activity.

[23] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[24] USACE Channel Project Summary Data used for Beaumont and Port Arthur.

[25] The Port of Orange, Texas, will be included in the analysis for this complex; however, no data from the above sources existed for this port.

Port Profile (4): Port of New York/New Jersey

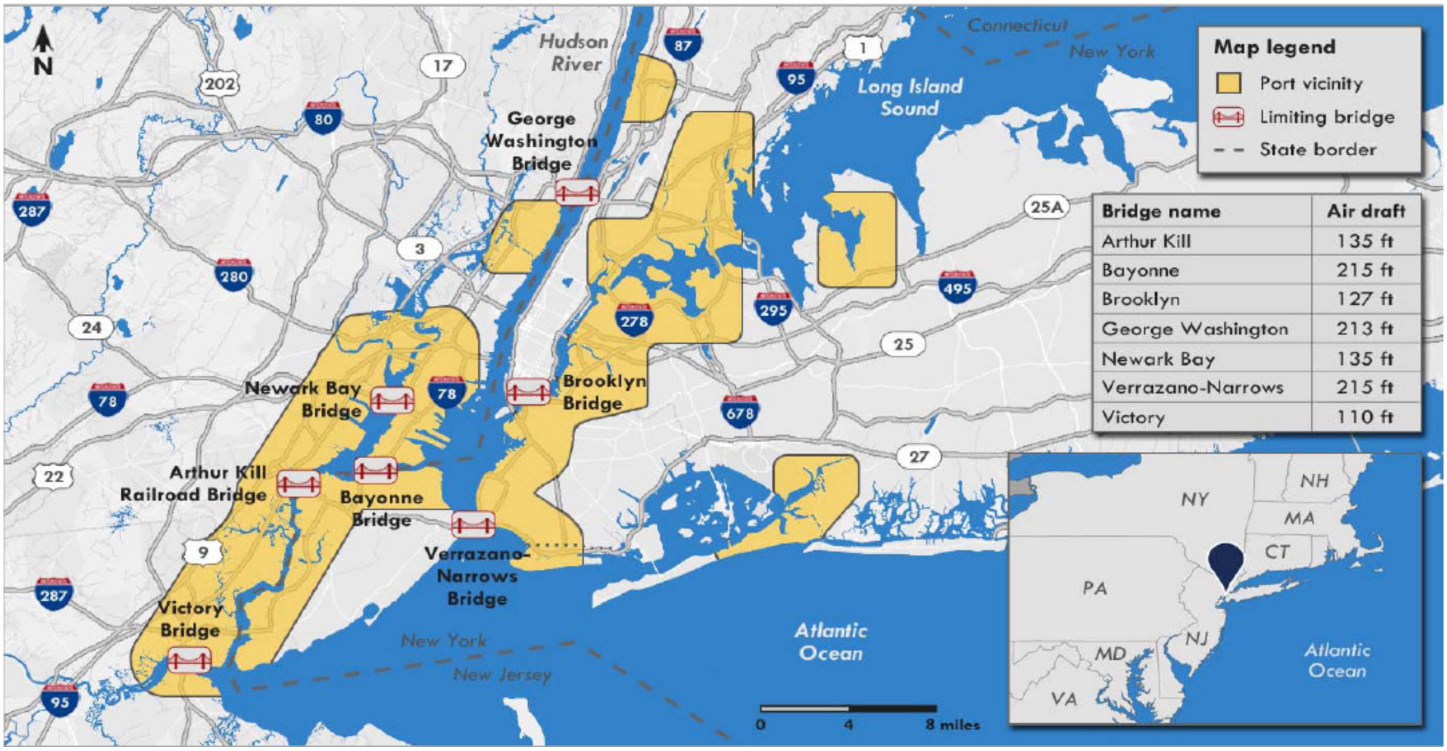

Figure A-19. Port of New York/New Jersey layout (BTS 2017).

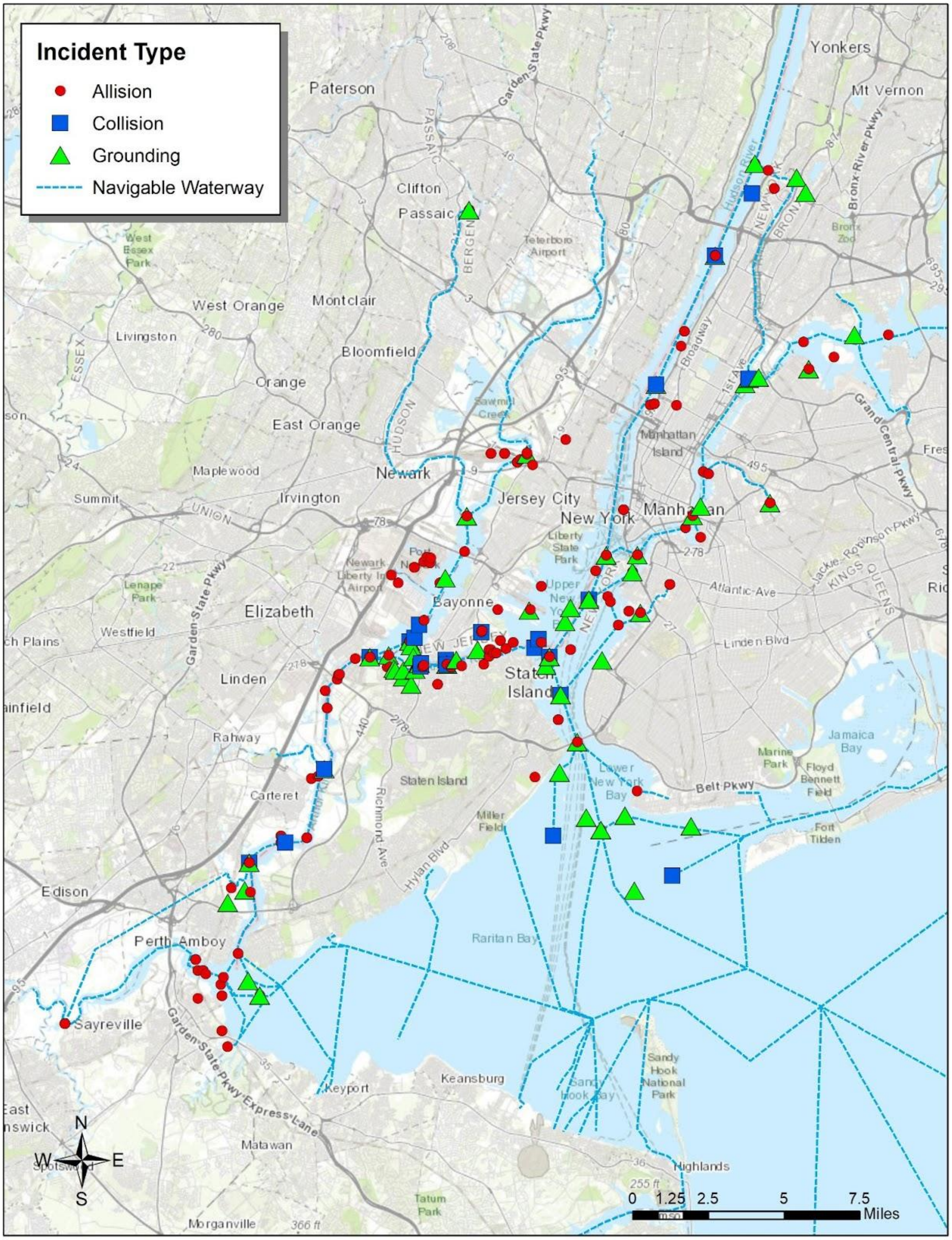

Figure A-20. Accident data near the Port of New York/New Jersey.

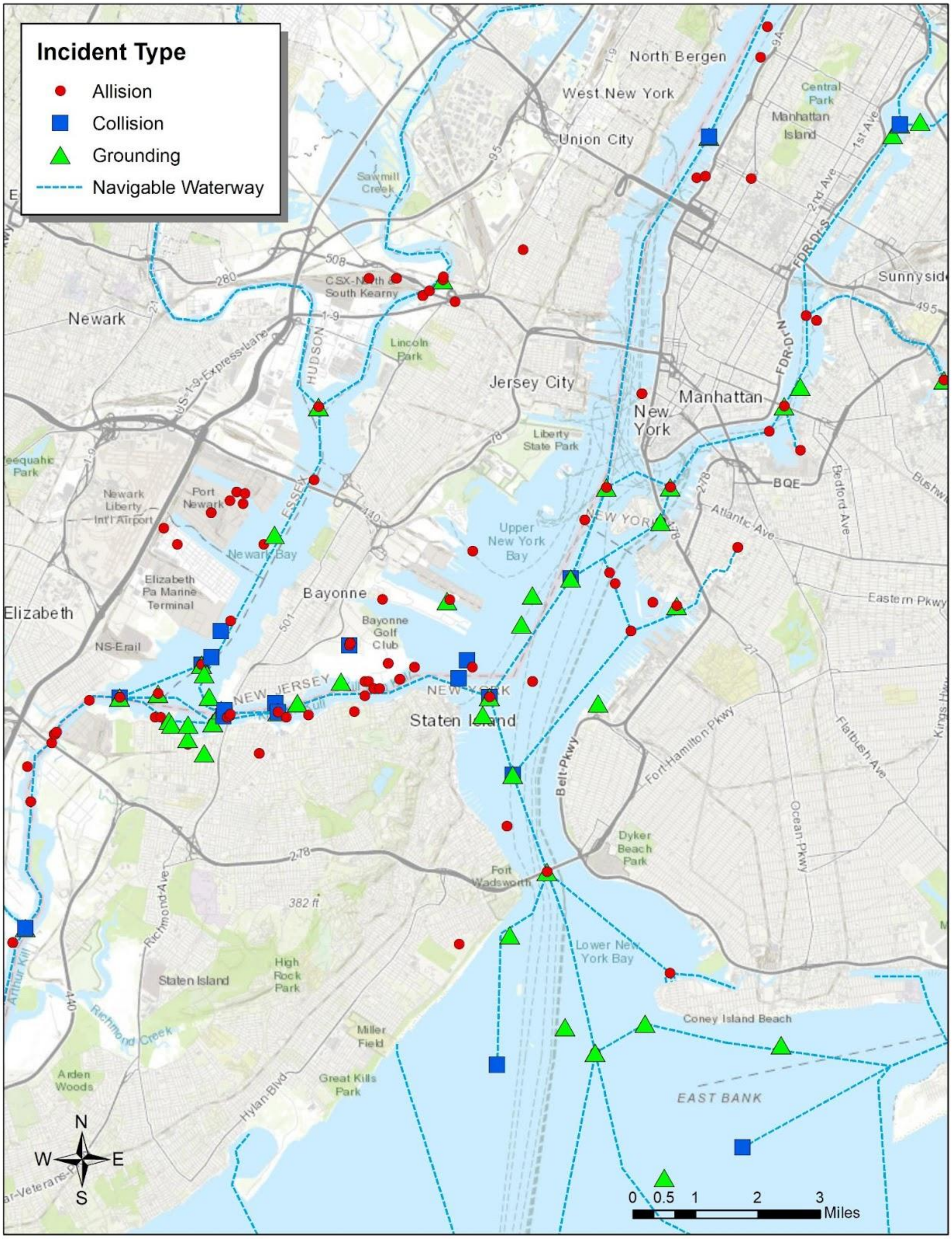

Figure A-21. Accident data near the Port of New York/New Jersey (zoomed view #1).

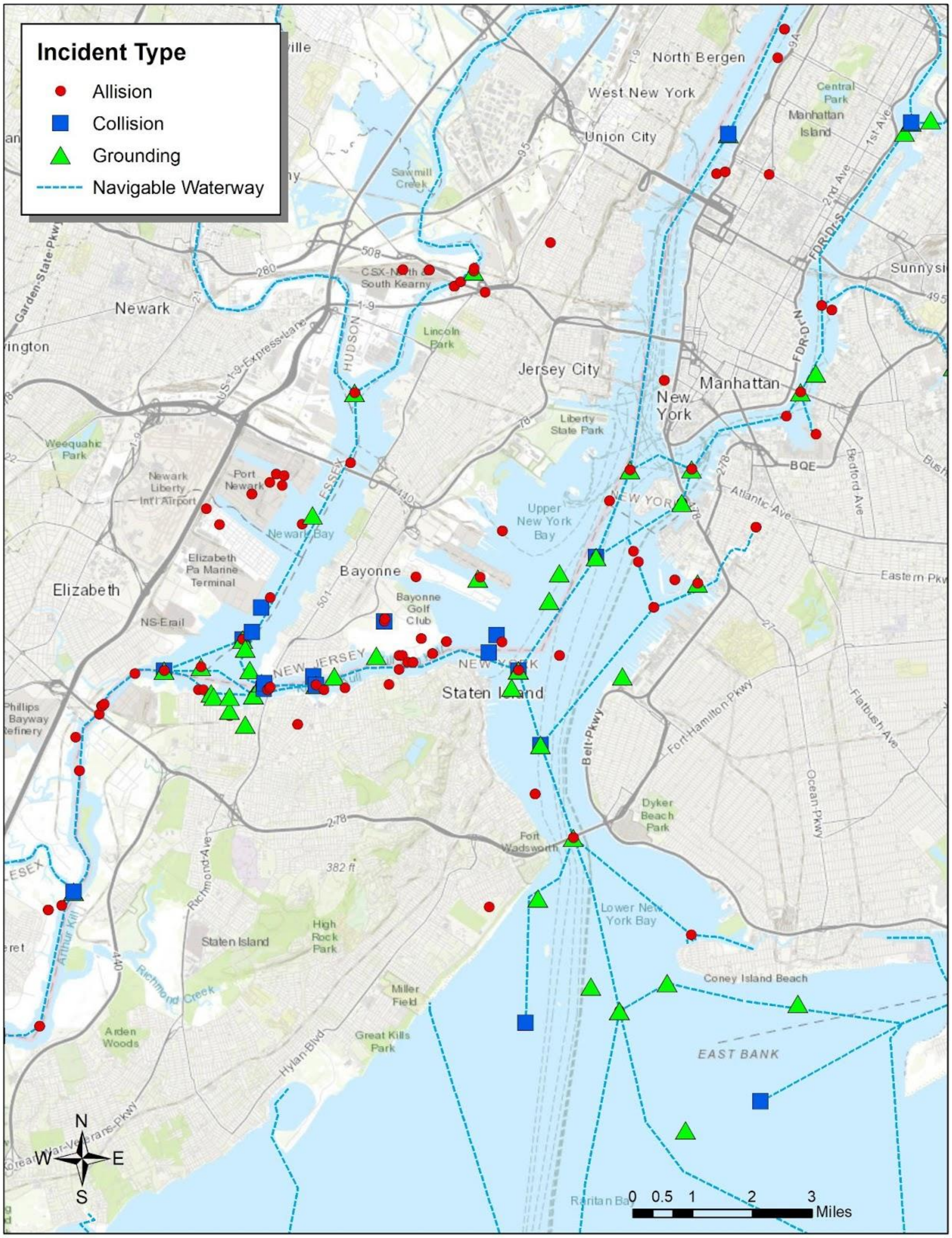

Figure A-22. Accident data near the Port of New York/New Jersey (zoomed view #2).

Table A-5. Data for the Port of New York/New Jersey.

Source[26]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[27]	Number of Vessels Within 5 feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**89,588,533**	**$193,255,498,642**	**13**	**7,976**	**32–50**	**261**	**6**
Port of New York/New Jersey	88,894,622	$41,576,649,783	10	7,751	50	194	3
Newark, NJ	No Data	$148,163,152,857	No Data	No Data	No Data	No Data	No Data
Albany, NY	693,911	$468,860,628	3	146	32	32	1
Hudson River, NY	No Data	No Data	No Data	79	33	35	2
Perth Amboy, NJ	No Data	$3,046,835,374	No Data	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

Due to the high volume and value of cargo being transported through the Port of New York/New Jersey each year, Precision Navigation's implementation would allow for more safe and efficient transport of goods, leading to a major increase in the port's overall economic activity.

[26] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[27] USACE Channel Project Summary Data used for Port of New York and New Jersey.

Port Profile (5): Port of Savannah, Georgia

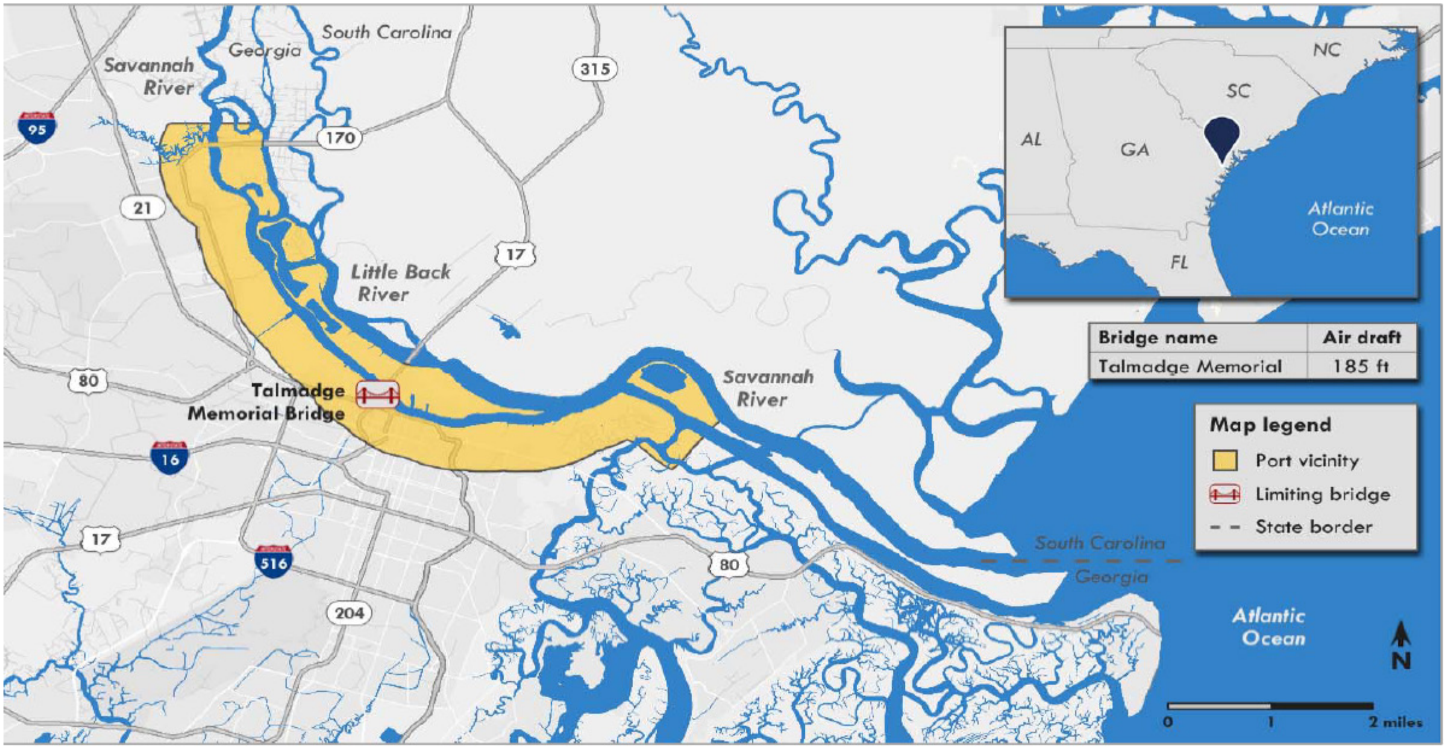

Figure A-23. Port of Savannah, Georgia, layout (BTS 2017).

Figure A-24. Accident data for the Port of Savannah, Georgia.

Table A-6. Data for the Port of Savannah, Georgia.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[28]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Savannah, GA	38,344,120	$89,633,902,964	3	5,022	42	1,490	244

Current Technology and Port Characteristics

Savannah's port moves a very large quantity of ultra large container vessels in a very narrow channel. The Garden City Container terminal is the most congested part of the river, with 8,500 consecutive linear feet of berthing space accounting for nearly 80 percent of all traffic on the river. This terminal also contains a large turning basin, where 90 percent of all vessels turn around before heading to sea. With only six tugboats to assist vessels maneuvering in and around berths, traffic is scheduled carefully to maximize efficiency and minimize delays.

Pilots use the SeaIQ PPU, which ties into ships' AIS to retrieve information such as heading and ship dimensions. Additionally, NOAA's electronic navigational charts (ENCs) are used in conjunction with a local survey company that creates a bathymetric ENC overlay from local USACE monthly survey data.

