Appendix D

BP Cherry Point Vessel Traffic Analysis Study Report

BP Cherry Point

Vessel Traffic Analysis

Prepared for
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Seattle, Washington

Prepared by
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in collaboration with
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Contents

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Project Team

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The project team is composed of key individuals from Glosten and its two subcontractors, Northern Economics, Inc. (NEI) and Environmental Research Consulting (ERC). The Glosten Associates coordinated the study, providing experience in vessel traffic analysis, casualty prediction, operations, and navigation. NEI’s expertise in economic forecasting supported their primary role of developing the vessel traffic database and traffic forecasts. ERC, an expert in vessel casualty statistics and ecological impact, provided support with the development of the incident database and statistics.

Executive Summary

Introduction

The Glosten Associates, Inc. (Glosten) in conjunction with two subcontractors, Northern Economics Inc. (NEI) and Environmental Research Consulting (ERC), undertook a marine vessel traffic analysis (VTA) to identify the change in oil spill risk as a consequence of the introduction of the North Wing of the BP Cherry Point Marine Terminal (Terminal).

The North Wing was added in 2001 to supplement the existing South Wing. The North Wing gives the Terminal additional capacity to load or unload refined petroleum products.

The US Army Corps of Engineers (USACE) is preparing an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA) to inform its decisions regarding the Department of the Army permit to operate the North Wing. The purpose of this VTA is to provide technical information to the EIS on the incremental risk of vessel incidents, marine pollution spills, and the volumes of crude oil cargo, refined product cargo, or fuel oil spilled.

BP currently holds a Department of the Army Permit (No. 1992-1-00435) issued under Section 10 of the *Rivers and Harbors Act*. At issue are potential modifications to that permit, revocation of the permit, or continuation of the permit in its present form. The one focus of the USACE in the EIS is the incremental risk of vessel accident and release of crude oil cargo, refined product cargo, or vessel fuel into the environment from marine vessels when the Terminal is operating with two berths (both North and South Wings in operation) compared to operating with a single berth (South Wing only).

Technical Objective – Predictions of Risk Measures

The objective of the work described in this Executive Summary and the final report prepared by Glosten is to characterize the incremental number of incidents, number of oil spills, and the combined volumes of crude oil cargo, refined product cargo, or vessel fuel spilled. The predictions of the below-listed values are based on historical data from Puget Sound. Due to the scarcity of events in Puget Sound, supplemental national and international data was also used to produce comparable results. Risk predictions are modeled for 2010 and forecast to 2030. The calculated values include:

- Annual vessel traffic days (24 hours) in the study area.
- Annual vessel traffic days – by vessel type and geographic subarea.
- Annual vessel traffic days in the study area – by vessel activity.
- Incident rates – by vessel type, vessel activity, geographic subarea and incident type.
- Probability of a spill when an incident occurs – by vessel type and incident type.
- Annual number marine incidents – total for study area.
- Annual number marine incidents – by geographic subarea and by incident type.
- Annual number of vessel spills – total for study area.
- Annual number of spills – by geographic subarea and by incident type.
- Annual volume of oil outflow – total for study area.
- Annual volume of oil outflow – by subarea, by vessel type and incident type.

However, it is not possible to predict with perfect certainty incident, spill, and outflow values that are required for the comparisons. This is because of the uncertain quality and scarcity of data, the significant annual variations thereof, and uncertainties in forecasting vessel traffic 20 years into the future. The approach chosen in this comparative risk assessment is to use a Monte Carlo simulation to forecast a range of incident, spill, and volume predictions.

The Monte Carlo simulation is an industry standard technique for combining probability distributions of the underlying parameters. It is implemented by choosing thousands of random numbers from the probability distributions of the underlying parameters, and multiplying them together to get thousands of different outcomes. For this project, ten thousand (10,000) random selections were chosen from the underlying probability distributions to produce 10,000 predictions of the values of interest.

Thus, instead of predicting singular incident, spill, and outflow values for the required comparisons, a probability distribution for each value is calculated. The calculated values are plotted as cumulative probability distributions, and statistics of the distributions are tabulated. The average value of the predicted distribution for the number of incidents and spills is reported. The median and 95th percentile of the predicted distribution for the annual spill volumes is reported.