Half of all container traffic is tide-restricted. Savannah Pilots Association policy is to operate with no less than 10 percent (which is 4 feet) of the vessel's draft with under-keel clearance, and this occurs on a daily basis. Vessels with draft greater than 42 feet must wait until high tide to transit the port; the tide-restricted vessels account for approximately half of all traffic at the port.

A problem that is becoming more prominent at the port is the potential for vessels to hit bridges. As the Panama Canal has widened, larger and larger ships have started to come to Savannah, particularly Neo-Panamax vessels. These and other large vessels that comprise about 25 percent of all container vessels are traveling with less than 10 feet of clearance under bridges. That number is expected to increase as ship sizes continue to grow. There are NOAA port sensors on the bridge to give real-time air gap information.

A good candidate for Precision Navigation because:

The increased technological capabilities combined with the amount of cargo being transported through the port and that cargo's immense value would allow increases in efficiency and cargo capacity to translate to large economic gains at the Port of Savannah, Georgia.

While there already exists a substantial technological infrastructure that includes Portable Pilot Units (PPUs) and bathymetric overlays, NOAA's real-time updates and single-source data capabilities would enhance Savannah's ability to schedule traffic and avoid safety concerns with larger ships traveling close to bridges at a higher rate than ever before. Additionally, if an increase in draft were achieved, both an increase in cargo capacity as well as a decrease in traffic due to tide restrictions would lead to even higher economic gains.

[28] USACE Channel Project Summary Data used.

Port Profile (6): Port of Los Angeles, California

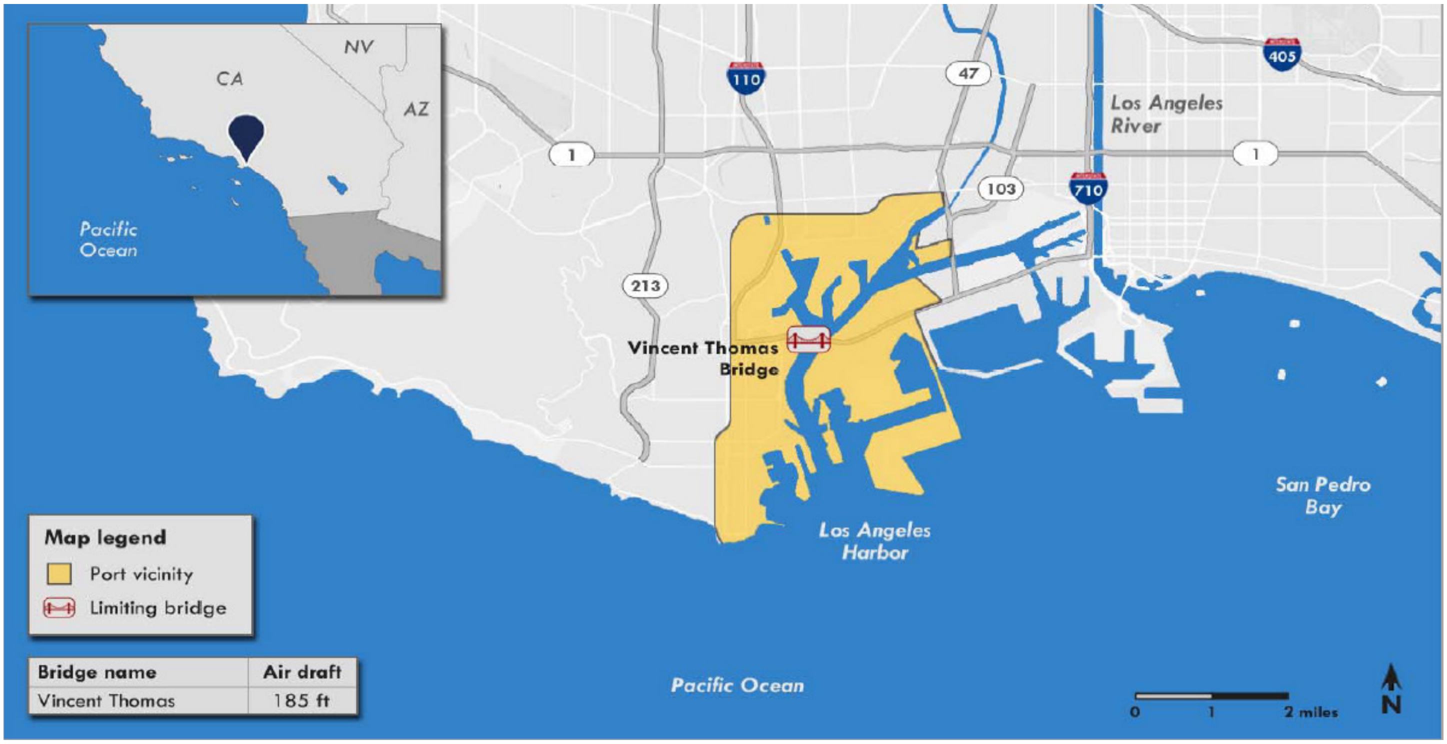

Figure A-25. Port of Los Angeles, California, layout (BTS 2017).

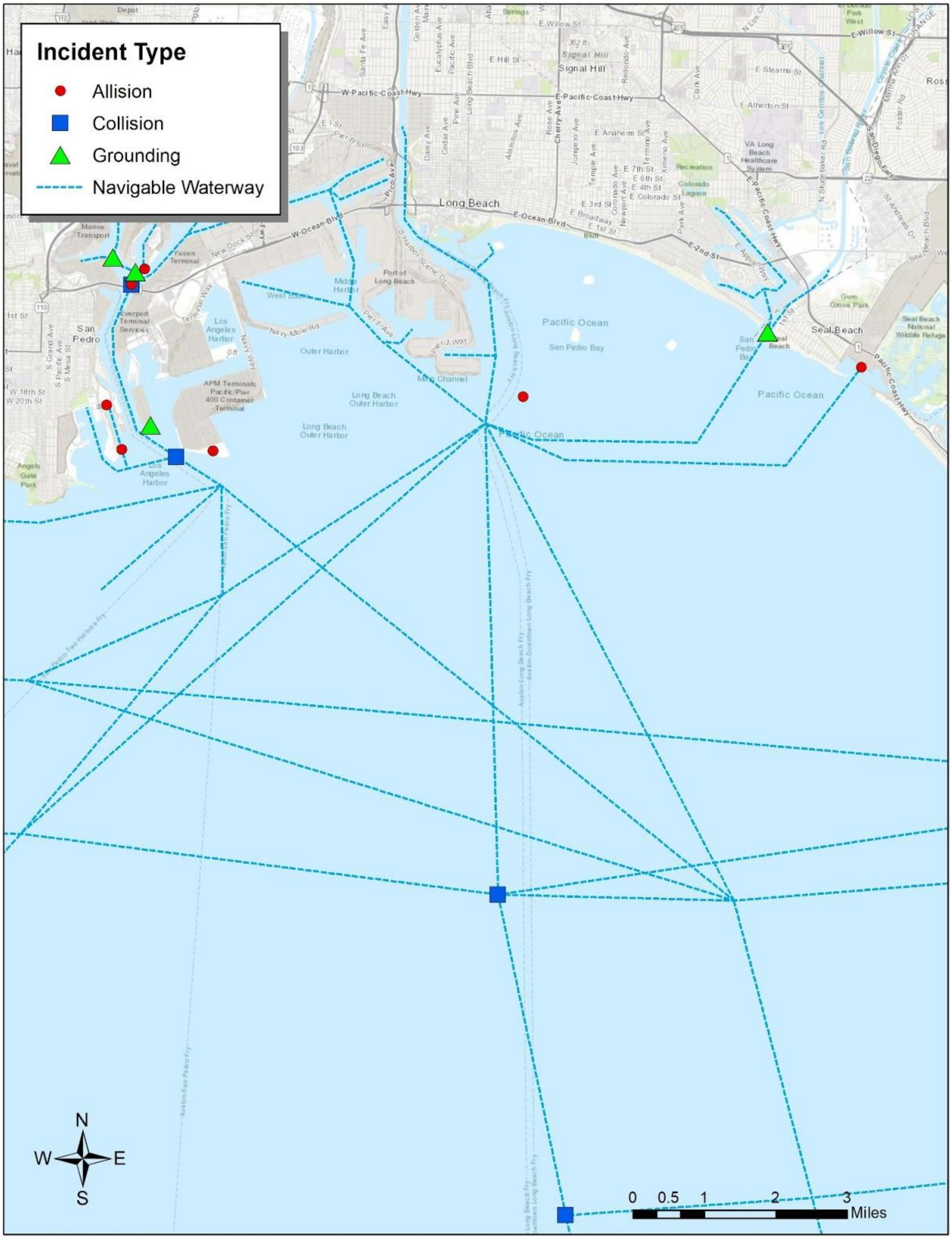

Figure A-26. Accident data for the Port of Los Angeles, California.

Table A-7. Data for the Port of Los Angeles, California.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[29]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Los Angeles, CA	58,926,048	$283,939,690,551	8	3,387	81	0	0

Current Technology and Port Characteristics

Pilots at the Port of Los Angeles have used PPUs since they were first developed to help understand port conditions and optimize go–no-go decision-making, although not all vessels and trips require such technology at this port. More recently, pilots have been using SeaIQ's PPUs.

While there are relatively few safety hazards and a very deep channel, the Port of Los Angeles does not currently bring in extremely large container ships—unlike the neighboring Port of Long Beach, California—because there is no terminal where the largest container ships can go.

A good candidate for Precision Navigation because:

The Port of Los Angeles, California, was the highest ranked port for import and export value. The port also ranked high for tonnage amount. These factors indicate that Precision Navigation could have a major impact on economic activity if the technology even slightly improved traffic conditions at the port or the port builds a terminal that makes it possible for larger container ships to enter.

[29] USACE Channel Project Summary Data used.

Port Profile (7): Ports of the Columbia River

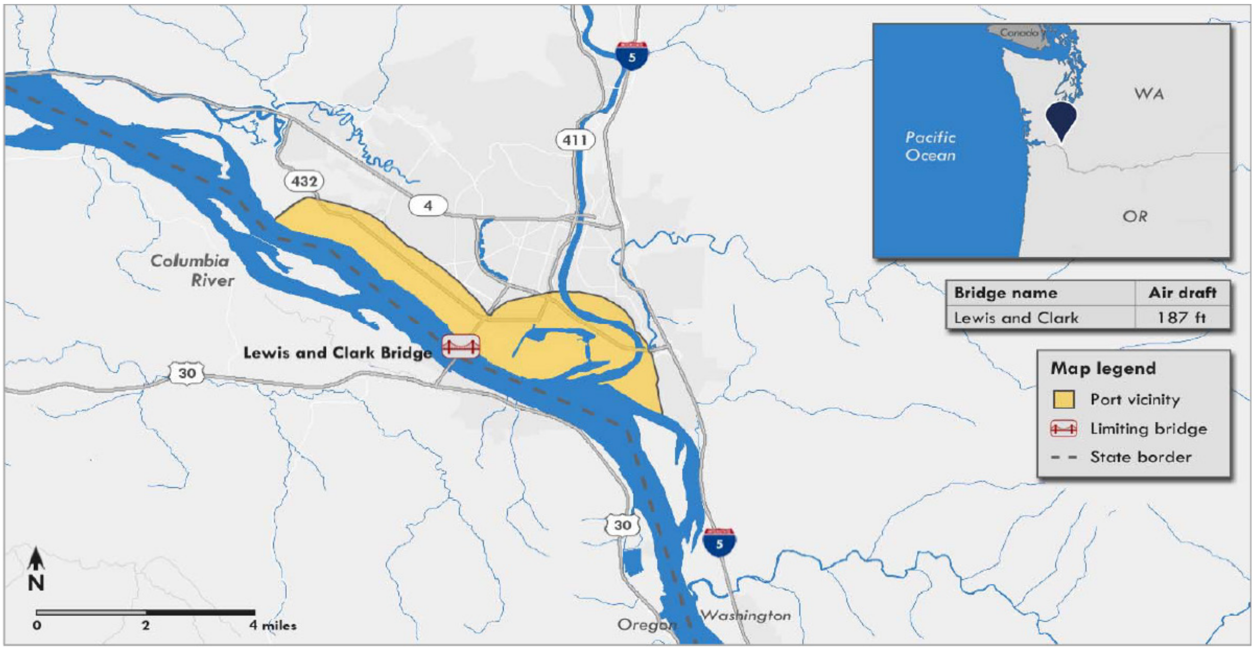

Figure A-27. Port of Longview, Washington, layout (BTS 2017).

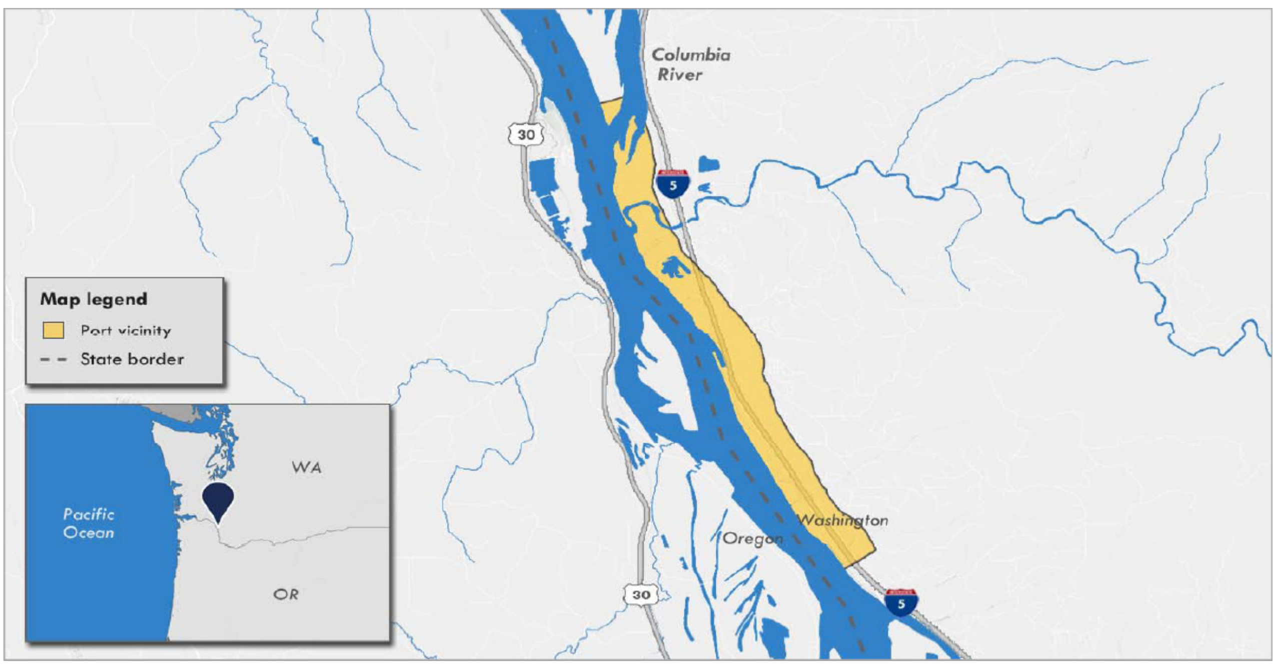

Figure A-28. Port of Vancouver, Washington, layout (BTS 2017).

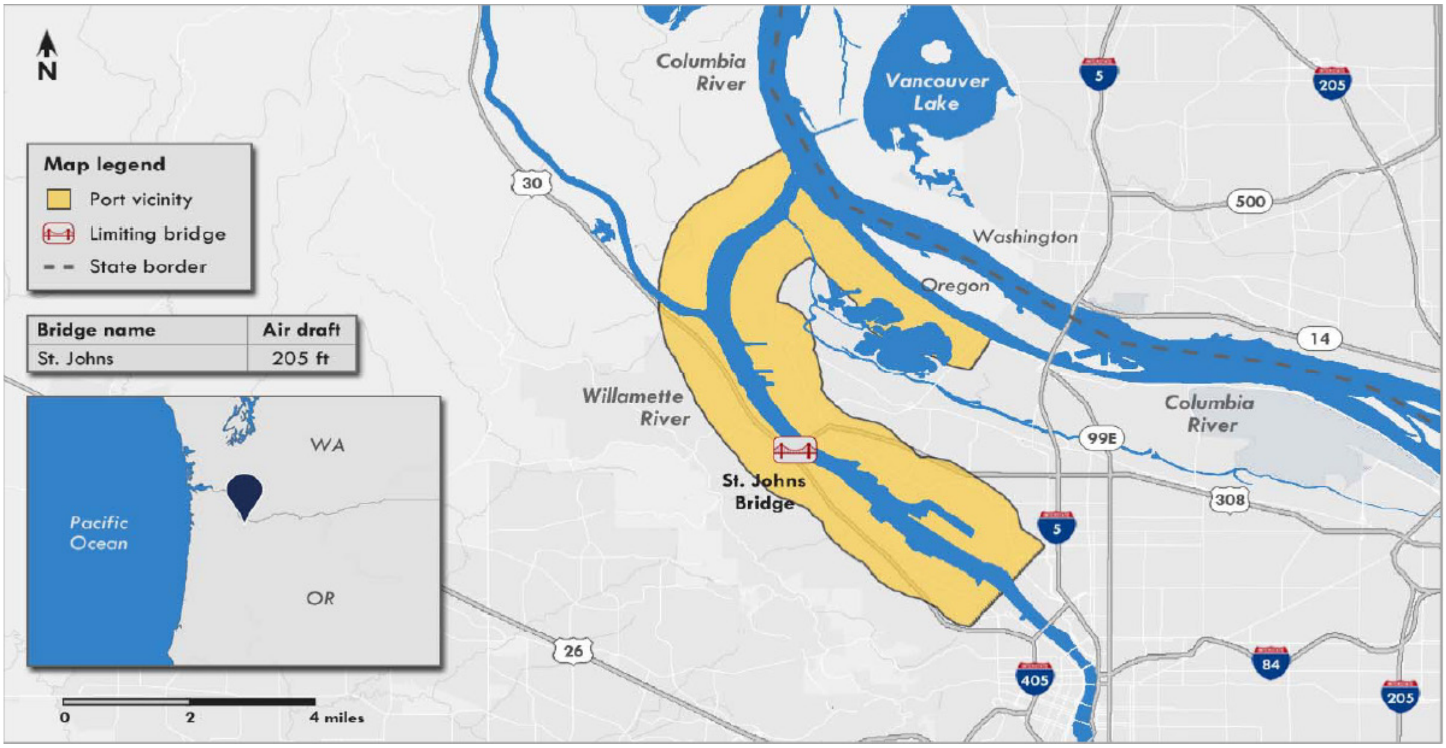

Figure A-29. Port of Portland, Oregon, layout (BTS 2017).

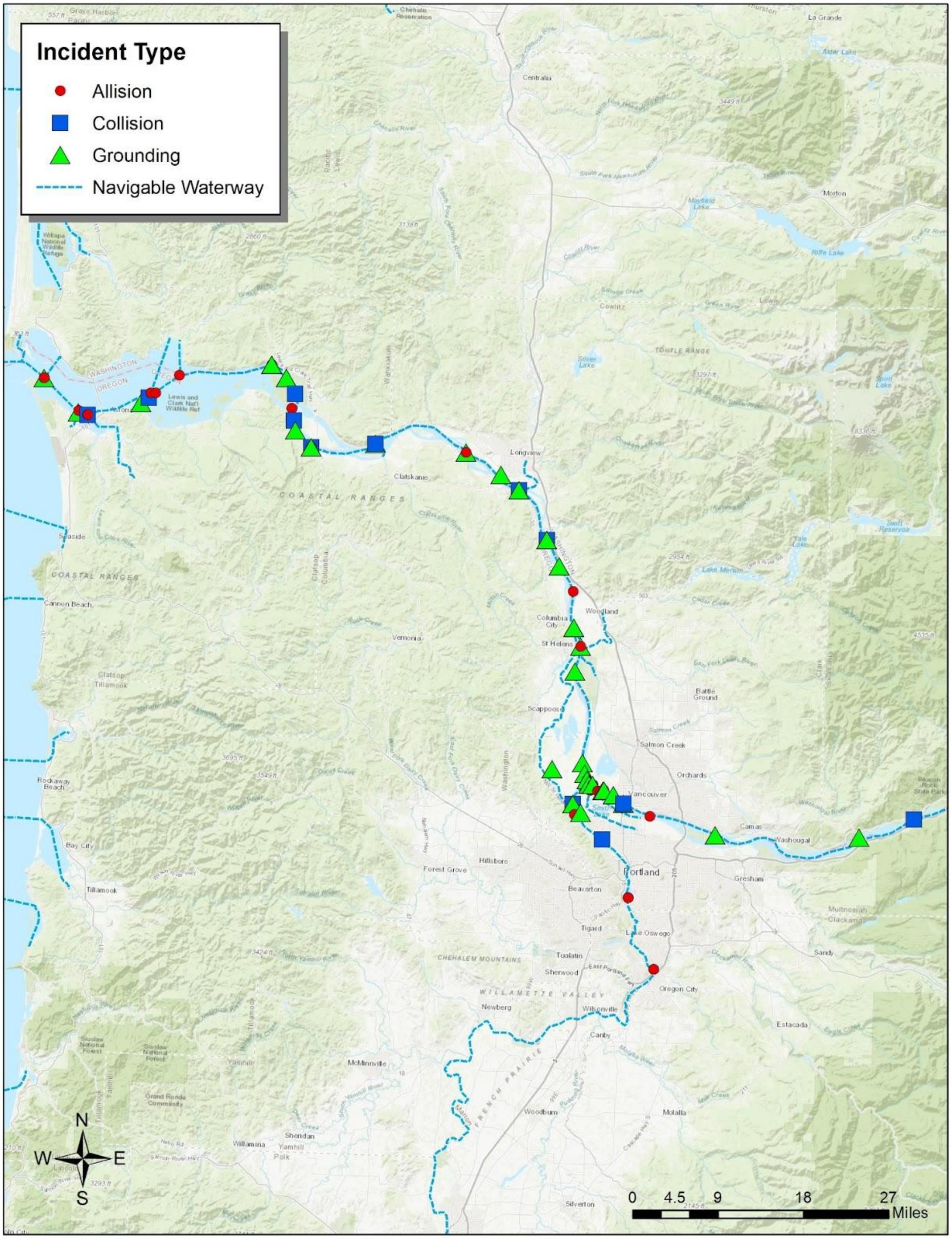

Figure A-30. Accident data for the Ports of the Columbia River.

Table A-8. Data for the Ports of the Columbia River.

Source[30]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[31] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**49,255,210**	**$20,992,170,945**	**25**	**2,869**	**14–43**	**588**	**367**
Astoria, OR	No Data	$49,098,562	4	327	37	11	1
Portland, Astoria, St. Helens, Longview, Vancouver and Kalama Area, Other Ports	No Data	No Data	5	18	39	8	8
Longview, WA	12,271,617	$2,733,205,375	No Data	611	43[32]	191	131
Kalama, WA	13,924,407	$3,547,629,965	8	402	43	120	84
Vancouver, WA	7,342,282	$4,177,665,567	1	613	43	88	51
Columbia River, WA (Port of Portland)	15,716,904	$10,484,571,476	7	886	43	164	88
Columbia River below Vancouver and Portland	No Data	No Data	No Data	12	14	6	4

A good candidate for Precision Navigation because:

Ports along the Columbia River had many safety incidents and vessels traveling close to the maximum draft allowance. These indicators suggest that Precision Navigation's implementation would lead to safer navigation and less congestion along the Columbia River, as well as more economic activity from ships being able to increase their cargo capacity.

[30] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[31] USACE Channel Project Summary Data used for Columbia River, WA (port of Portland).

[32] Declared drafts for Longview and Kalama found on port websites: *https://portofkalama.com/marine-terminals/*, http://www.portoflongview.com/180/Marine-Terminals.

Port Profile (8): Port of Virginia

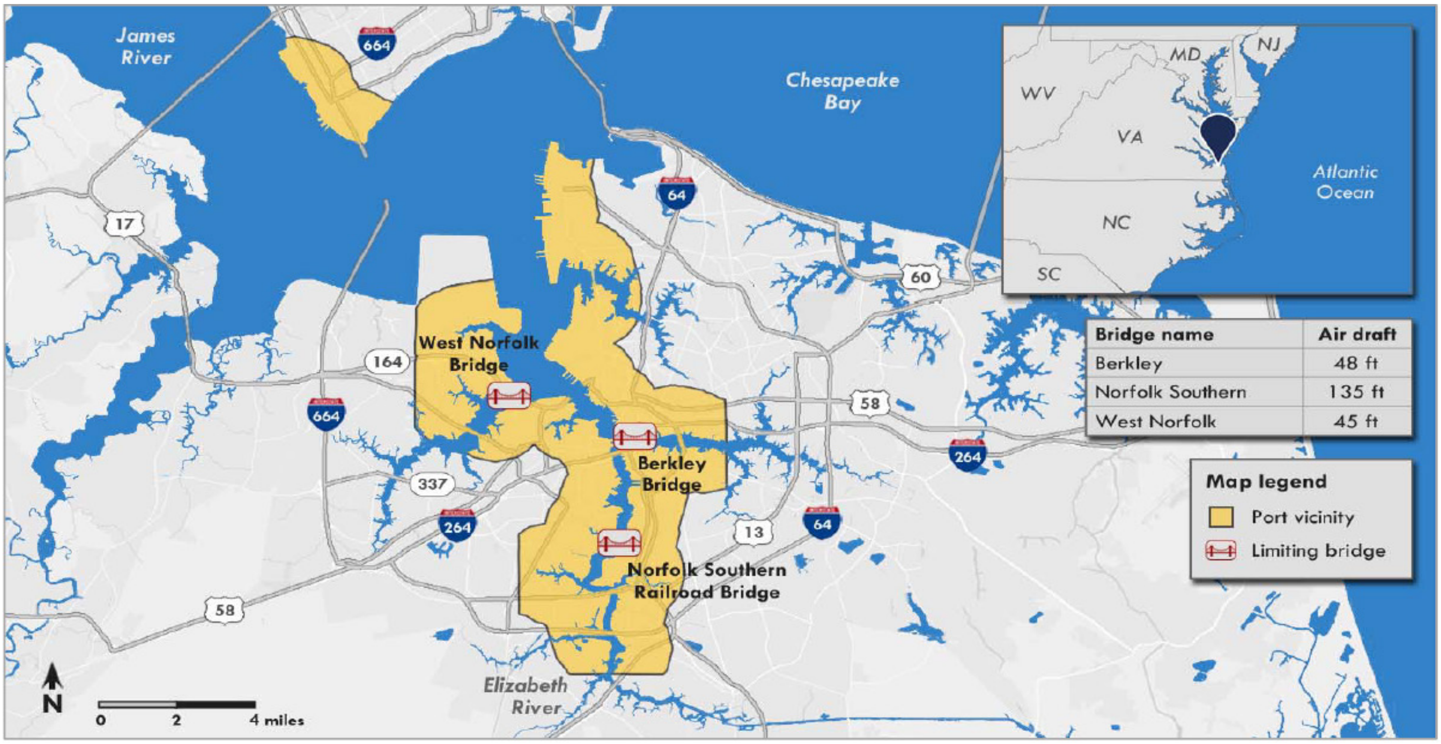

Figure A-31. Port of Virginia layout (BTS 2017).

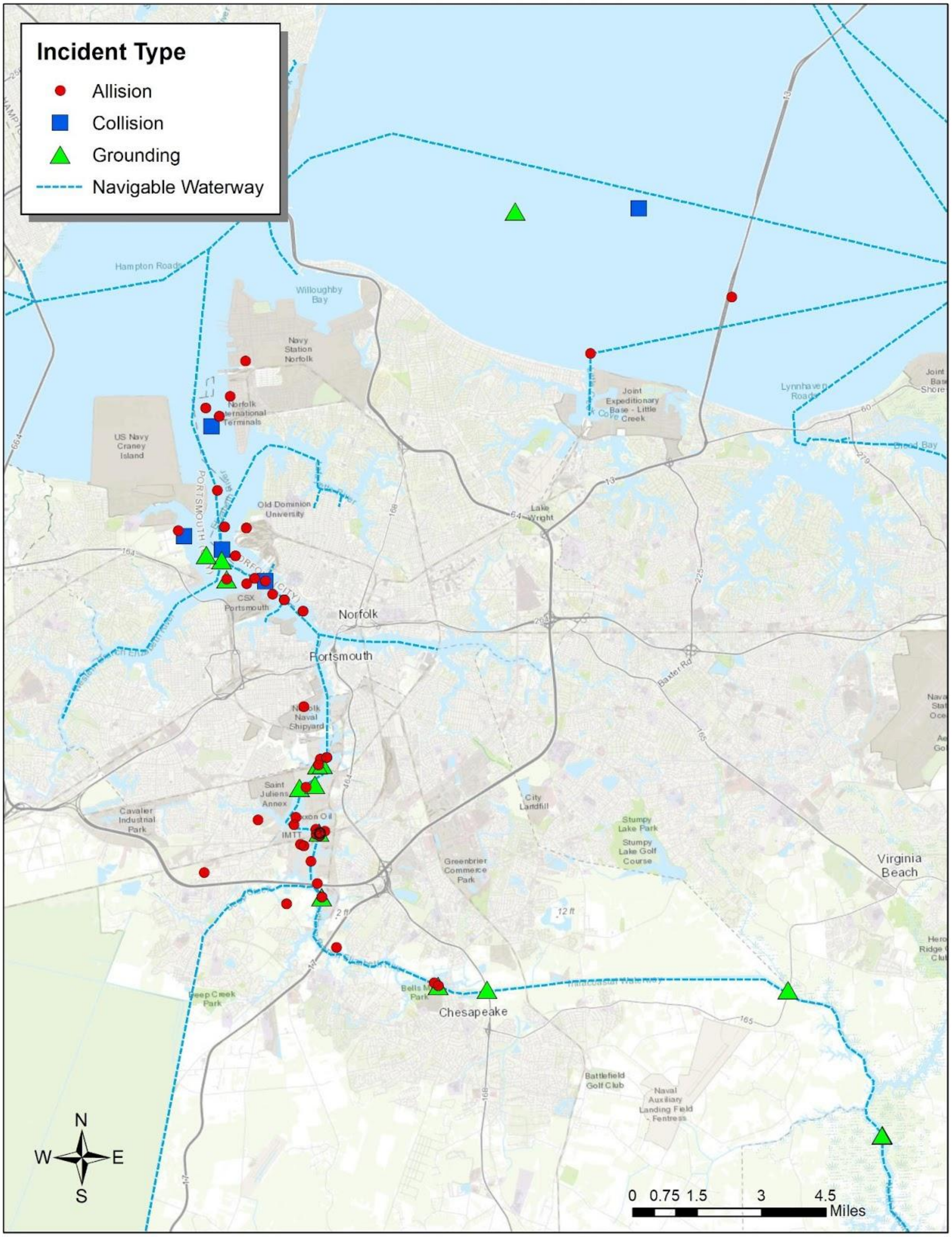

Figure A-32. Accident data for the Port of Virginia.

Table A-9. Data for the Port of Virginia.

Source[33]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[34]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**61,659,223**	**$72,946,152,057**	**61**	**4,051**	**50**	**136**	**24**
Elizabeth River (Southern Branch), VA	No Data	No Data	16	384	50	1	1
Elizabeth River (Eastern Branch), VA	No Data	No Data	26	6	50	0	0
Elizabeth River, VA	No Data	No Data	18	3,661	50	135	23
Port of Virginia	61,659,223	$72,946,152,057	No Data	No Data	No Data	No Data	No Data
Elizabeth River (Western Branch), VA	No Data	No Data	1	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

The Port of Virginia ranked high for number of safety incidents as well as tonnage and import/export value. These factors indicate that Precision Navigation would lead to safer navigation into port, and increases in traffic efficiency or draft allowance would result in high economic gains.

[33] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[34] Used Declared Draft Allowance found on Port of Virginia website: *http://www.portofvirginia.com/about/fast-facts/*

Port Profile (9): Port of Long Beach, California

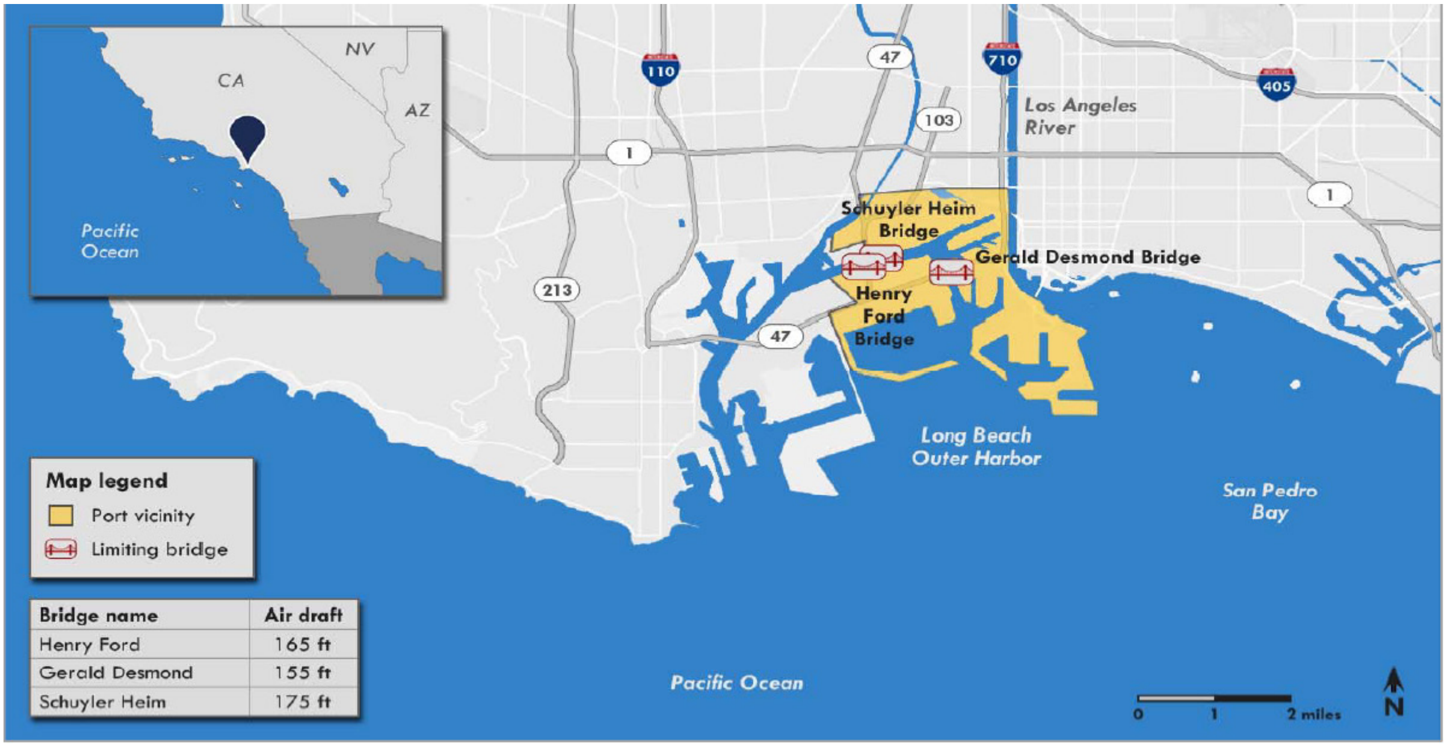

Figure A-33. Port of Long Beach, California, layout (BTS 2017).

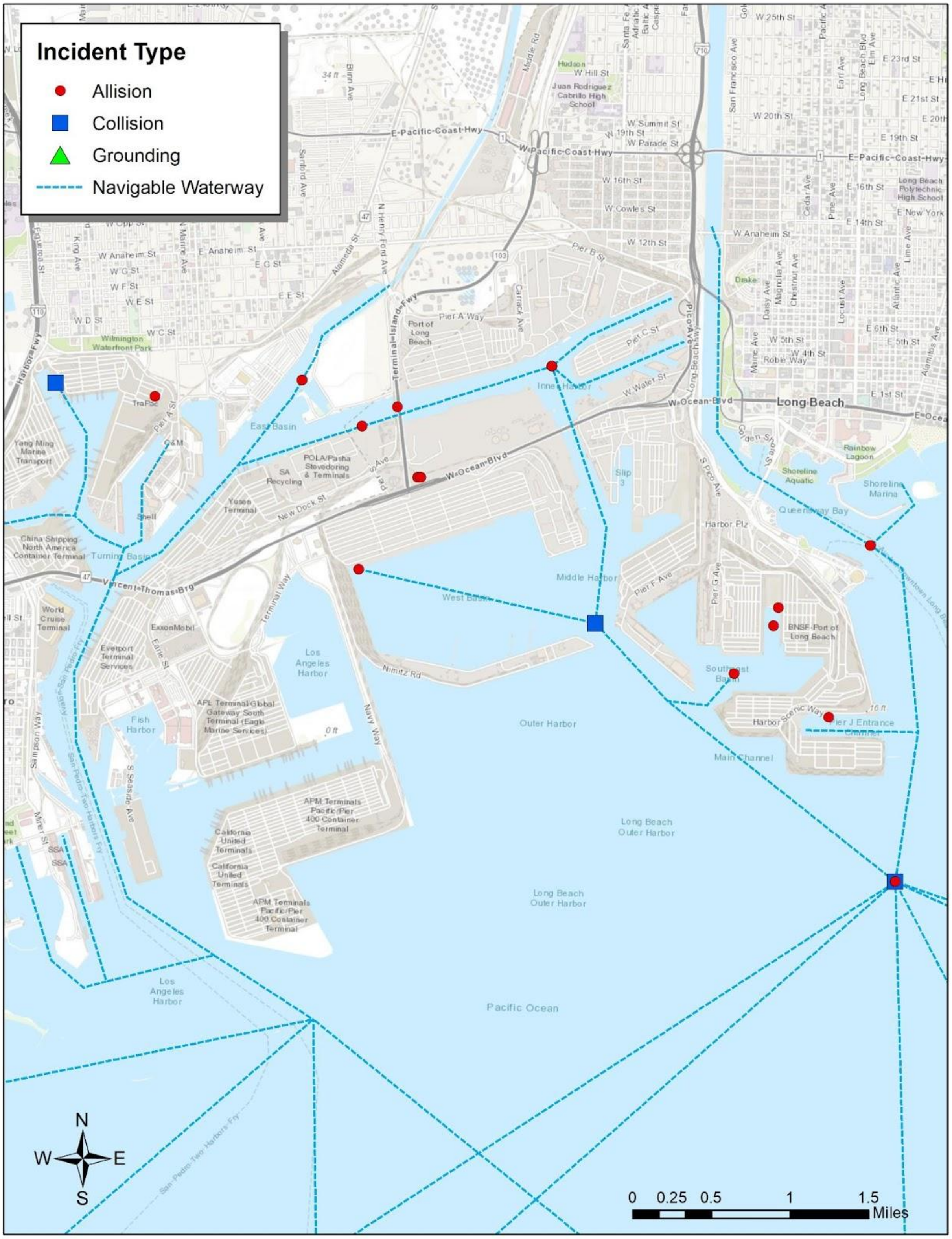

Figure A-34. Accident data for the Port of Long Beach, California.

Table A-10. Data for the Port of Long Beach, California.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[35]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Long Beach, CA	**74,169,681**	**$99,896,578,633**	**15**	**4,419**	**76**	**18**	**0**

Current Technology and Port Characteristics

The Port of Long Beach has many vessel types traveling in and out of port, including large oil tankers with deep drafts. While the port does not have many major safety concerns, navigational technology has played a crucial role in developing pilots' ability to more efficiently and confidently travel through the port.

Pilots at Long Beach have used PPUs since they were first developed to help understand port conditions and optimize go–no-go decision-making, although not all vessels and trips require such technology at this port. More recently, pilots have been using SeaIQ's PPUs and oil tankers have utilized NOAA's pilot program for precision navigation to allow wider ships and ships with larger drafts to come into port more easily.

Draft used to be restricted to 65 feet due to swells and roll and pitch. But precision navigation has allowed for the draft allowance to increase to 69 feet, which has resulted in oil tankers being able to increase the amount of oil loaded onto each vessel.

A good candidate for Precision Navigation because:

Precision Navigation was already implemented at Long Beach and the draft allowance increased from 65 feet to 69 feet, which led to over $10 million saved by shippers (NOAA 2017). Although only a small number of deep draft oil tankers (representing a small portion of overall port traffic) are currently using precision navigation, the resulting efficiency and increase in oil capacity has led to large economic gains in a short time period since the implementation of precision navigation.

[35] USACE Channel Project Summary Data used.