The reported distribution statistics are to be interpreted as a measure of risk. The average values do not mean that this will be the average number of incidents or spills in 2030; rather, it means that the statistic is the average of 10,000 attempts to predict the number of incidents and spills in 2030. Likewise, the median and 95th percentiles reported do not mean that, in the year 2030, the median spill volume or the 95th percentile spill volume will be the predicted values. Again, they are the median and 95th percentile of 10,000 attempts to predict the spill volume in 2030.

In addition, the methodology for sampling oil outflows includes several binary processes. For example, in the Monte Carlo simulations, the question is asked "*if a collision occurs, was there a spill*?" The answer is binary, either *Yes* or *No*. Thus, when doing 10,000 predictions of what will happen in 2030, rare events that contribute significantly to the 95th statistic of the oil outflow distribution, such as collisions, may or may not have been included in the prediction.

As a consequence, the 95th percentile is an unstable measure to use for comparison with another set of 10,000 predictions. When looking at the 95th percentile results, conclusions should be made from differences in order of magnitude, rather than percentage differences. To emphasize this appropriate interpretation of results, spill volume outflow distributions in Glosten's incremental risk assessment report are plotted on a logarithmic scale.

The statistics of the probability distributions are a measure of the accuracy of the predicted values. They are not a prediction of the statistics of the distribution of incidents, spills, and volumes that will occur in the forecast year.

If there are no uncertainties in the predictions, then the average, median, 95th percentile, and all other statistical measures will be identical, because all 10,000 predictions will result in the same number; e.g., if there are no uncertainties in the forecast of vessel traffic movement, no uncertainties in the volumes of oil they will be carrying, no uncertainties in the forecast of incident rates, no uncertainties in the rate at which a spill occurs as a result of an incident, and no uncertainties in any of the other underlying parameters, then there will be no uncertainty in the prediction of the number of incidents, number of spills, and the volume of oil outflow that will occur in 2030. The prediction will be that there are a particular number of incidents, a particular number of spills, and a particular volume of oil outflow. This prediction accuracy, however, is clearly impossible.

Technical Objective – Comparison of Risk Measures

Since it is clearly impossible to predict the actual number of incidents and spills, or the volume of oil outflow in 2030, with and without the North Wing at the BP Terminal, it is only appropriate to compare common statistical measures of the prediction sets. The selected statistics to characterize incremental risk are the average, 50th and 95th percentiles. It is appropriate to compare the average prediction for the number of incidents, or for the number of spills with and without the North Wing, or some other combination of the matrix of cases (see the Comparison Matrix section in the body of this report). With respect to volume of oil outflow, it is appropriate to compare the median (50th percentile) of the 10,000 predictions or some other percentile value (e.g., 95th), rather than the average.

The choice of comparison, using either the average prediction or a percentile of the predictions, is a result of the mathematical detail of the Monte Carlo simulation. A brief explanation is that number of incidents and number of spills are integer numbers; i.e., there cannot be a fraction of an incident or a fractional number of spills. A Poisson sampling method is implemented in the Monte Carlo simulation that predicts an integer number of incidents, including the possibility of zero incidents, in each of the 10,000 predictions for the forecast year.

It is notable that the average of 10,000 integers may not be an integer. A percentile value of a distribution of 10,000 integers, many of which are zeros, does not produce a meaningful number; e.g., many of the 10,000 predictions resulted in zero incidents in several of the subareas. For example, consider the case of 2,500 predictions with 3 incidents and 7,500 predictions with no incidents. The median of these 10,000 predictions is zero. The average of these 10,000 predictions, however, is 0.0003 incidents. Of the 10,000 predictions in the example case, half of the predictions are for zero incidents, and half of the 10,000 predictions are for zero or more number of incidents; thus, the median value is zero. By reporting the average for annual number of potential incidents and spills, predictions and differences between predictions of less than one are captured in the incremental risk analysis.

The appropriate measure to compare oil outflow is not the average of the 10,000 predictions, but rather the median (50th percentile) or 95th percentile. The reason is that, unlike predictions of the number of incidents, which because of the Poisson method resemble a normal distribution, oil spill volume predictions have possibilities of very large values. This skews the oil outflow distribution to have a shape that does not resemble a normal distribution. Some of the 10,000 predictions for oil outflow for the year 2030 contain values that are the result of the combination of very rare samples. When calculating the average of the 10,000 predictions, the predictions with very large outflow volumes have a significant impact on the average, but do not distort the median. Consequently, comparisons between the averages of two sets of 10,000 predictions, one of which might contain a very large oil outflow and the other of which might not (purely because the random sampling of very rare events), are not meaningful.

For example, in a set of 10 predictions where the first set is {1,2,3,4,5,6,7,8,9,100} and the second set is {1,2,3,4,5,6,7,8,9,1000000}, the last of the predictions in the second set produces a rare very high number, but the first does not, and the two averages are 14.5 and 100,004.5, respectively. The median (50th percentile) of the first set is 5.5 and the median of the second set is 5.5, which indicates that the two sets of predictions are similar. The 95th percentile of the first set is 54.5 and the 95th percentile of the second is 500,004.5, which indicates that a rare combination showed up in the second set, but not in the first.

Although sometimes challenging to decipher, it is important to keep these issues in mind when comparing the statistics of the various prediction sets.

Scope

The scope of the vessel traffic analysis encompasses marine vessels within the study area shown in Figure 1. The study area includes vessel transit lanes of the north Puget Sound up to the Canadian border, and the local maneuvering area at the BP Cherry Point Facility. Traffic routes through the transit lanes are shown on a study area map. The study area is subdivided into seven (7) subareas. Predictions are presented for the entire study area both by geographic subarea and by incident type.

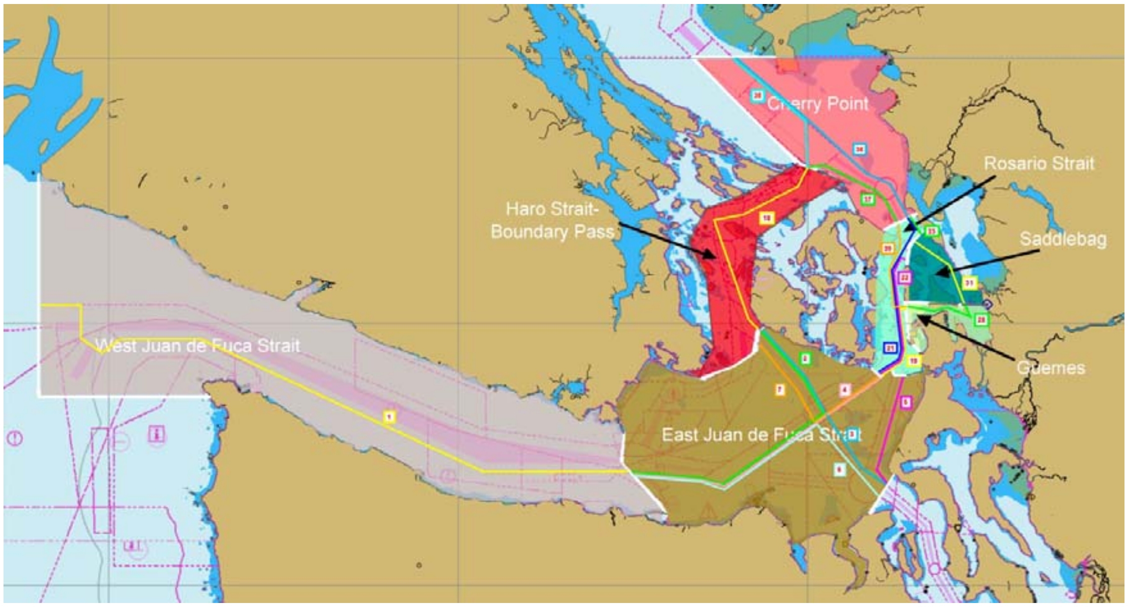

Figure 1 **Study Area Subareas and Routes**

The forecast year is 2030. Vessel traffic is calculated for two time periods: 2010 to represent current conditions, and 2030 to represent future conditions. The 2010 time period was established to take advantage of the most current year in which data from all three of the chosen sources were available. The forecast for 2030 is chosen to provide a 20-year future time period for analysis, which is consistent with the length of the future forecast used in the vessel traffic risk assessment by George Washington University (VTRA) in 2008.

The vessel traffic includes the following traffic components:

- **BP Traffic** – BP-calling tankers and tugs escorting and docking the BP-calling tankers.