Port Profile (10): Ports of Puget Sound

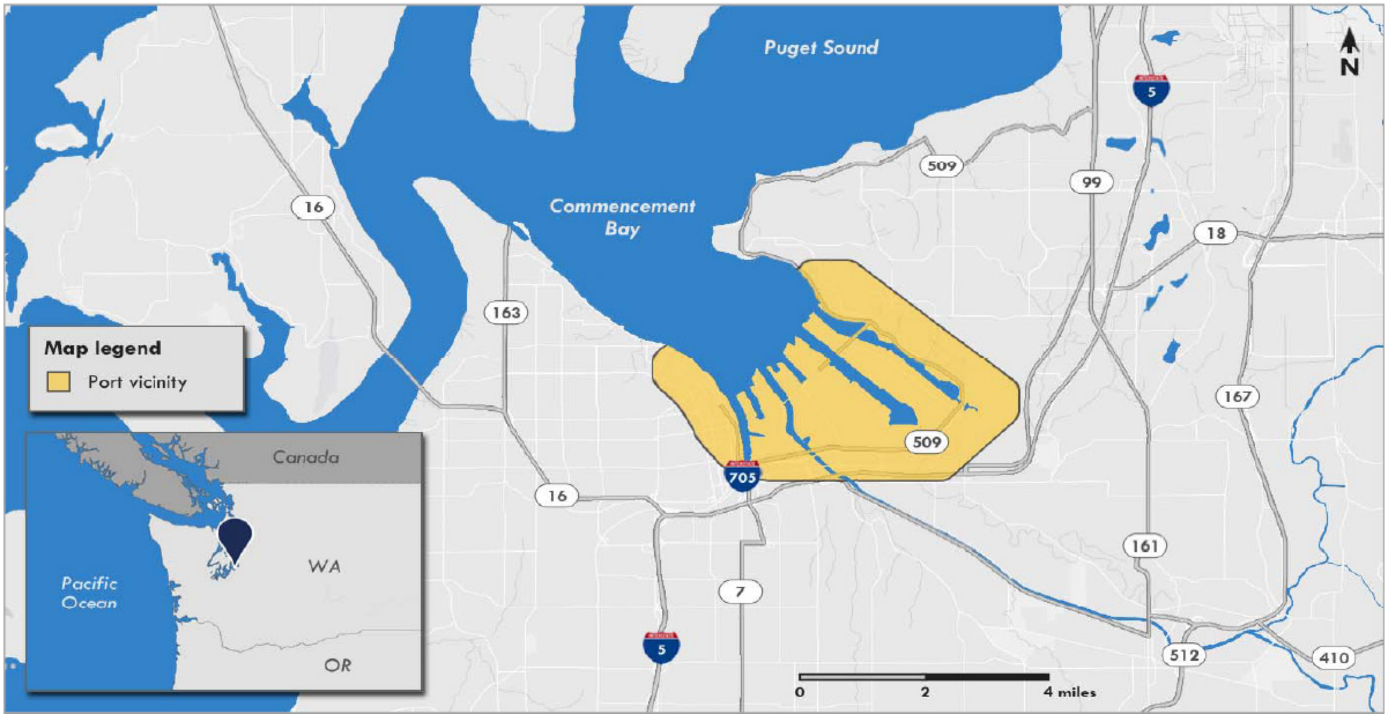

Figure A-35. Port of Seattle, Washington, layout (BTS 2017).

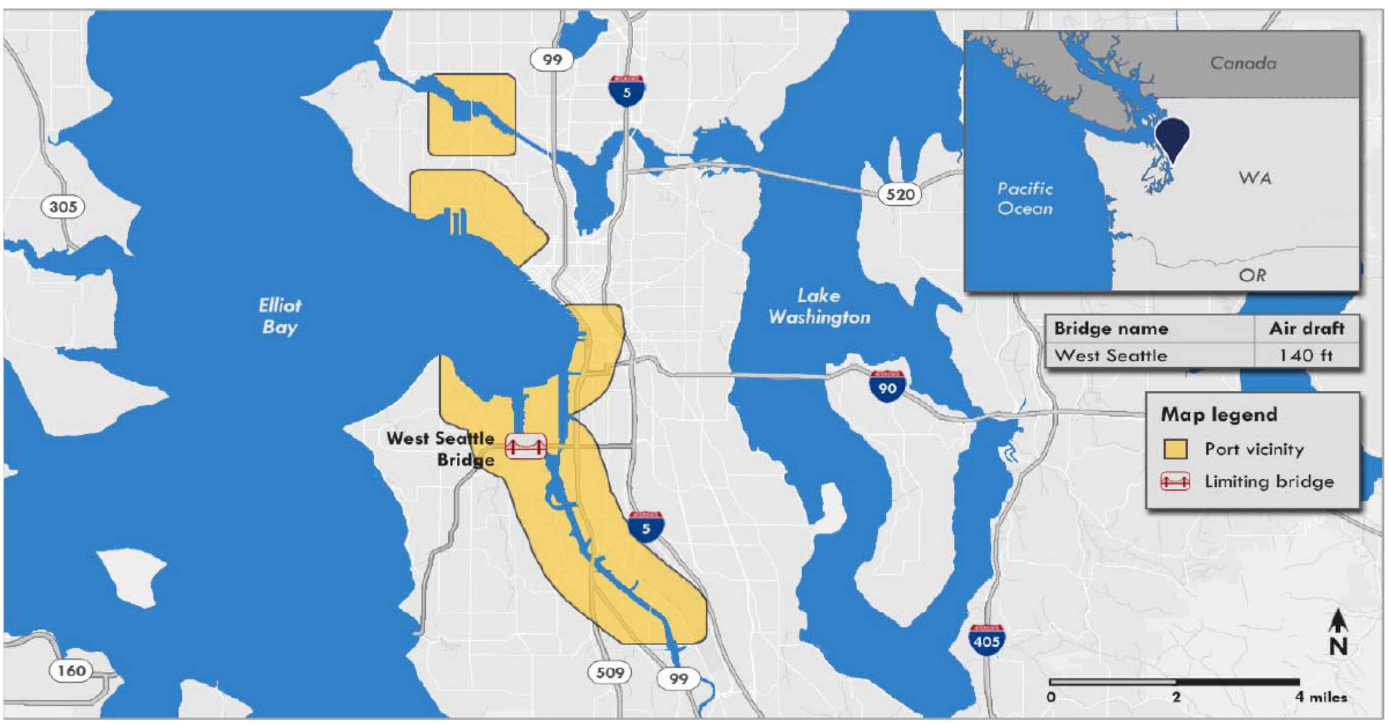

Figure A-36. Port of Tacoma, Washington, layout (BTS 2017).

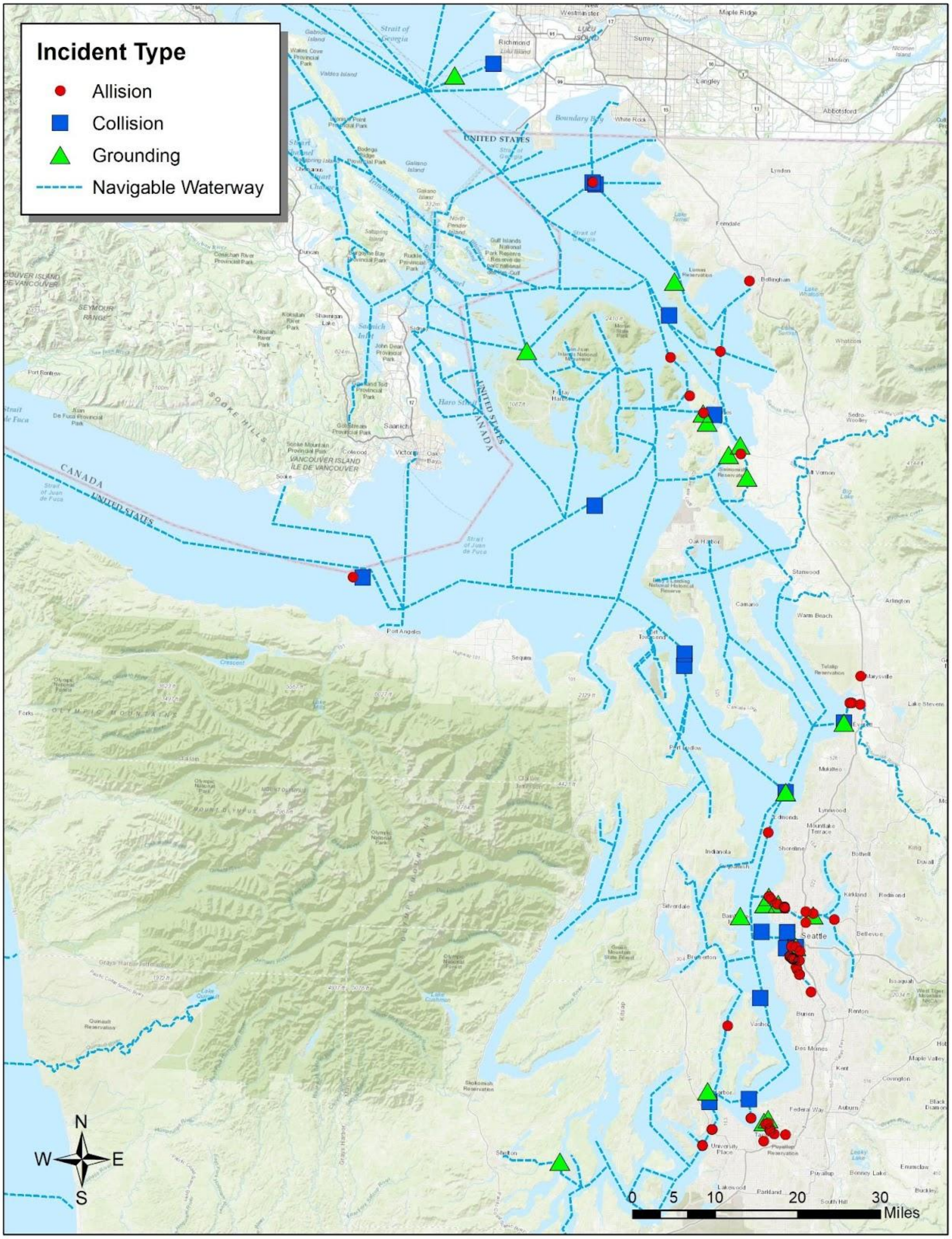

Figure A-37. Accident data for the Ports of Puget Sound, Washington.

Table A-11. Data for the Ports of Puget Sound, Washington.

Source[36]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[37] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**42,913,278**	**$79,995,689,241**	**1**	**7,501**	**33-51**	**61**	**11**
Port Angeles, WA	640,778	$90,722,020	No Data	275	43	7	1
Port Townsend, WA	No Data	$1,644,303	No Data	16	23	1	1
Olympia, WA	634,815	$119,141,707	No Data	42	35	19	3
Tacoma, WA	19,480,844	$50,221,167,996	No Data	2,253	51	1	0
Seattle, WA	19,403,707	$25,024,237,436	1	3,340	51	3	0
Everett, WA	525,681	$1,351,180,353	No Data	346	40	1	1
Anacortes, WA	2,227,453	$1,002,444,169	No Data	494	47	9	1
Bellingham, WA	No Data	$1,489,255,703	No Data	65	33	4	2
Puget Sound Area, WA, Other Ports	No Data	No Data	No Data	670	48	16	2
Blaine, WA	No Data	$695,895,554	No Data	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

The ports in the Puget Sound area ranked high for total tonnage, import/export value, and number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as a large increase in economic activity.

[36] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[37] USACE Channel Project Summary Data used for Tacoma and Seattle.

Port Profile (11): Ports of the Bay Area, California

Figure A-38. Port of Oakland, California, layout (BTS 2017).

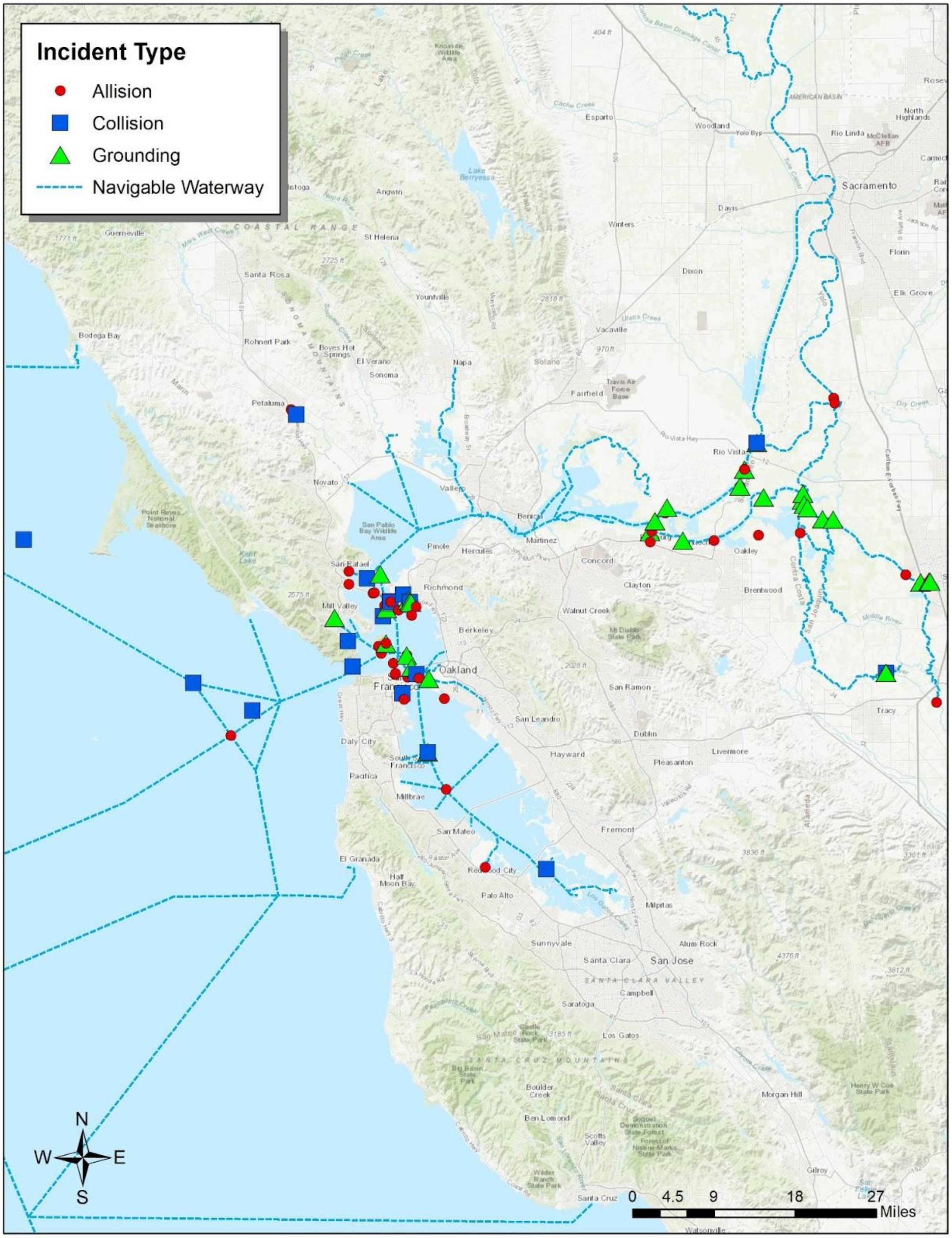

Figure A-39. Accident data for the Ports of the Bay Area, California.

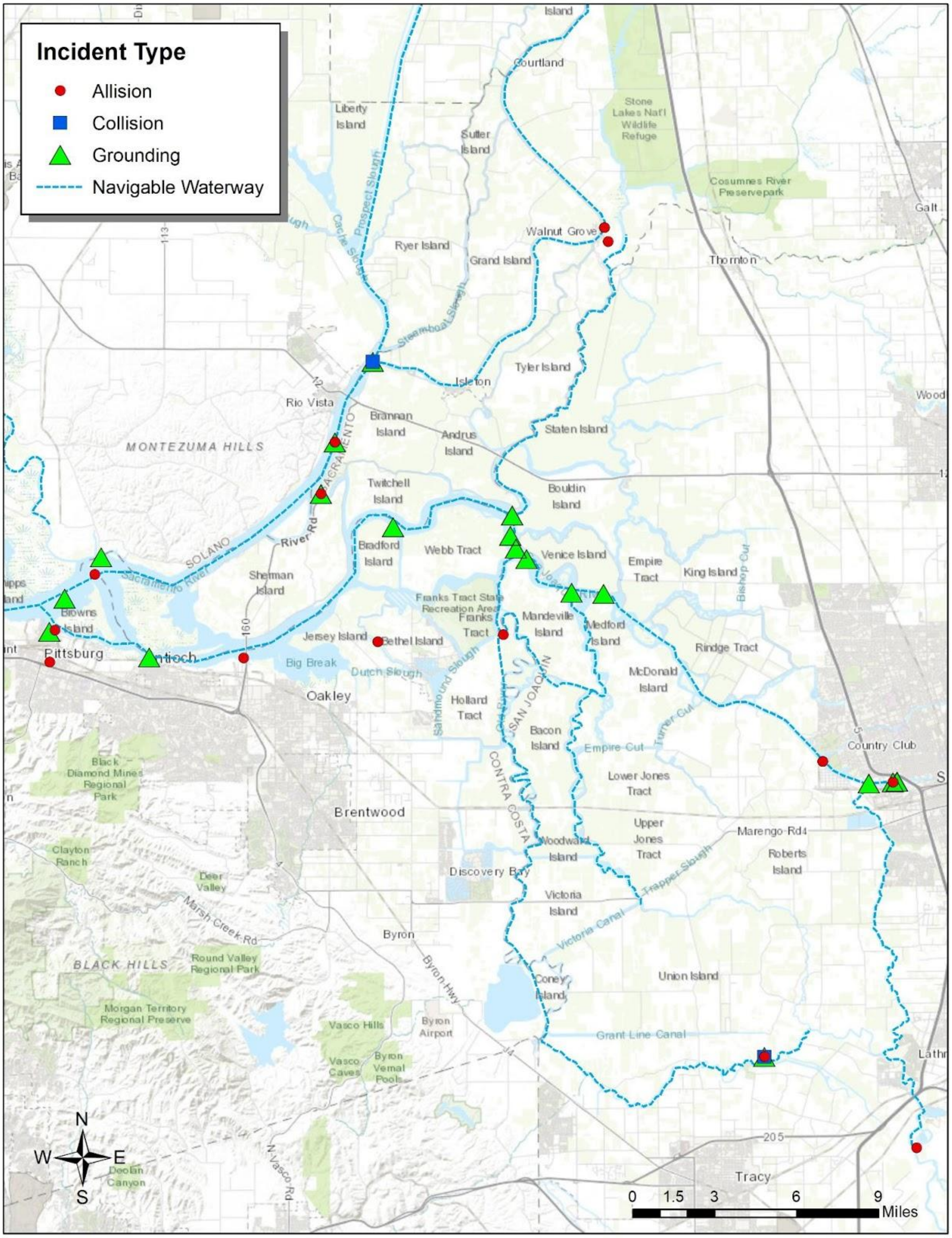

Figure A-40. Accident data for the inland Ports of the Bay Area, California.

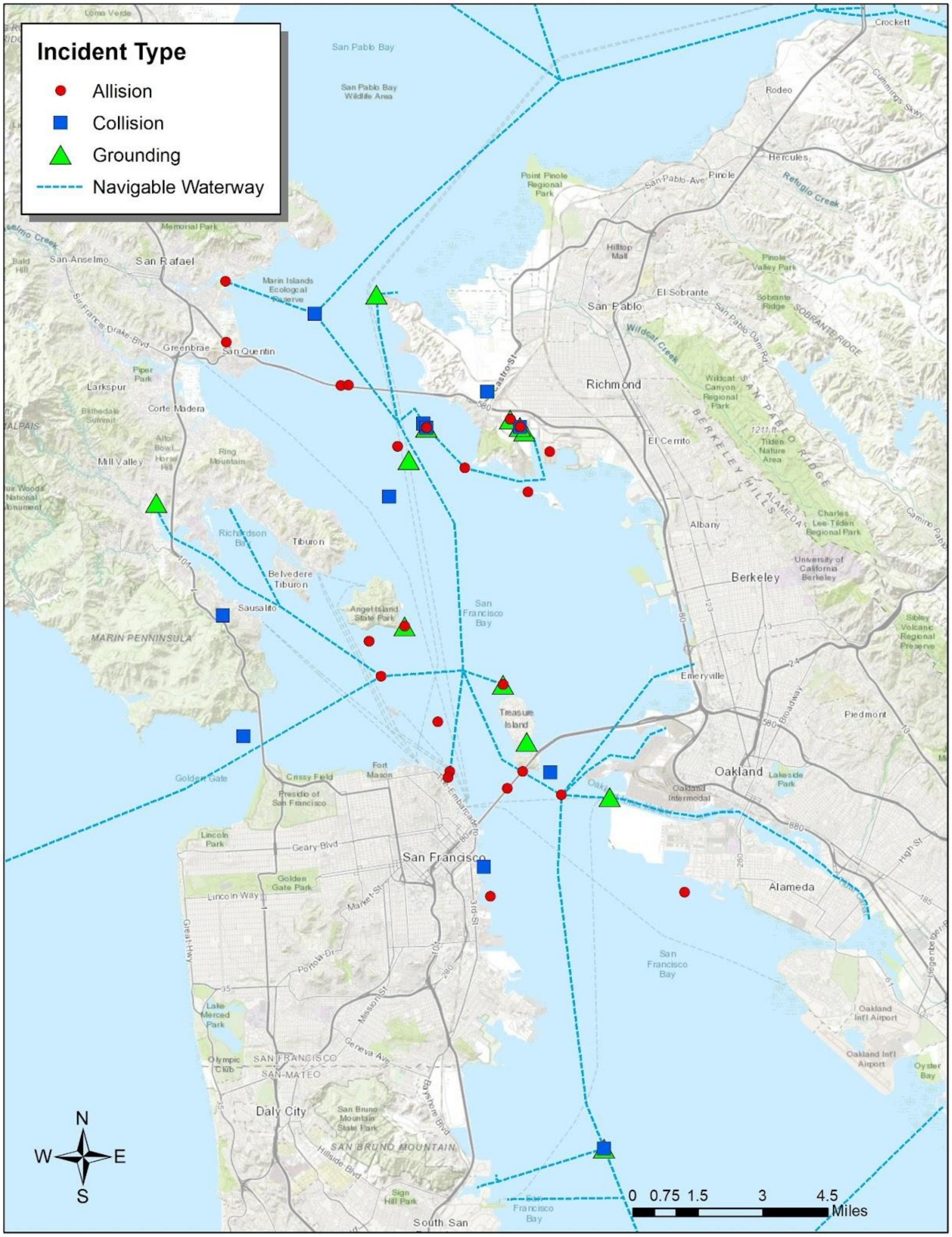

Figure A-41. Accident data for the Ports of San Francisco and Oakland, California.

Table A-12. Data for the Ports of the Bay Area, California.

Source[38]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[39] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**44,140,875**	**$69,218,319,089**	**22**	**5,615**	**38–52**	**139**	**36**
San Joaquin River, CA	No Data	$30,313,104	No Data	95	35	37	11
Stockton, CA	5,029,264	$932,779,681	2	431	40	16	6
San Francisco, CA	1,108,480	$4,382,428,841	No Data	236	44	6	3
Redwood City, CA	2,006,835	$39,303,727	1	68	38	18	11
Oakland, CA	17,272,538	$47,789,592,990	5	2,943	50	7	0
Richmond, CA	18,723,758	$8,595,486,529	14	884	49	17	1
San Pablo Bay, CA	No Data	$23,552,251	No Data	113	39	37	3
Carquinez Strait, CA	No Data	$3,370,983,428	No Data	845	52	1	1
Crockett, CA	No Data	$261,348,364	No Data	No Data	No Data	No Data	No Data
Martinez, CA	No Data	$3,512,107,382	No Data	No Data	No Data	No Data	No Data
Selby, CA	No Data	$280,422,792	No Data	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

The Ports of the Bay Area ranked high for total tonnage, import/export value, and number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as a large increase in economic activity.

[38] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[39] USACE Channel Project Summary Data used for Stockton and Oakland.

Port Profile (12): Ports of the Delaware River

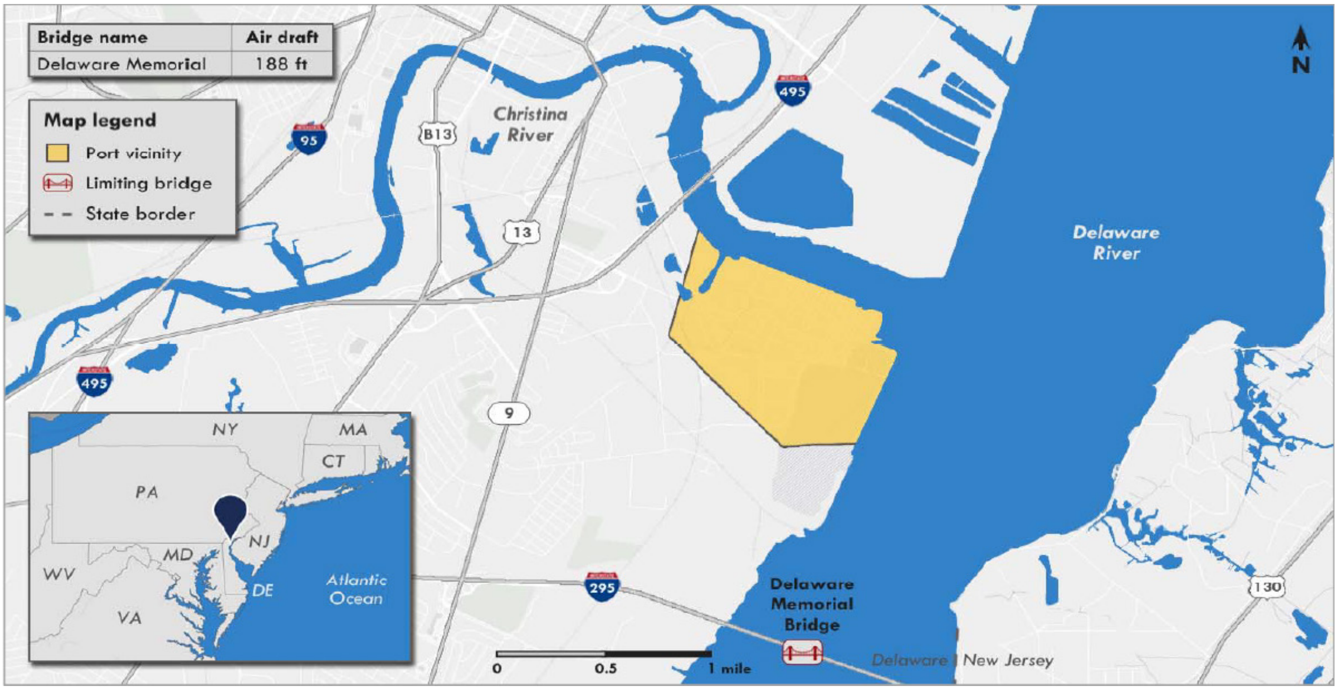

Figure A-42. Port of Wilmington, DE Layout (BTS 2017)

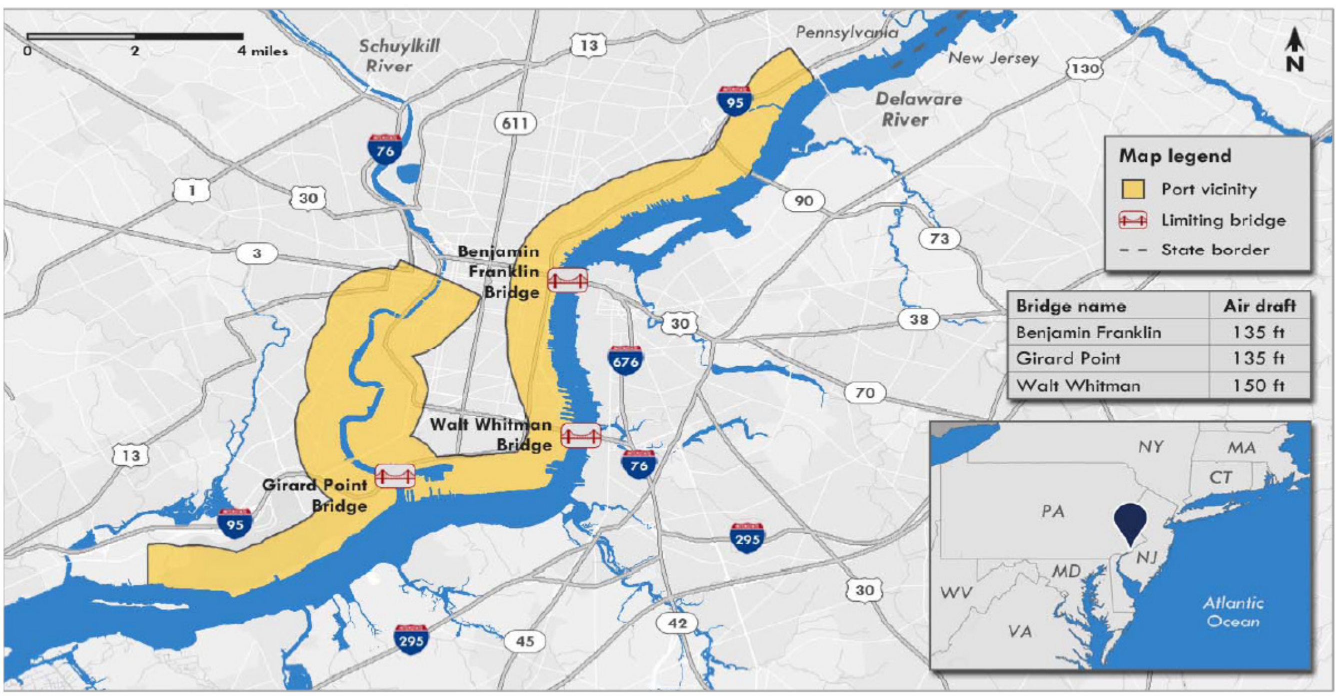

Figure A-43. Port of Philadelphia, Pennsylvania, layout (BTS 2017).

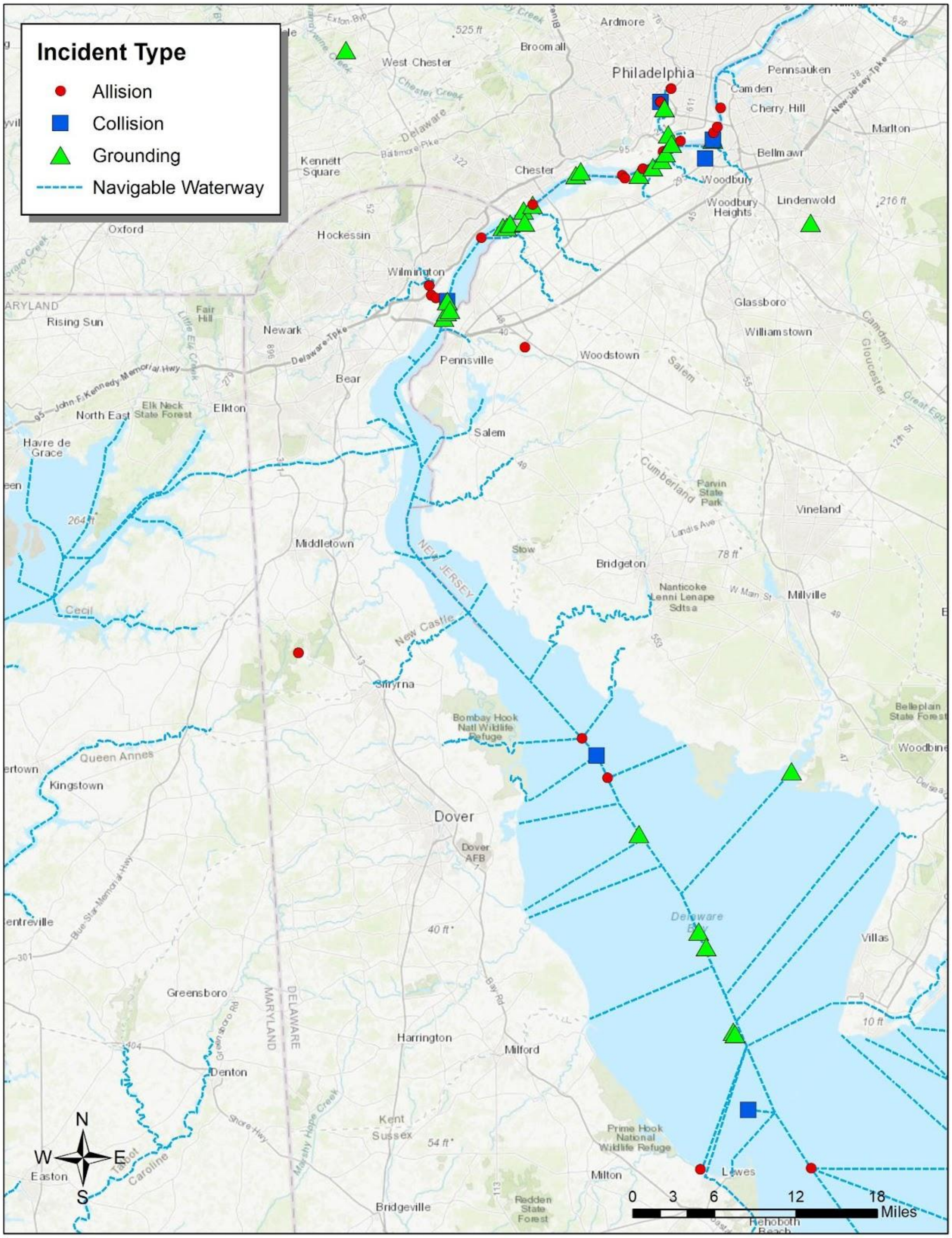

Figure A-44. Accident data for the Ports of the Delaware River.

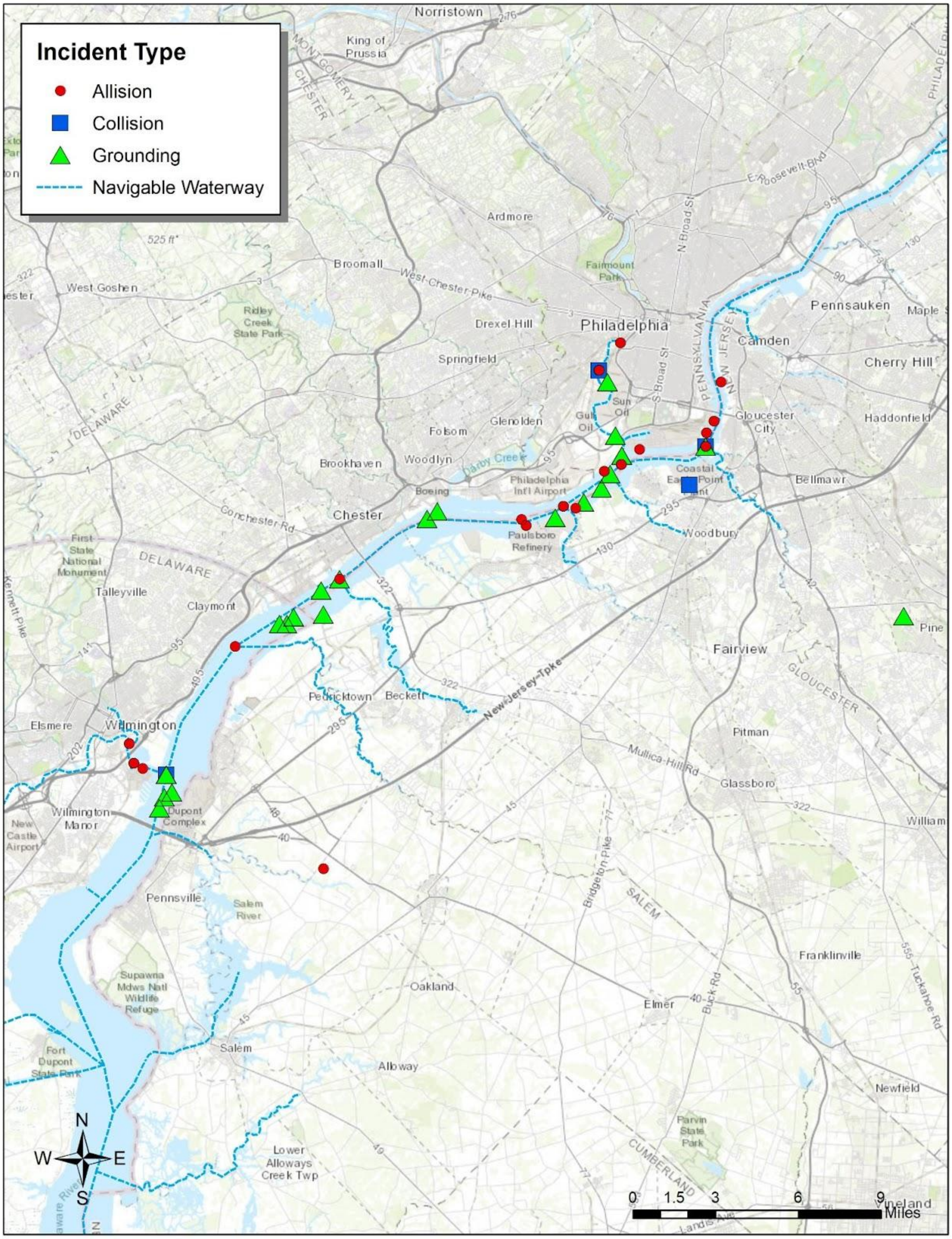

Figure A-45. Accident data for the inland Ports of the Delaware River.

Table A-13. Data for the Ports of the Delaware River.

Source[40]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[41] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**53,057,758**	**$43,908,247,452**	**39**	**4,325**	**41–54**	**128**	**47**
Chester, PA	2,137,855	$9,030,921,216	5	322	46	1	1
New Castle, DE	3,617,738	No Data	No Data	91	46	2	1
Camden, NJ	4,620,674	$126,915,192	19	661	41	42	5
Philadelphia, PA	16,291,954	$22,560,954,764	10	1,584	45	20	6
Delaware River/ Wilmington, DE	5,636,778	$11,366,639,916	1	721	45	0	0
Marcus Hook, PA	8,914,556	No Data	No Data	366	46	27	21
Paulsboro, NJ	11,838,203	$822,816,364	3	483	46	13	11
Lower Delaware Bay, DE	No Data	No Data	1	97	54	23	2
Lower Delaware Bay, NJ	No Data	No Data	No Data	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

The ports along the Delaware River ranked high for total tonnage and import/export value, number of safety incidents, and number of vessel calls. This indicates that Precision Navigation could lead to an increase in navigational safety, improvement in traffic conditions and congestion, and a large increase in economic activity.

[40] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[41] USACE Channel Project Summary Data used for Philadelphia and Delaware River/Wilmington, DE.

Port Profile (13): Port of Charleston, South Carolina

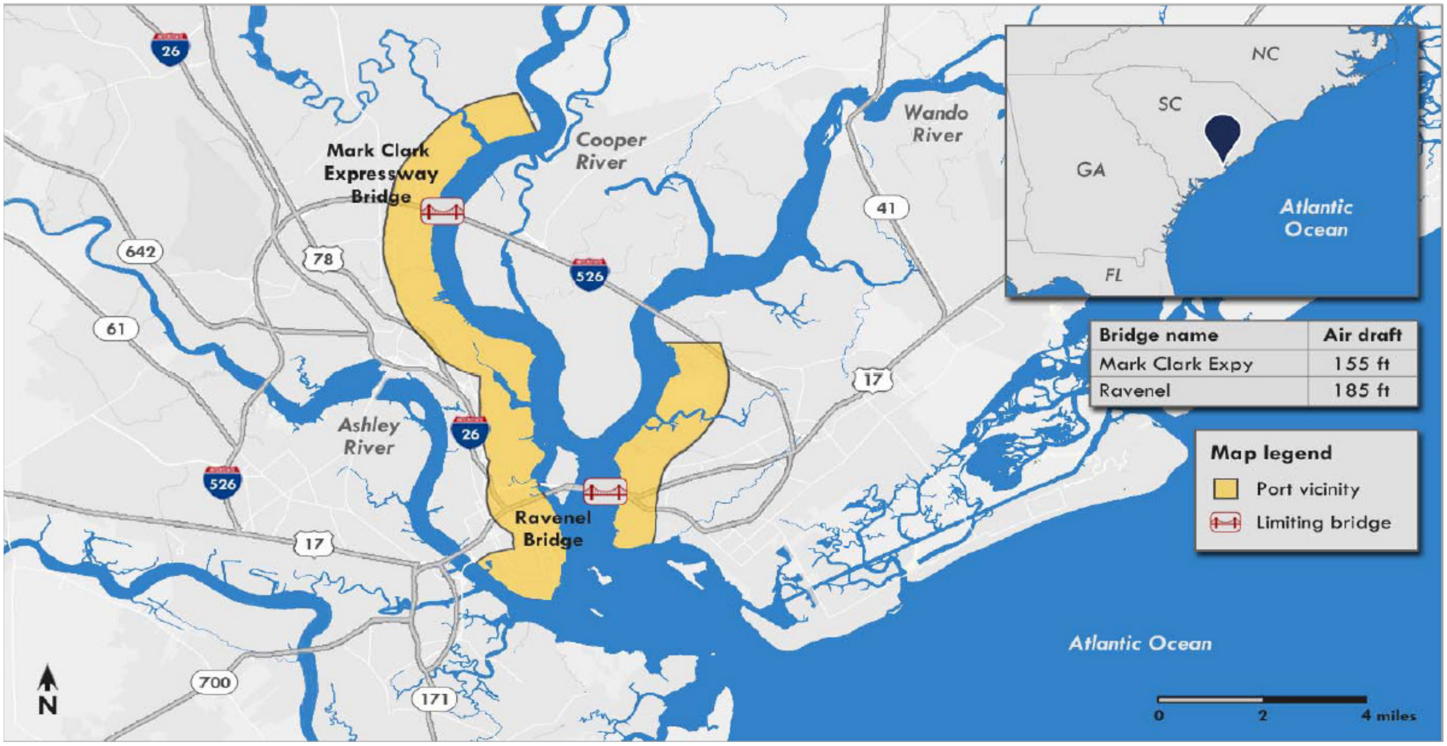

Figure A-46. Port of Charleston, South Carolina, layout (BTS 2017).