- **General Traffic** – General traffic includes existing tankers, tank barges, bulk carriers, general cargo carriers, tugboats, and passenger/fishing vessels. Future general traffic includes forecasted changes in the existing traffic transiting the study area.
- **Cumulative Traffic** – Cumulative traffic includes tankers, tank barges, bulk carriers, general cargo carriers, tugboats, and passenger/fishing vessels that are likely to be generated by terminals or other facilities that do not yet exist. General and Cumulative traffic are referred to as Non-BP traffic.

Four projects were considered reasonably foreseeable by the study team and are included in forecasting cumulative traffic:

- New oil production from the Alaska OCS beginning in 2024.
- Shale oil production from the North Slope with substantial volumes online by 2016.
- Expansion of Kinder Morgan’s Transmountain pipeline to export oil to Asia in 2016.
- Bulk carrier and tug traffic calling at the Gateway Pacific Terminal Project by 2030.

Marine vessels are divided into six (6) groups, which are:

- Tankers.
- Tank barges.
- Bulkers.
- Cargo vessels.
- Tugs.
- Passenger and Fishing Vessels.

Vessel activities are divided into four (4) groups, which are:

- Underway.
- Maneuvering.
- Moored at dock.
- Anchored.

Marine incidents that have a potential for oil spill are divided into six (6) incident types, which are:

- Collisions.
- Allisions.
- Groundings.
- Transfer errors.
- Bunkering errors.
- Other non-impact incidents with spill potential.

Comparison Matrix

The matrix of cases for the comparisons necessary to support the EIS includes combinations of the following parameters.

- Year; 2010 (existing) and 2030 (the forecast year).
- Without and With the North Wing of the BP terminal dock.
- Number of vessel calls at the BP terminal.
- Combinations of traffic other than BP calling traffic:
  - 2010 vessel traffic as recorded.
  - General traffic increases or decreases to the forecast year.
  - Cumulative traffic changes to the forecast year.

The matrix of combinations is shown in Table 1.

Table 1 Case Matrix

Case	Year	South Wing	North Wing	BP Calls	Traffic Other Than BP calling Vessels
1	2010	Yes	No	Maximum – single wing (335)	2010 Existing
2	2010	Yes	No	2010 actual calls (329)	
3	2010	Yes	Yes	2010 actual calls (329)	
4	2030	Yes	No	Maximum – single wing (335)	General Traffic in 2030
5	2030	Yes	Yes	BP “High” forecast (420)	
6	2030	Yes	No	Maximum – single wing (335)	General Traffic plus Cumulative Traffic in 2030
7	2030	Yes	Yes	BP “High” forecast (420)	

Analysis cases reorganized by component traffic distributions are shown in Table 2.

Table 2 Traffic Components by Case

	Case						
Traffic Components	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BP Traffic							
BP single wing max: 1 Wing	X			X		X	
BP 2010 actual: 1 Wing		X					
BP 2010 actual: 2 Wings			X				
BP “High”: 2 Wings					X		X
Non-BP Traffic							
Non-BP Existing 2010	X	X	X				
Non-BP General 2030				X	X	X	X
Non-BP Cumulative 2030						X	X

Comparisons are made of the prediction statistics between the following prediction pairs:

- Cases 2 and 3 – Additional Wing.
- Cases 4 and 5 – Additional Wing and Additional BP Calls.
- Cases 5 and 7 – Additional Cumulative Traffic.

Other comparisons are presented within the body of this report.

Input Data – Data Sources

This study required two types of input data: traffic data and incident data. Both sources of data had challenges associated with them; either overlapping sources with inconsistencies and noise in the traffic data, or too little data necessitating interpolation and extrapolation in the incident data. Data from the study area was used first; however, there has been a scarcity of incidents in the Puget Sound. For incidents where there was insufficient data from the study area or where data would be independent of location, national and international data was also used. For traffic, data from outside the study area; i.e., Port Metro Vancouver, was used to help supplement and define traffic from within the study area.