Figure A-47. Accident data for the Port of Charleston, South Carolina.

Table A-14. Data for the Port of Charleston, South Carolina.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[42]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Charleston, SC	24,800,841	$69,750,643,504	5	3,979	45	426	28

A good candidate for Precision Navigation because:

The Port of Charleston ranked high for total tonnage and import/export value, as well as the number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as a large increase in economic activity.

[42] USACE Channel Project Summary Data used.

Port Profile (14): Port of Baltimore, Maryland

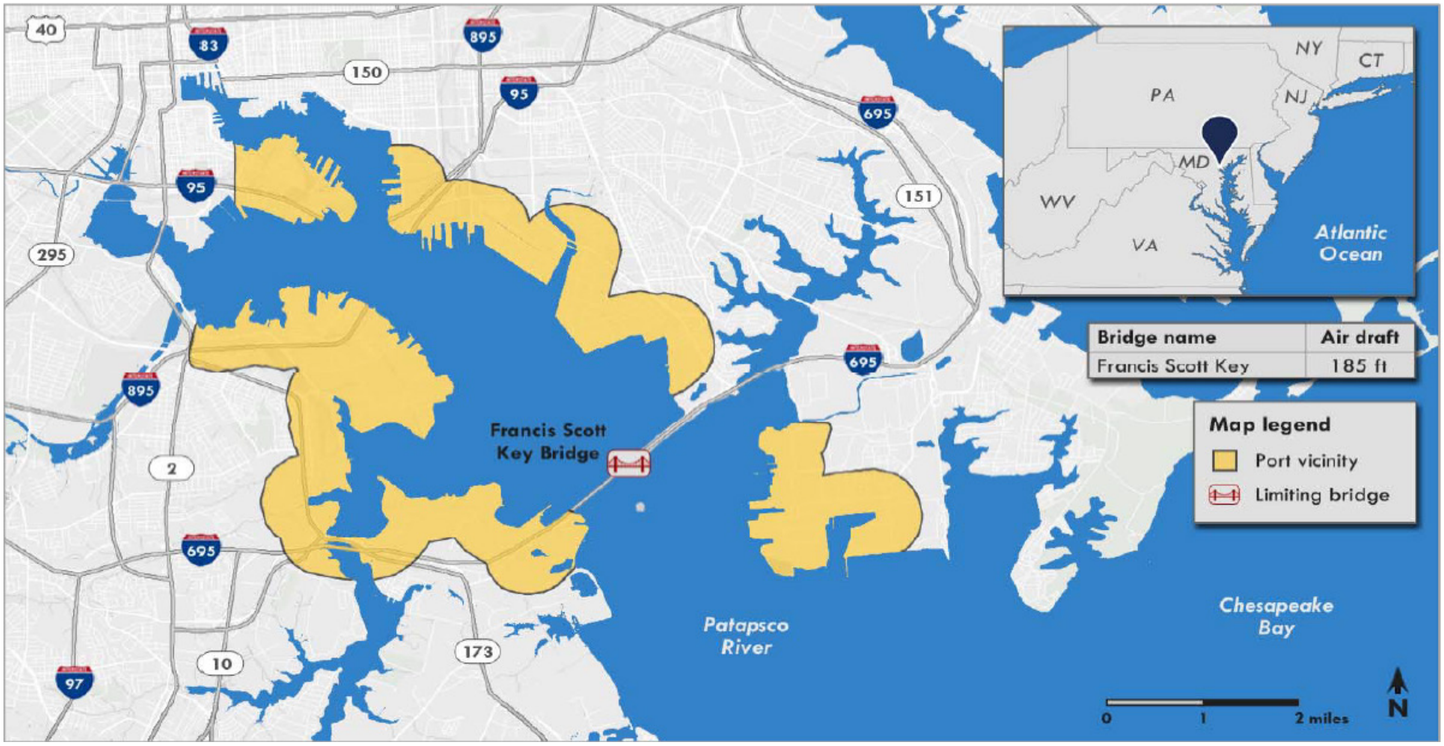

Figure A-48. Port of Baltimore, Maryland, layout (BTS 2017).

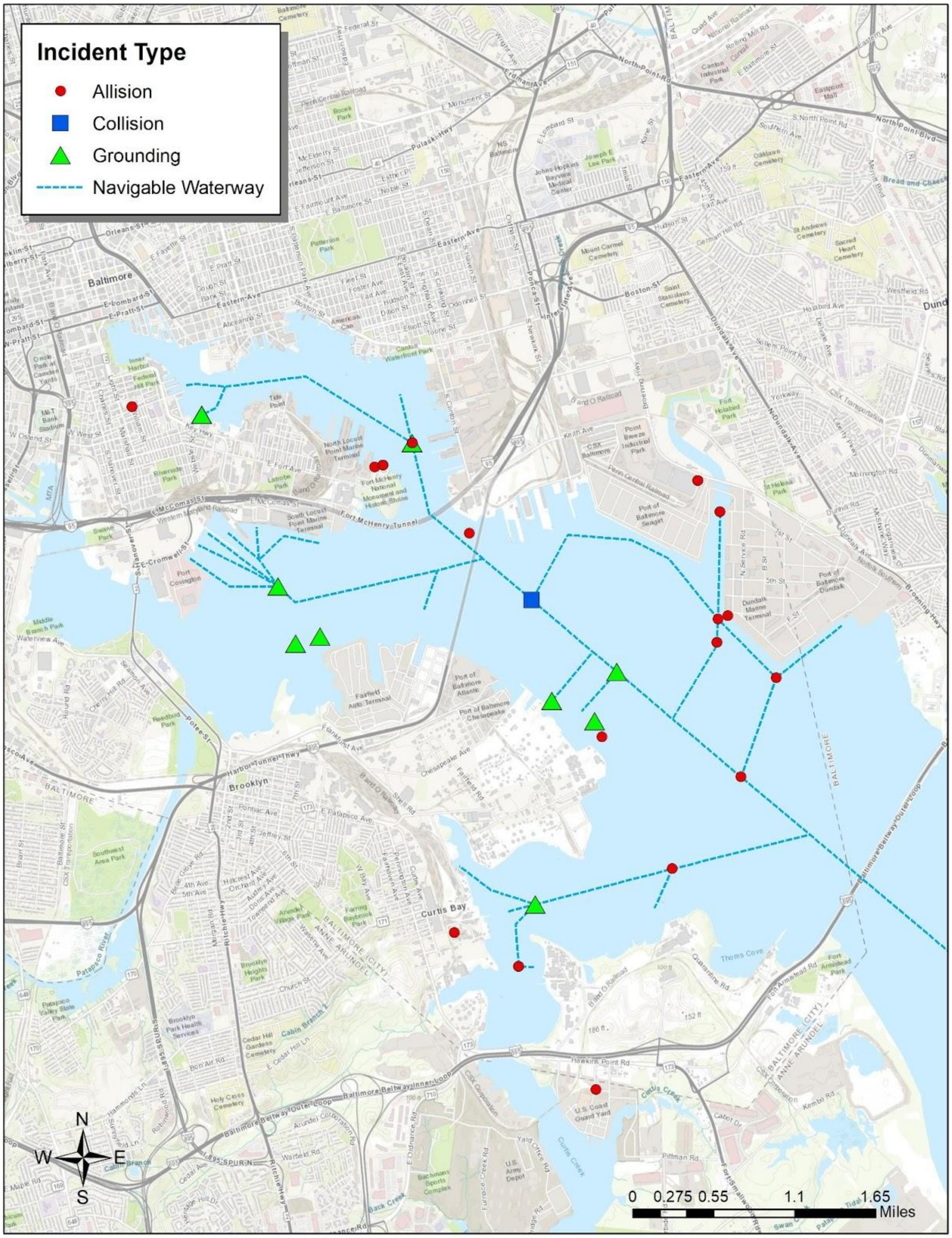

Figure A-49. Accident data for the Port of Baltimore, Maryland.

Table A-15. Data for the Port of Baltimore, Maryland.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[43]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Baltimore, MD	38,936,357	$53,942,441,301	10	3,899	50	192	1

A good candidate for Precision Navigation because:

The Port of Baltimore ranked high for total tonnage and import/export value, as well as the number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as a large increase in economic activity.

43 USACE Channel Project Summary Data used for Houston, Texas City, Freeport, and Galveston Bay.

Port Profile (15): Port of Jacksonville, Florida

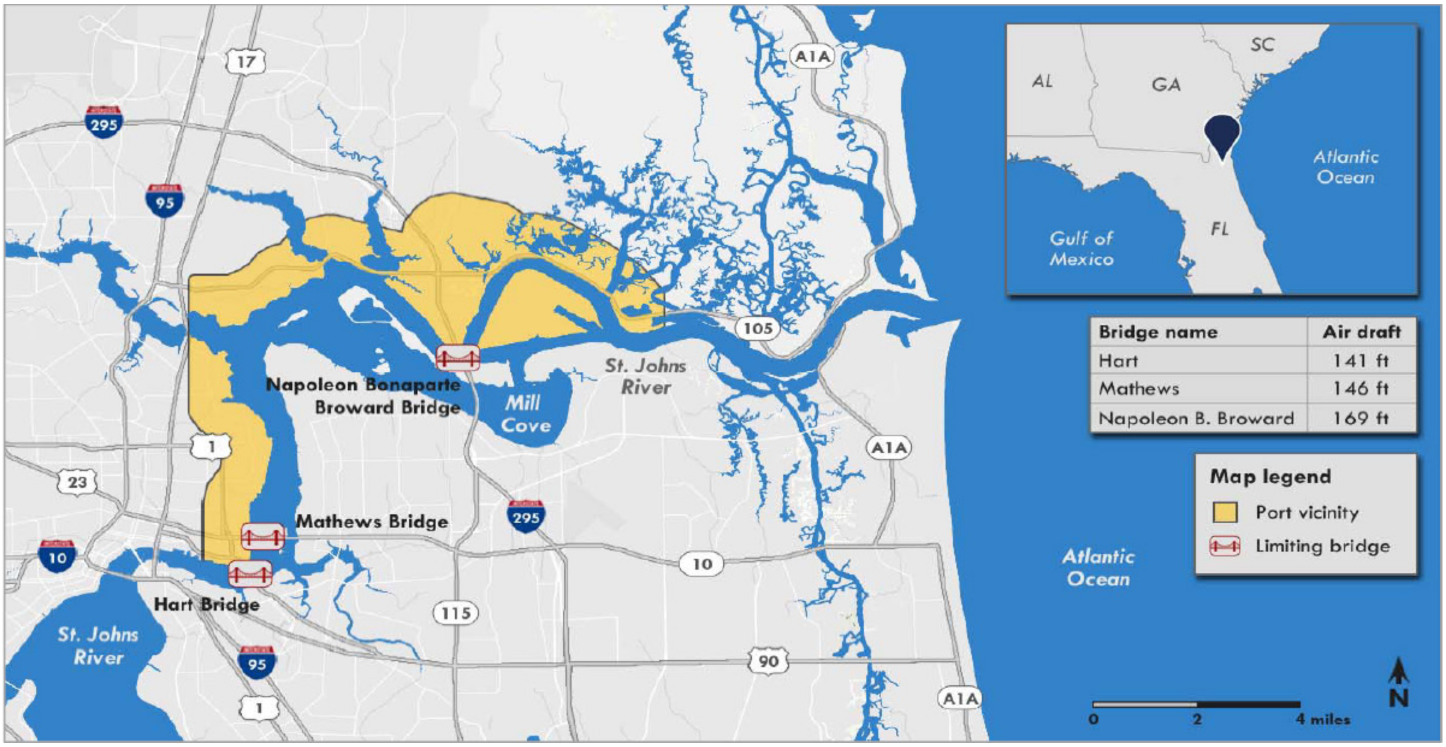

Figure A-50. Port of Jacksonville, Florida, layout (BTS 2017).

Figure A-51. Accident data for the Port of Jacksonville, Florida.

Table A-16. Data for the Port of Jacksonville, Florida.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[44]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Jacksonville, FL	**11,256,894**	**$25,321,698,323**	**15**	**2,948**	**40**	**516**	**116**

A good candidate for Precision Navigation because:

The Port of Jacksonville, Florida, ranked high for total number of vessel calls and vessel calls close to the maximum draft allowance. This indicates that Precision Navigation could lead to an improvement in the traffic conditions, congestion, and cargo capacity if an increase in draft allowance occurred.

[44] USACE Channel Project Summary Data used.

Port Profile (16): Ports of Corpus Christi, Texas

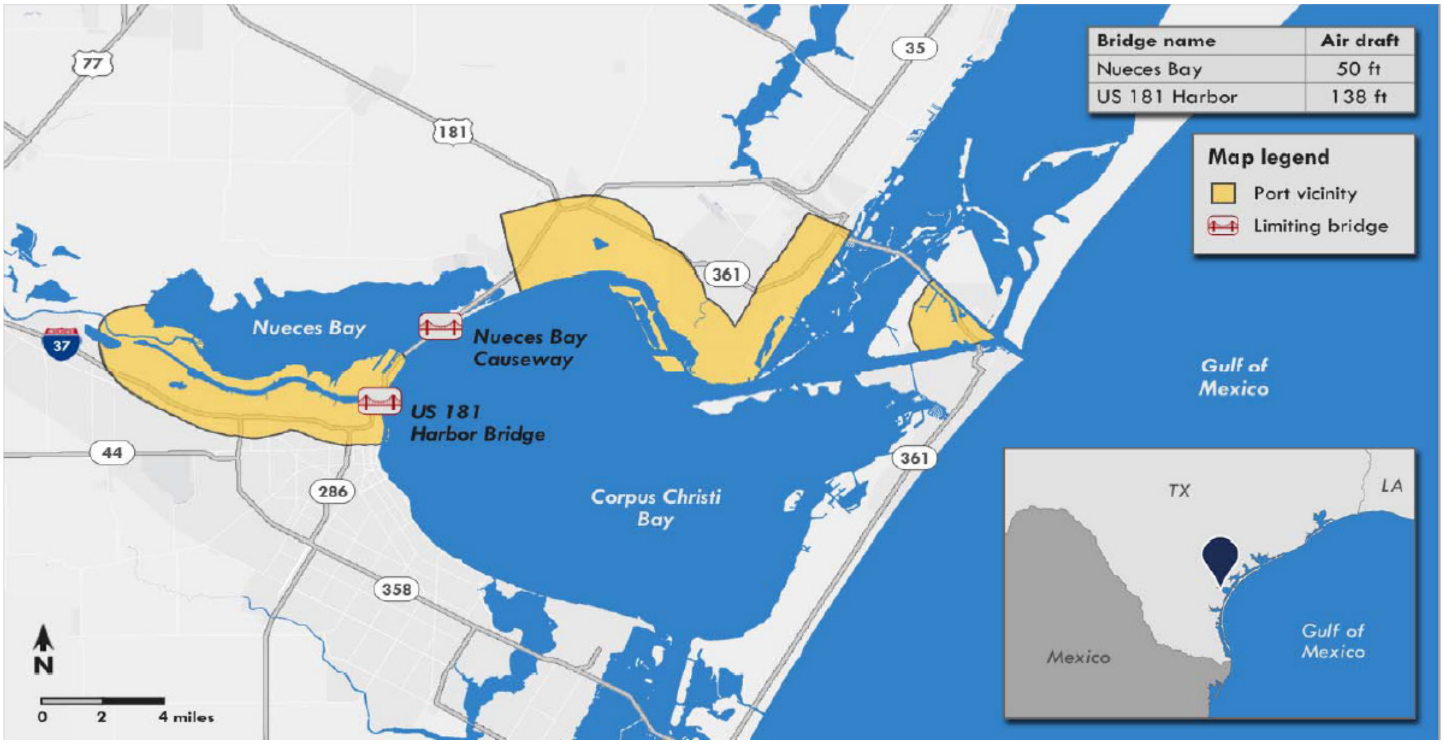

Figure A-52. Ports of Corpus Christi, Texas, layout (BTS 2017).

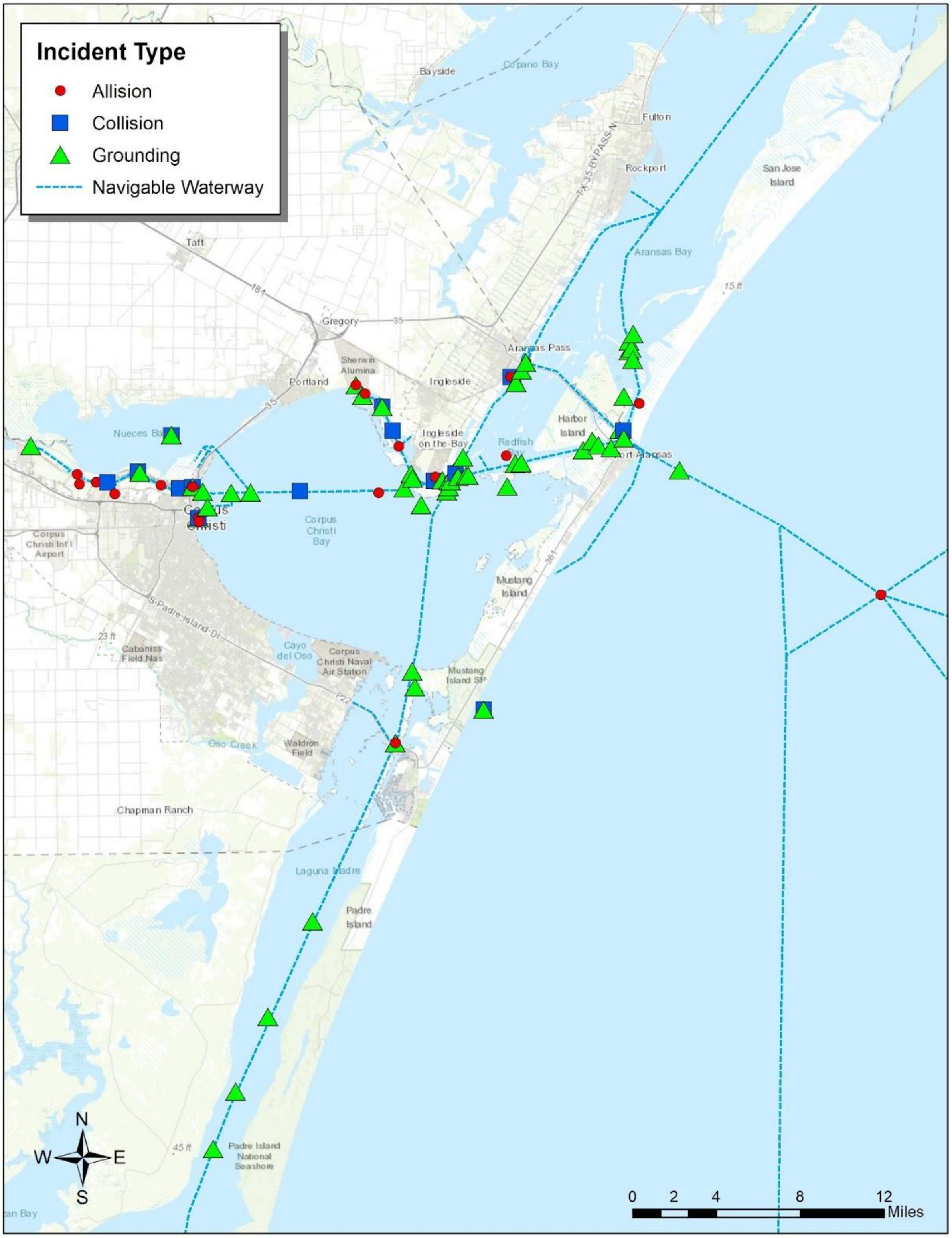

Figure A-53. Accident data for the Ports of Corpus Christi, Texas.

Table A-17. Data for the Ports of Corpus Christi, Texas.

Source[45]	Foreign Tonnage (short tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[46] (WCSC 2017)	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**60,248,327**	**$22,732,985,390**	**14**	**3,379**	**12–52**	**53**	**22**
Aransas Pass, TX	No Data	No Data	13	83	12	47	21
Corpus Christi, TX	60,248,327	$22,732,985,390	1	3,257	52	2	0
Harbor Island, TX	No Data	No Data	No Data	39	36	4	1

A good candidate for Precision Navigation because:

The ports in the Corpus Christi area ranked high for total tonnage and number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as a large increase in economic activity from increased cargo capacity.

[45] "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

[46] USACE Channel Project Summary Data used for Corpus Christi, TX.

Port Profile (17): Port Everglades, Florida

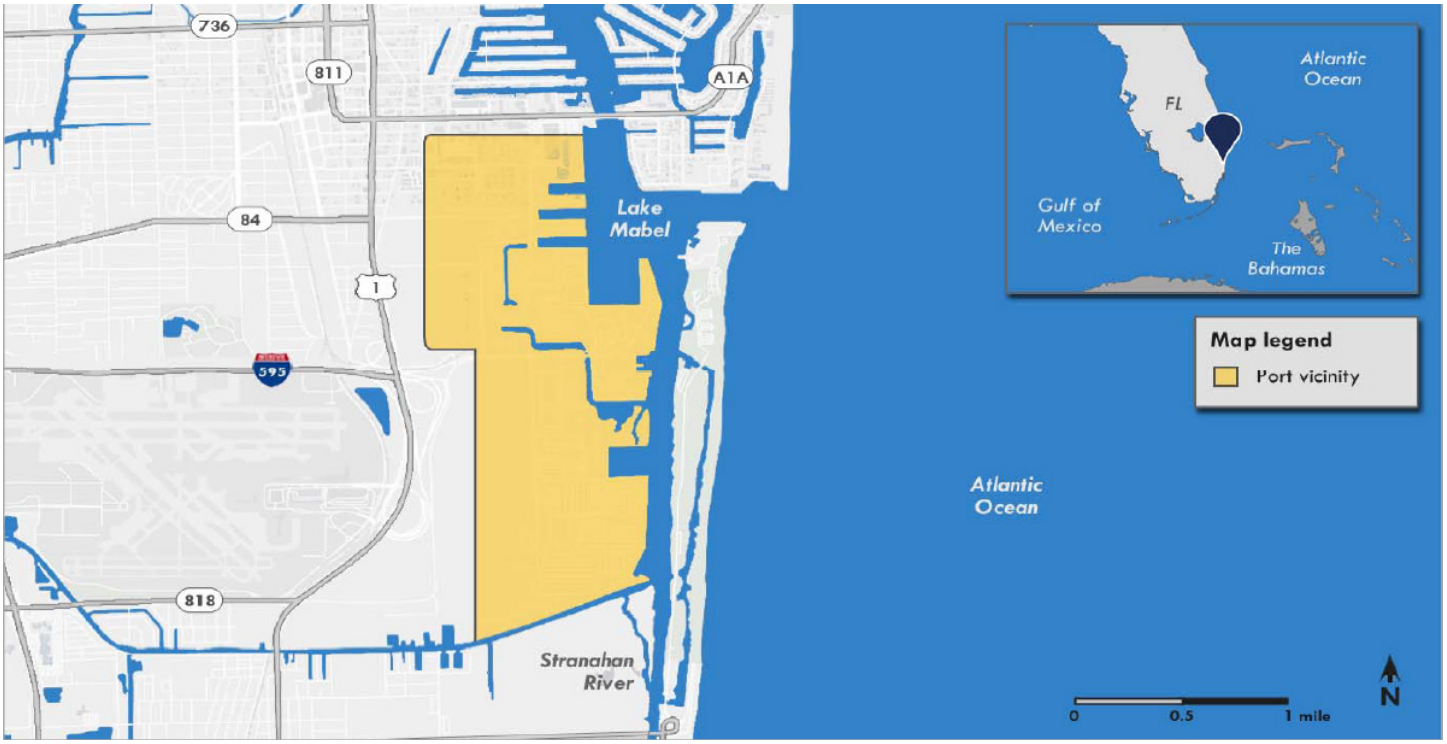

Figure A-54. Port Everglades, Florida, layout (BTS 2017).

Table A-18. Data for Port Everglades, Florida.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[47]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Port Everglades, FL	**10,974,433**	**$23,172,641,038**	**No Data**	**7,671**	**42**	**160**	**1**

Current Technology and Port Characteristics

The Port Everglades experience strong gulf stream currents east of the sea buoy, requiring pilots to board vessels 2 to 3 nautical miles east of the sea buoy to line up on the channel and increase the vessels' speed before entering the channel. Counter currents inside the channel often require vessels to maintain speed to stay safely in the channel. Deep draft and large vessels require the use of tugs to slow them down once inside the jetties. Turning inside the port from the main channel to the Intracoastal Waterway (ICW) is confined and requires the use of tugs to carry out the turn. Strong currents in this area have a profound effect on the vessel. The main channel and ICW are often overcrowded with small pleasure craft that do not understand the limited maneuverability of these vessels. Most of Port Everglades is limited to one-way traffic due to the size of the vessels in relation to the available water. Vessels wait offshore until outbound vessels clear the channel before entering.

Pilots at Port Everglades have access to and utilize various technologies to help navigate, such as ECDIS with radar and AIS overlays, and on occasion a PPU on certain vessels to assist with the maneuver. Also, as a standard, pilots are well trained in the use of all radar systems found onboard a vessel. Monitoring the weather, currents, and tides are also common tasks of any pilot. Port Everglades is not a particularly deep draft port, so huge container ships with large drafts do not typically come into port there. Lightering also does not take place at the port; however, many large containerships will go to another port, such as Freeport, Bahamas, to offload cargo before coming to Port Everglades.

Tides do play a role in how vessels come into port at Port Everglades. Tide jobs do happen on occasion. Most of the port users have tight schedules and do not want to wait for a tide window, so they plan ahead to arrive at the maximum "any tide" draft that is allowed in the port. During times of negative tides, the maximum allowable draft gets reduced further to keep vessels afloat at all stages of any tide.

A good candidate for Precision Navigation because:

Port Everglades ranked high for total number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as an increase in economic activity. In addition, the added draft could allow larger container ships to navigate to port safely, increasing economic activity and reducing the need for cargo offloading at neighboring ports.

[47] USACE Channel Project Summary Data used.

Port Profile (18): Port of Mobile, Alabama

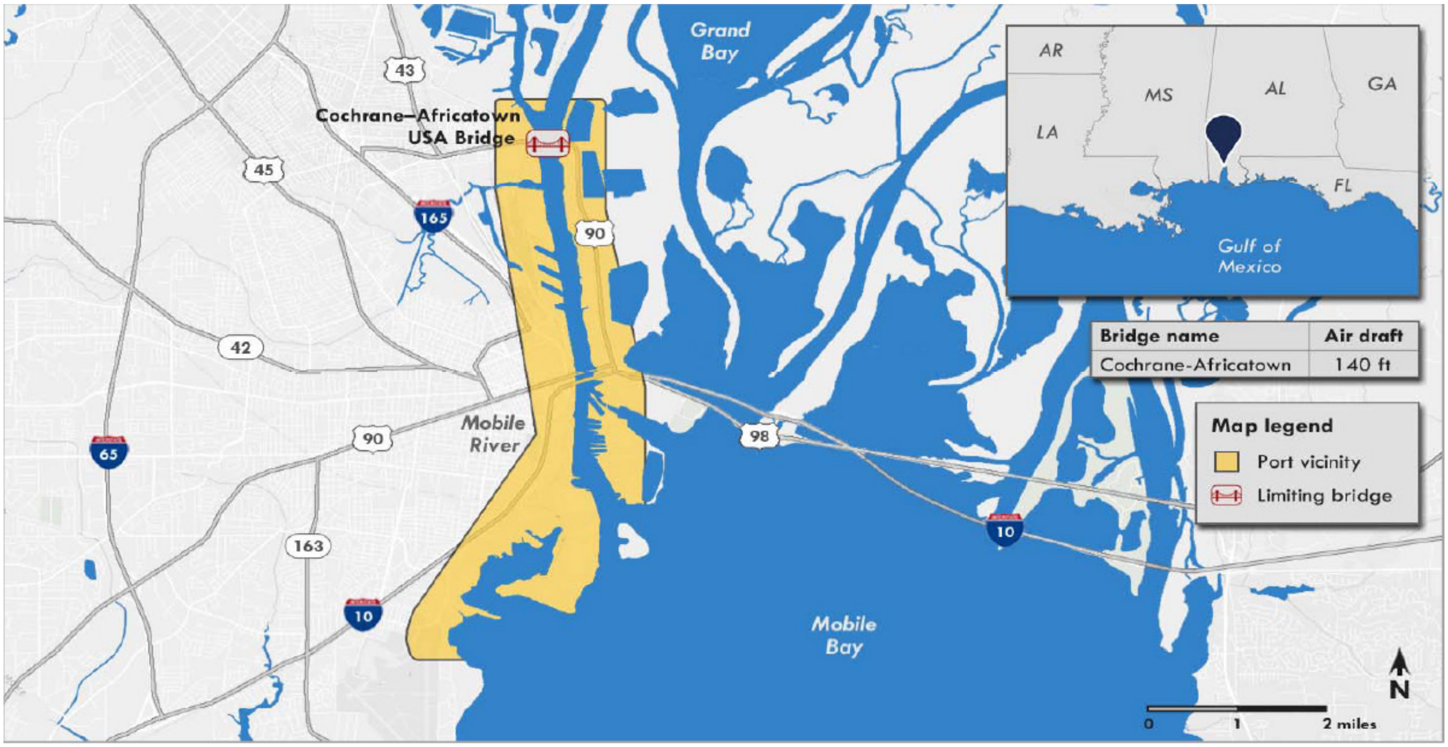

Figure A-55. Port of Mobile, Alabama, layout (BTS 2017).

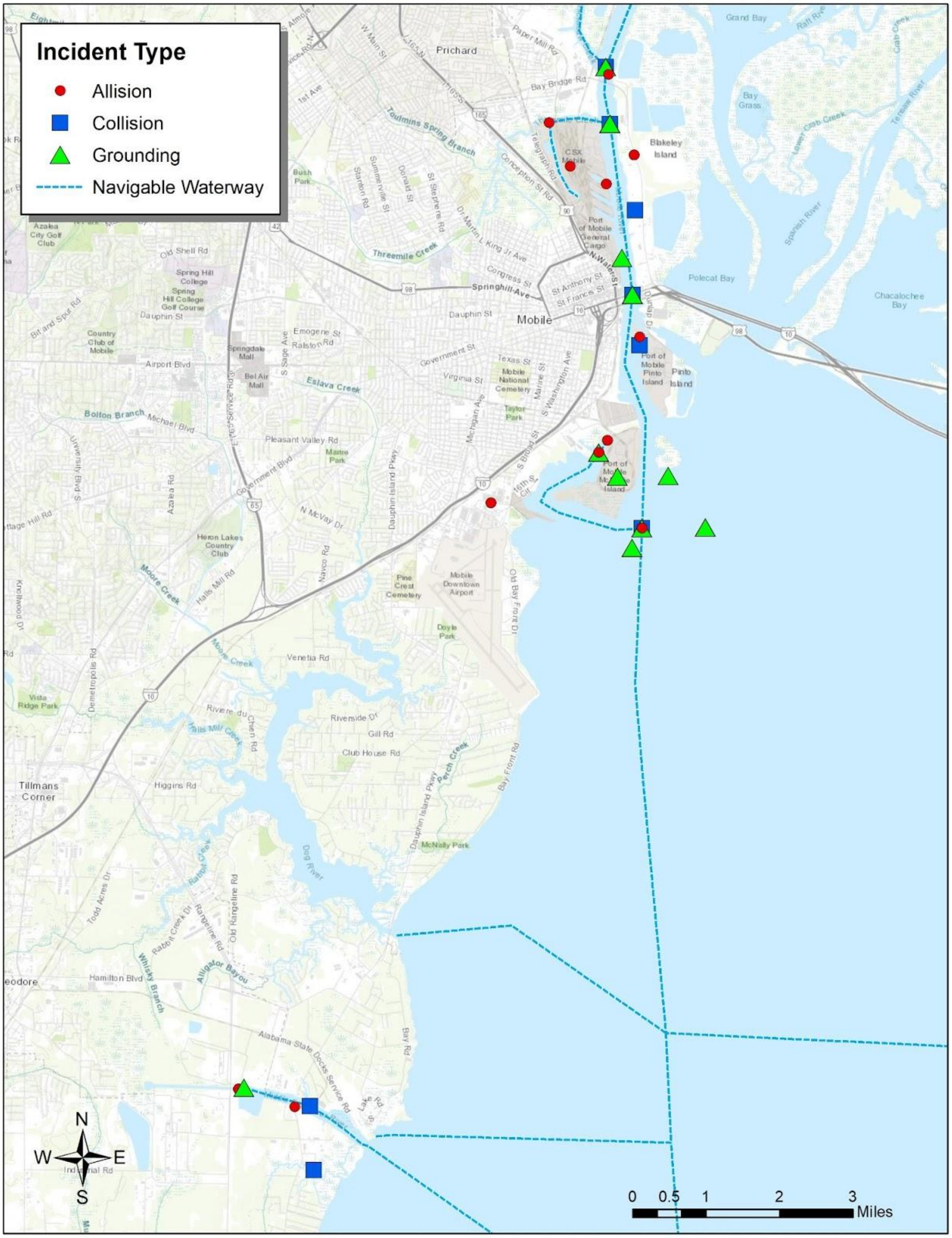

Figure A-56. Accident data for the Port of Mobile, Alabama.

Table A-19. Data for the Port of Mobile, Alabama.

Source[48]	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[49]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Total	**35,561,751**	**$15,511,942,327**	**67**	**2,835**	**51**	**0**	**0**
Mobile, AL	35,561,751	$15,511,942,327	5	2,835	51	0	0
Three Mile Creek, AL	No Data	No Data	62	No Data	No Data	No Data	No Data

A good candidate for Precision Navigation because:

The Port of Mobile, Alabama, ranked high for total tonnage and number of safety incidents. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as the safety of navigation in and out of the port.

48 "No Data" indicates one of the following: data were included in another port, data do not exist, or data were not available.

49 USACE Channel Project Summary Data used.

Port Profile (19): Port of Lake Charles, Louisiana

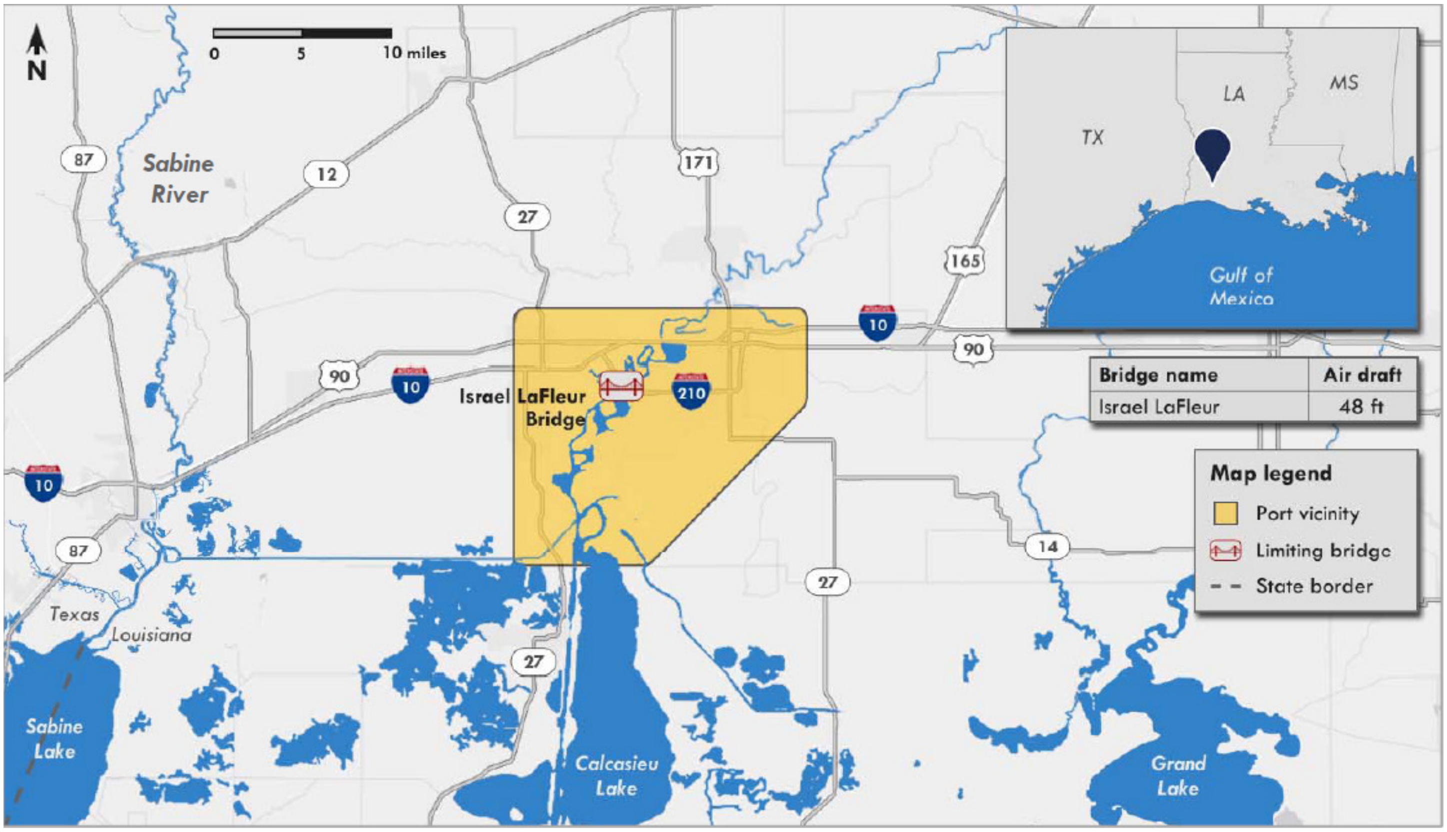

Figure A-57. Port of Lake Charles, Louisiana, layout (BTS 2017).

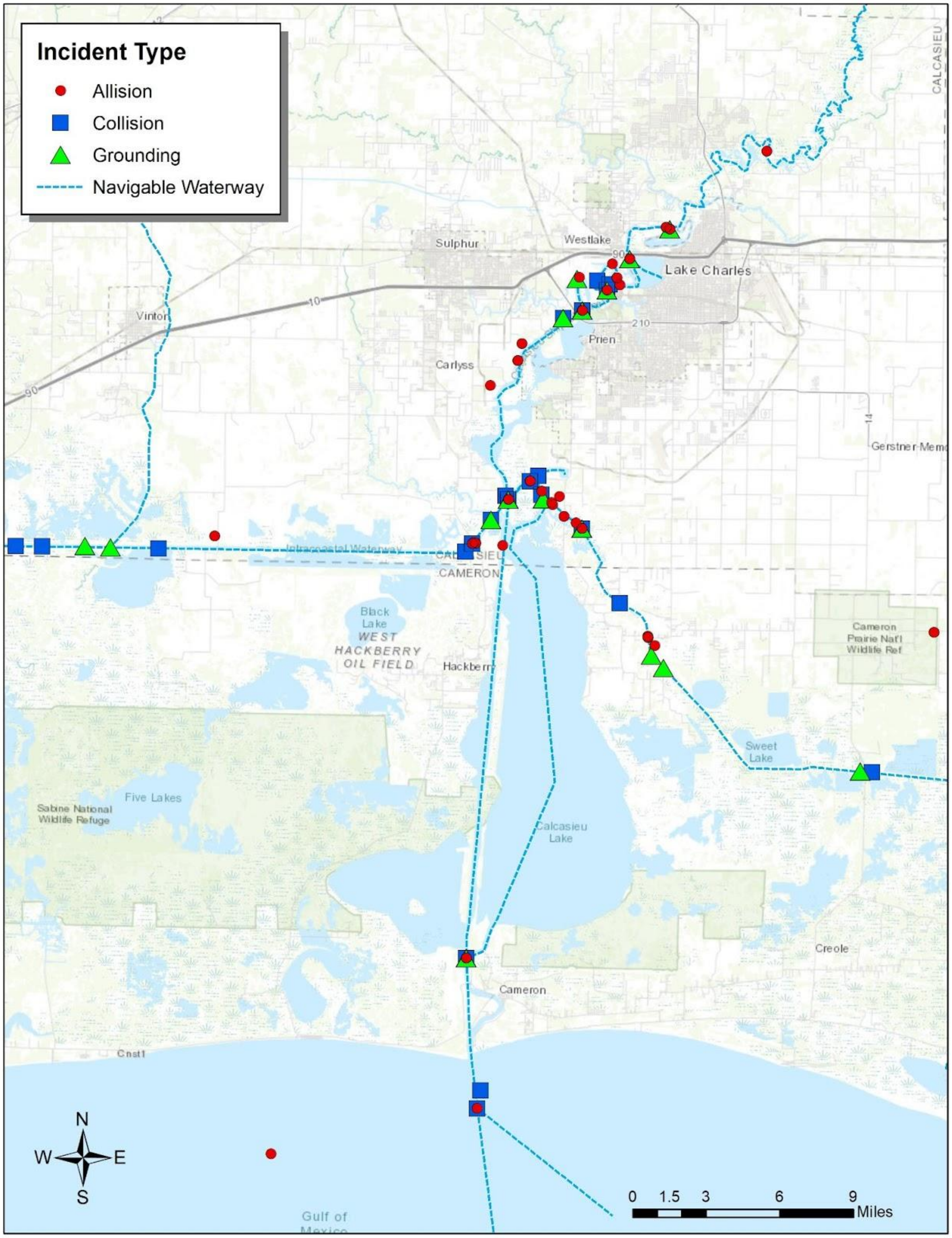

Figure A-58. Accident data for the Port of Lake Charles, Louisiana.