Traffic Data

NEI obtained data on vessels calling at ports in the State of Washington and the relevant ports in British Columbia. Data on the State of Washington's piloted, deep draft vessels was accessed through the Marine Exchange of Puget Sound. Data on vessels in British Columbia is supplied by the Canadian Coast Guard's Victoria Marine Communications and Traffic Services (MCTS). Vessel traffic volumes obtained from the aforementioned sources were compared to The State of Washington's Department of Ecology Vessel Entries and Transits annual report (VEAT). The forecast relies heavily upon a commodity-based economic forecast generated by BST Associates, as well as historic trends and patterns of vessel behavior from 1995 through 2010.

Incident Data

An incident is an event or circumstance deemed by the US Coast Guard and/or the State of Washington Department of Ecology to have the potential for an oil spill. A spill may or may not have occurred. Spills are a subset of incidents.

A variety of the best available, public and proprietary, primary reporting sources and existing databases have been used for developing ERC case records, including: National Response Center Incident Reports, US Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) Marine Casualty and Pollution Database, US Coast Guard CASMAIN Database, US Coast Guard Marine Safety Information System, Lloyd's Maritime Casualty Database, Emergency Response Notification System, International Tanker Owners Pollution Federation Database, US Coast Guard Compendium Database, US Coast Guard Pollution Incident Reporting System, International Oil Spill Database, Office of Pipeline Safety (now Pipeline and Hazardous Material Safety Administration) databases, and approximately 36 state-specific databases, including Washington Emergency Response Tracking System (ERTS). Sixteen years, 1995 through 2010, of historical records were compiled in the incident database.

Traffic and incident data was then categorized by the project-specific groups for vessel type, activity type, and geographic subarea. Incident data was also categorized into the project-specific incident types.

Data Organization

Grouping

Organizing data into groups, particularly incident data, is necessary due to the limited number of incident records from within the study area. This study is not predicting risk from a single vessel, in a single, particular activity, for a single incident type and location. While that approach could predict a singular outcome, it would potentially be a prediction for which there is no historical occurrence, e.g. there are no data on which to base the prediction. . Instead, the study models all vessels, in all activities, incident types, and locations and reports their cumulative statistics. For example, the study area is subdivided into seven (7) subareas, and these subareas are further grouped to define incident rates. Organizing data into groups is appropriate for a cumulative, statistical analysis.

Grouping incident data allows predictions to be more likely forecast from historical trends with more supporting data. All incident data is grouped into the categories, or types, given above for four parameters: vessel type, activity type, incident type, and geographic subarea. Yet, there is variability within the groups. That is why input parameters based on historical data are modeled with a distribution, reflective of the range of specific vessels and incidents grouped together.

Scenario Parameters

This organization allows risk to be studied by these four parameters, and combinations thereof. For example, results are presented by incident type and by geographic subarea. The combination of one vessel type, one activity type, one incident type, and one geographic subarea is a scenario. For example, one scenario is "a tanker grounding while transiting in Juan De Fuca West." The combination of all six (6) vessel types (v), four (4) activity types (a), six (6) incident types (i), and seven (7) locations (l) gives 6 × 4 × 6 × 7 = 1,008 scenarios for each analysis case. The 1,008 scenarios are assumed to include all combinations of the scenario parameters that will significantly contribute to the quantity of oil that may potentially be spilled.

Technical Approach – Monte Carlo Simulation

Each case in the matrix of cases (Table 1) is evaluated by defining scenarios, determining the quantity of oil outflow in each scenario, and summing the number of incidents, spills, and spill volumes for all scenarios. Total oil outflow for a given case is determined by summing all the predictions of the individual spills that occur in that case.

Variable Definitions

Oil outflow for an individual scenario is a function of five input variables: vessel traffic days, incident rate, spill probability, outflow percentage, and vessel capacity. Vessel traffic days TD are forecast to the study year, 2010 or 2030. A vessel traffic day is equal to twenty-four hours of time in the study area. Traffic days may be further defined with respect to the type of vessel (v), the activity (a), and/or the location (l). Subscripts on a variable indicate that the variable is defined with respect to those parameters, e.g. $TD_{v,a,l}$. Subscript c indicates it is defined with respect to case forecast year (2010 or 2030). Incident rate $IR_{v,a,i,l}$ is calculated from the historical incident and traffic data. Incident rates are in the units of number of incidents per vessel traffic day. Spill probability $SP_{c,v,i}$ is the probability that an incident will result in a spill. Outflow Percent $OP_{v,i}$ is the percent the total vessel capacity released if a spill occurs. Vessel Capacity $VC_{c,v}$ is the potential total volume of cargo oil or bunker fuel onboard. *TD*, *SP*, *OP*, and *VC* are each modeled with a probability distribution, while average annual *IR*s are applied. The approach to calculate number of incidents, number of spills, and spill volume is described next, and followed by further explanation of each input variable.

Incident and Spill Calculation

To determine the number of incidents that occur for a given scenario, $NI_{v,a,i,l}$, it is assumed that incidents are rare and occur independently of the time since the last incident, and thus follow the Poisson distribution. A Poisson sampling method predicts an integer number of incidents, including the possibility of zero incidents, given an average annual incident rate (*IR*) and a sample of vessel traffic days (*TD*). For each incident that occurs, whether a spill occurs is found by sampling the spill probability distribution and multiplying by ($SP_{c,v,i}$) (%). When a spill does occur, it is necessary to determine the spill volume ($SV_{c,v,a,i,l}$) (gallons). For impact and other non-impact incident types, spill volume is the product of Outflow Percent ($OP_{v,i}$)(%) and Vessel Capacity ($VC_{c,v}$) (gallons). Spill volume is sampled directly for bunker and transfer errors, independent of vessel capacity.

The inputs used to determine total oil outflow have variability and uncertainty. The uncertainties are due to the errors in the historical record, sampling errors introduced by the small population of the data set, and uncertainties in the extrapolation to forecasted values. Because of uncertainty in projections and variability in historical data, a Monte Carlo simulation is employed to generate a probabilistic set of potential outcomes or predictions. The Monte Carlo simulation cycles through each case parameter and scenario parameter, building a database of incidents and spills identified by these parameters, as detailed in Figure 2. The Monte Carlo model and risk assessment method are given in Section 4 in the body of this report.