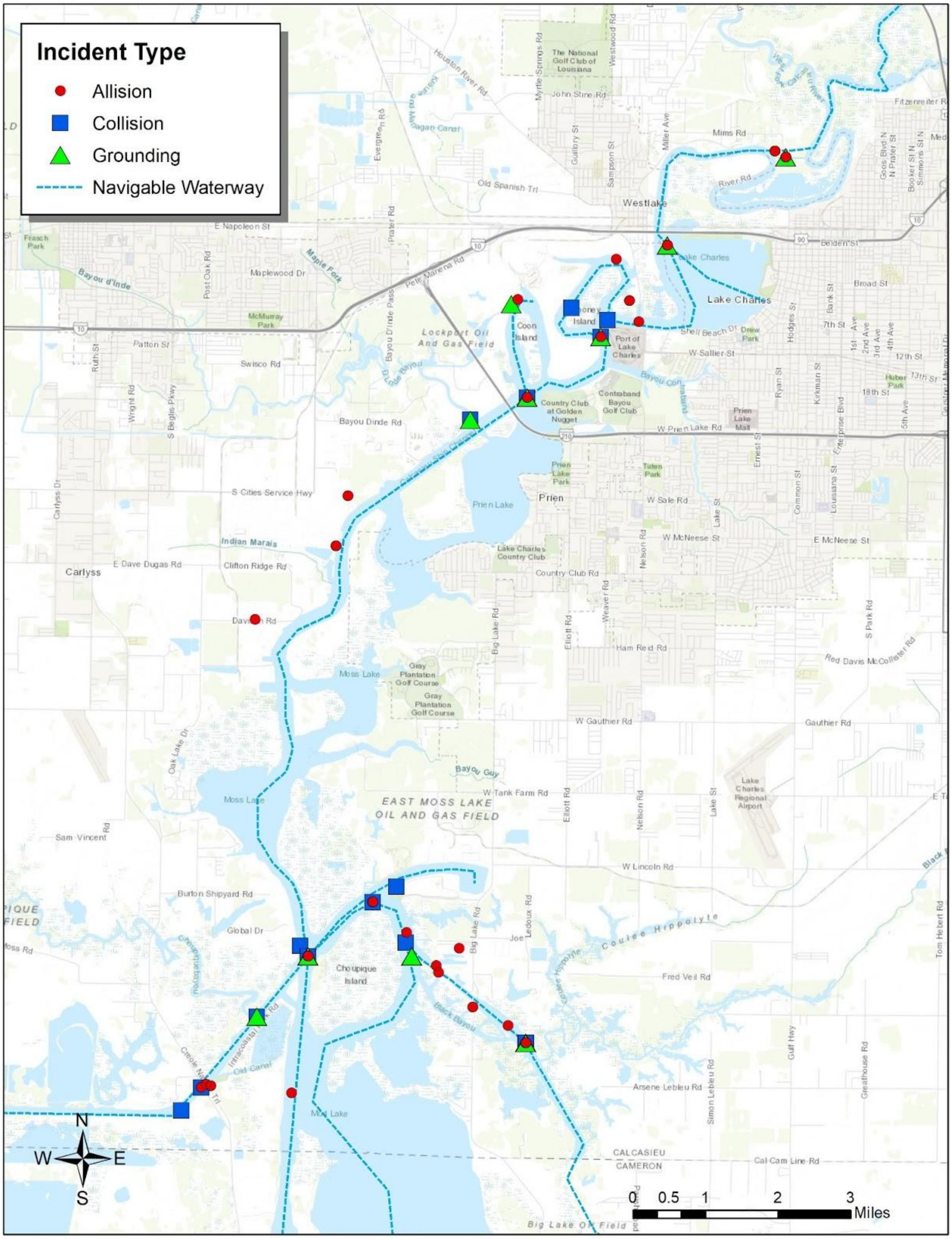

Figure A-59. Accident data for the inland portion of Port of Lake Charles, Louisiana.

Table A-20. Data for Port of Lake Charles, Louisiana.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[50]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Lake Charles, LA	26,471,462	$11,178,173,759	3	1,951	40	403	95

A good candidate for Precision Navigation because:

The Port of Lake Charles ranked high for number of vessel calls close to the maximum draft allowance. This indicates that Precision Navigation could lead to a large increase in cargo capacity and therefore economic activity if a draft allowance increase is achieved.

[50] USACE Channel Project Summary Data used.

Port Profile (20): Port of Miami, Florida

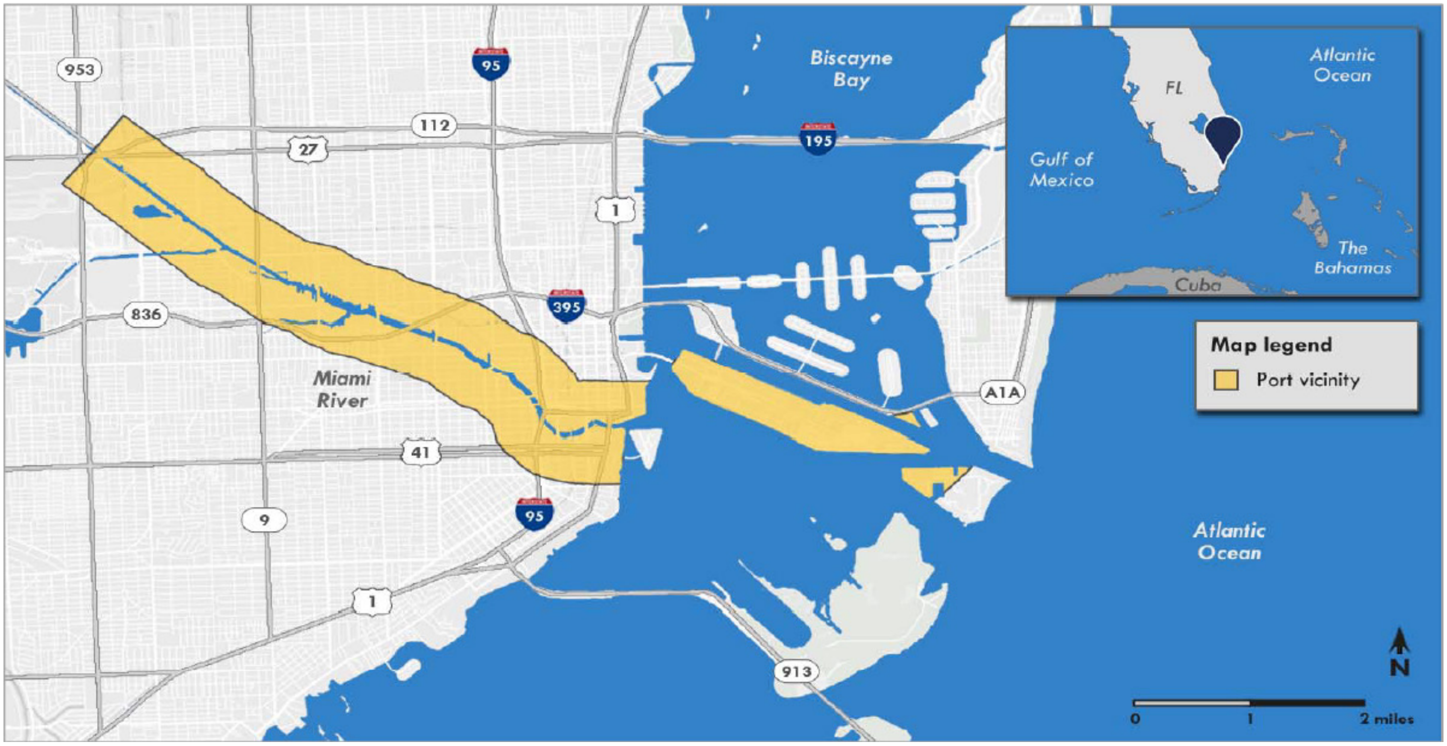

Figure A-60. Port of Miami, Florida, layout (BTS 2017).

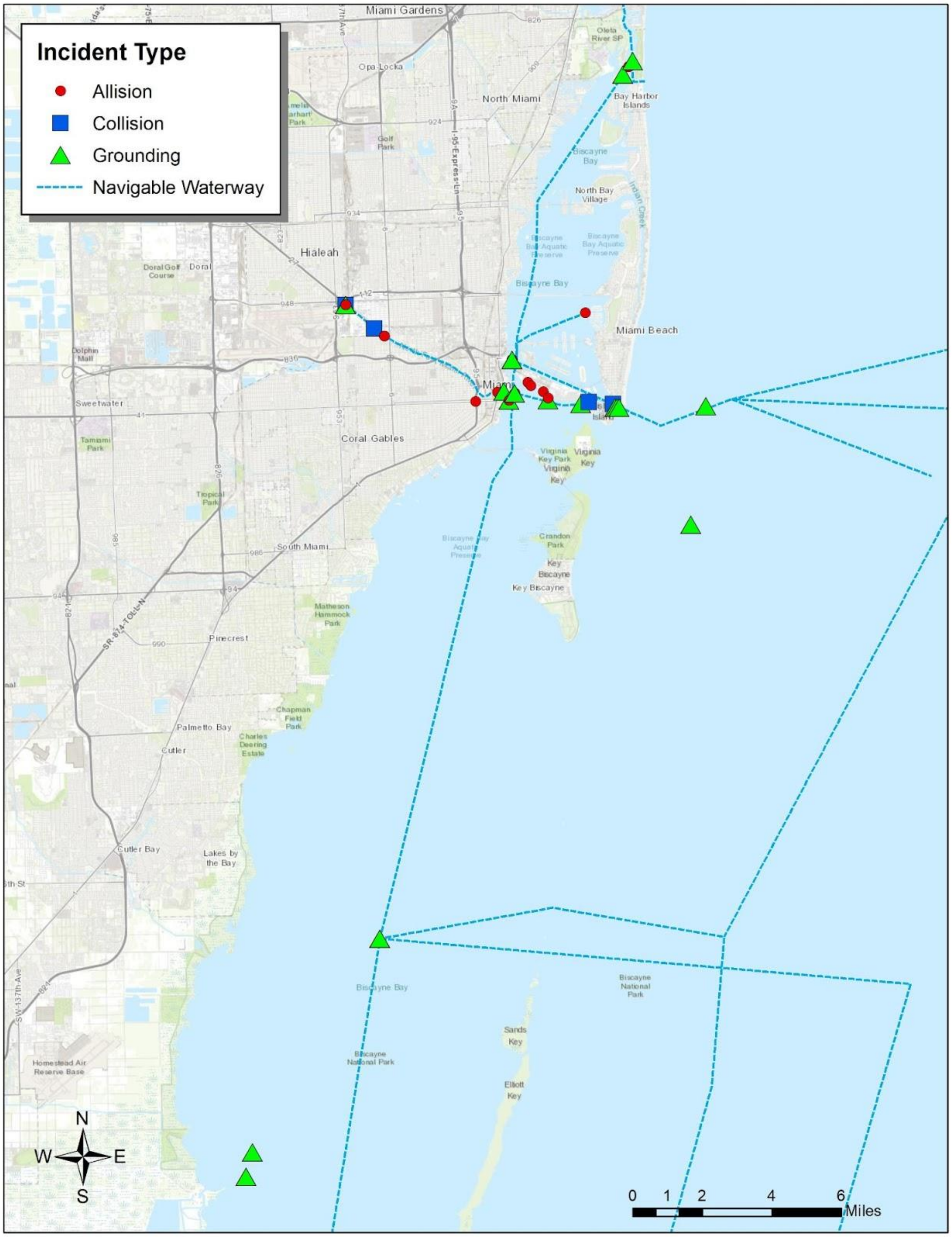

Figure A-61. Accident data for the Port of Miami, Florida.

Table A-21. Data for Port of Miami, Florida.

Source	Foreign Tonnage (Short Tons) (WCSC 2017)	Combined Import and Export Value (Census 2017)	Number of Allisions, Collisions, and Groundings Within 3 km of Port from 2002 to 2013 (USCG 2015)	Number of Vessel Calls (WCSC 2017)	Maximum Draft Used, in Feet[51]	Number of Vessels Within 5 Feet of Max Draft (WCSC 2017)	Number of Vessels Within 1 Foot of Max Draft (WCSC 2017)
Miami, FL	**7,787,619**	**$23,893,514,058**	**13**	**5,503**	**50**	**19**	**0**

A good candidate for Precision Navigation because:

The Port of Miami, Florida, ranked high for total number of vessel calls. This indicates that Precision Navigation could lead to an improvement in traffic conditions and congestion, as well as an increase in economic activity.

[51] USACE Channel Project Summary Data used.

Appendix B: Supporting Data

Table B-1 cites the data and breakdown of losses used to estimate the damage from allisions, collisions, and groundings (Wolfe and Pacheco 2019).

Table B-1. Estimated losses by allision, collision, and grounding from 2005 to 2017 ($2017).

Type of Loss	Allisions	Collisions	Groundings	Total
Deaths and missing ($ millions)	$78.4	$588.0	$39.2	$686.0
Injuries ($ millions)	$339.4	$332.3	$128.6	$800.3
Vessel losses ($ millions)	$169.7	$165.1	$251.3	$586.2
Cargo losses ($ millions)	$9.7	$3.4	$3.0	$16.1
Facility losses ($ millions)	$351.8	$20.3	$2.8	$374.9
Other losses ($ millions)	$363.6	$27.9	$4.9	$396.4
Number of incidents from 2005 to 2017	6,045	4,786	7,687	18,518
Total losses (sum of first 6 rows) ($ millions)	$1,312.5	$1,137.0	$430.0	$2,859.9
Loss per incident	$217,481	$237,518	$55,960	$154,439

Table B-2. Calculation of Total Hourly Operating Cost by Draft level for Port of New York/New Jersey.

Draft (Feet)	DWT Average (Short Tons)[a]	Additional DWT per Foot of Draft[a]	Vessel Calls (2017)[b]	Total DWT by Foot of Draft[c]	Total Added DWT with Extra Draft Foot[d]	Operating Costs at Sea[a]	Total Hourly Operating Costs for Each Draft Level[e]
1	47	400	-	-	-	$54	$0
2	447	400	-	-	-	$74	$0
3	847	400	-	-	-	$94	$0
4	1,247	400	2	2,494	800	$114	$228
5	1,647	400	-	-	-	$134	$0
6	2,047	400	-	-	-	$154	$0

Draft (Feet)	DWT Average (Short Tons)[a]	Additional DWT per Foot of Draft[a]	Vessel Calls (2017)[b]	Total DWT by Foot of Draft[c]	Total Added DWT with Extra Draft Foot[d]	Operating Costs at Sea[a]	Total Hourly Operating Costs for Each Draft Level[e]
7	2,447	400	-	-	-	$174	$0
8	2,847	400	-	-	-	$194	$0
9	3,247	400	2	6,494	800	$214	$428
10	3,647	400	-	-	-	$234	$0
11	4,047	400	2	8,094	800	$254	$508
12	4,447	400	7	31,129	2,800	$274	$1,918
13	4,847	400	-	-	-	$294	$0
14	5,247	400	4	20,988	1,600	$314	$1,256
15	5,647	400	12	67,764	4,800	$334	$4,008
16	6,047	400	119	719,593	47,600	$354	$42,126
17	6,447	400	36	232,092	14,400	$374	$13,464
18	6,847	400	28	191,716	11,200	$394	$11,032
19	7,247	400	51	369,597	20,400	$414	$21,114
20	7,647	400	70	535,290	28,000	$434	$30,380
21	8,047	400	159	1,279,473	63,600	$454	$72,186
22	8,447	400	75	633,525	30,000	$474	$35,550
23	8,847	400	99	875,853	39,600	$494	$48,906
24	9,247	400	115	1,063,405	46,000	$514	$59,110
25	9,647	1,348	180	1,736,460	242,640	$534	$96,120
26	10,995	1,474	456	5,013,720	672,144	$577	$263,112
27	12,469	1,608	544	6,783,136	874,752	$623	$338,912
28	14,077	1,747	591	8,319,507	1,032,477	$667	$394,197
29	15,824	1,893	411	6,503,664	778,023	$721	$296,331
30	18,859	2,065	334	6,298,739	689,710	$651	$217,434
31	21,760	2,267	185	4,025,662	419,395	$1,104	$204,178
32	24,027	2,521	202	4,853,521	509,242	$1,141	$230,482
33	26,548	2,733	347	9,212,272	948,351	$1,182	$410,154
34	29,281	2,858	258	7,554,584	737,364	$1,225	$316,050

Draft (Feet)	DWT Average (Short Tons)[a]	Additional DWT per Foot of Draft[a]	Vessel Calls (2017)[b]	Total DWT by Foot of Draft[c]	Total Added DWT with Extra Draft Foot[d]	Operating Costs at Sea[a]	Total Hourly Operating Costs for Each Draft Level[e]
35	32,139	2,987	380	12,212,947	1,135,060	$1,270	$482,600
36	35,126	3,306	416	14,612,555	1,375,296	$1,318	$548,288
37	38,432	3,507	251	9,646,516	880,173	$1,369	$343,535
38	41,939	3,712	481	20,172,659	1,785,312	$1,422	$684,142
39	45,651	3,860	336	15,338,624	1,296,848	$1,479	$496,832
40	49,510	4,136	293	14,506,528	1,211,848	$1,538	$450,536
41	53,646	4,325	412	22,102,289	1,782,037	$1,600	$659,200
42	57,972	4,616	286	16,579,897	1,320,081	$1,665	$476,190
43	62,587	4,976	182	11,390,895	905,632	$1,734	$315,527
44	67,563	5,149	231	15,607,130	1,189,419	$1,806	$417,109
45	72,712	5,326	100	7,271,233	532,633	$1,881	$188,100
46	78,039	5,492	58	4,526,243	318,507	$1,960	$113,661
47	81,049	5,756	19	1,539,931	109,364	$1,714	$32,557
48	84,913	6,043	14	1,188,782	84,602	$2,743	$38,402
49	90,956	6,338	3	272,868	19,014	$2,916	$8,748
50	97,294	N/A	-	-	N/A	$3,097	$0

[a] Values calculated from Charleston Harbor Study (USACE 1996).

[b] Values taken from entrance and clearance data (WCSC 2017).

[c] Values calculated by multiplying DWT average x vessel calls.

[d] Values calculated by multiplying additional DWT per foot of draft x vessel calls.

[e] Values calculated by multiplying vessel calls x operating costs at sea.

Table B-3. Calculation for Average Hourly Operating Cost at Sea for Port of New York/New Jersey.

Scenario	Total Vessel Calls (2017)[b]	Total DWT (Short Tons)[c]	Average DWT per Vessel[d]	Total Added DWT with Additional Foot of Draft[e]	Average Added DWT with Additional Foot of Draft[f]	Average Hourly Operating Costs at Sea[g]
Upper bound (for all vessel calls)[a]	7,751	233,307,867	30,100	21,162,324	2,730	$1,079
Lower bound (for vessel calls above 36 feet)[a]	2,666	140,143,594	52,567	11,435,470	4,290	$1,585

[a] For upper bound, summations include all values; for lower bound, summations only include values from draft levels above 36 feet.

[b] Sum of vessel calls in Table B-2.

[c] Sum of total DWT by foot of draft in Table B-2.

[d] Calculated: total DWT / total vessel calls.

[e] Calculated: Sum of total added DWT by extra draft foot in Table B-2.

[f] Calculated: total added DWT with additional foot of draft in Table B-2 / total vessel calls.

[g] Calculated: total hourly operating costs at each draft level / total vessel calls