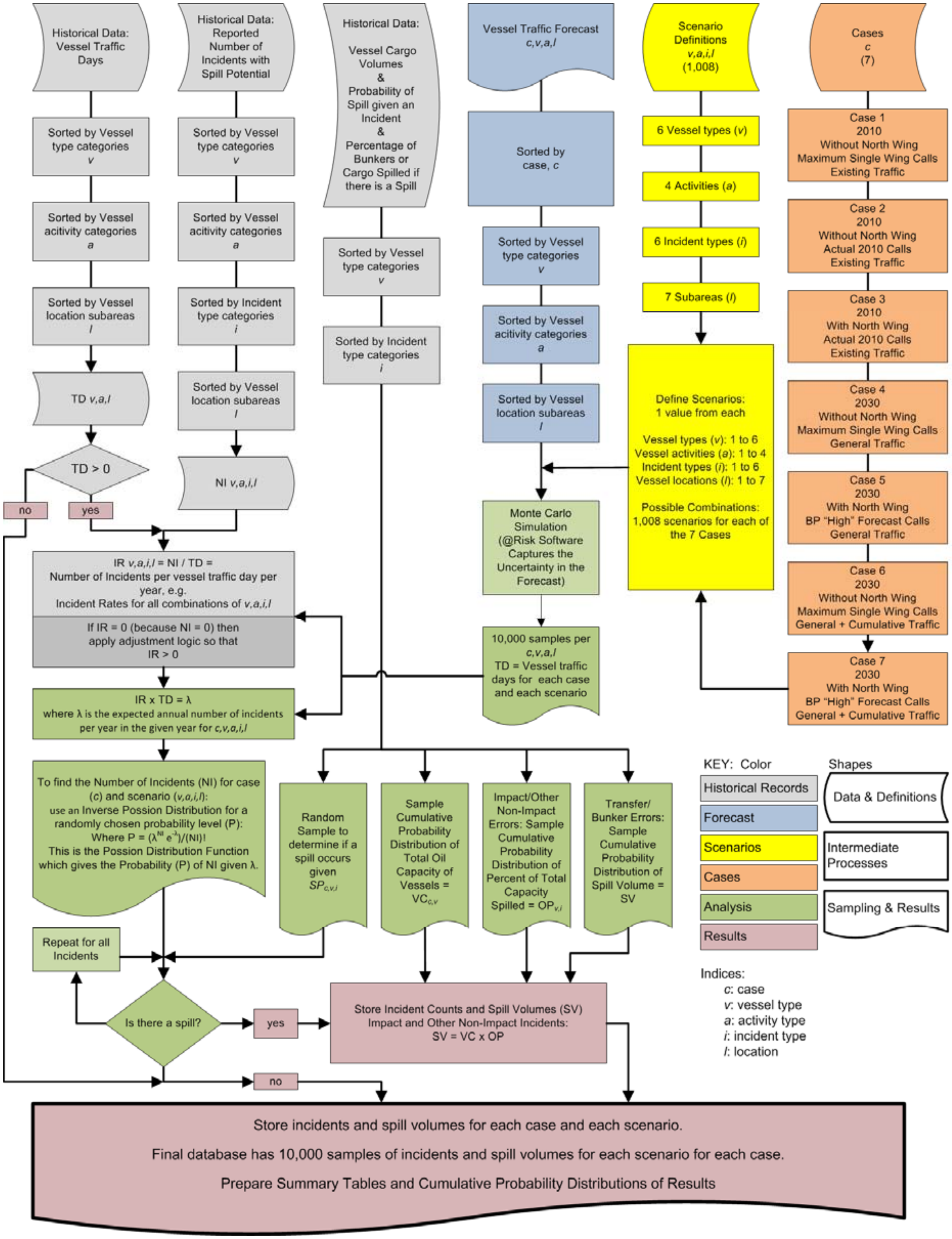

Figure 2 Monte Carlo Simulation Flow Diagram

Vessel Traffic Database

NEI examined the historic and current patterns of traffic and anchorage usage in the study area. The Marine Exchange of Puget Sound provided the primary input data. This database records piloted, deep draft vessel movement activity through actual arrival, shifts, and departure from calls to ports and anchorages in Washington. One port or anchorage, as well as entry and exit to and from the waterway, is recorded as the origin, and another is recorded as the destination for every vessel move. A sequence of moves comprises a route. The portion of each route within each subarea has a known distance. Average vessel transit speeds are calculated by vessel type and by subareas. Distance in nautical miles divided by transit speed in knots gives vessel transit time in hours. Converting hours to days gives vessel traffic days $TD_{v,a,l}$ within each subarea, for the activity type underway. Time at anchor and time at dock are calculated more simply by subtracting arrival time from departure time. Time spent maneuvering is estimated for entering or leaving an anchorage or a berth. Maneuvering time is subtracted from underway time. Including all 4 activities represents the total vessel exposure time. Actual 2010 vessel traffic days for BP-Tankers and tugs and for Non-BP, General Traffic are given in Tables 3 and 4.

Table 3 Study Area BP Vessel Traffic Days, 2010 Actual (329 Calls, 2 Wings)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	103	176	1	58	196	37	391	962
Tug	0	93	5	35	42	125	131	430

Table 4 Study Area Non-BP, General Vessel Traffic Days, 2010

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	193	570	29	536	82	22	89	1,521
Tank Barge	275	877	21	682	206	124	685	2,771
Bulker	756	464	209	35	22	2	238	1,726
Cargo	556	325	112	33	165	3	106	1,300
Tug	426	1,620	124	1,230	540	357	1,544	5,842
Passenger & Fishing Vessel	321	1,084	294	2,081	2,094	34	315	6,222

Source: NEI, 2013

The historical vessel traffic database is summarized in Sections 5 and presented in Appendix A of this report. Anchorage utilization at the eight primary anchorages in the study area is presented in Section 5.3. These are located at Cherry Point, Bellingham Bay, Vendovi Island, Anacortes, and Port Angeles. The vessel traffic database is input for the incident rates, described next, and is used for the vessel traffic forecast in 2030. The vessel traffic forecast is described following the Incident Rates section.

Incident Rates

Historical incident rates are calculated by dividing the number of incidents by number of vessel traffic days, where incident and traffic data share the same time period, vessel type, activity, and subarea. Incident and traffic data used to derive incident rates are from the project study area over the 16-year historical time period between 1995 and 2010. A total of 1,116 vessel incidents that occurred in the study area during the historical time period were categorized into the project-specific parameters and analyzed. Only 429 of the 1,1116 incident records were from vessel types included in the study: bulkers (15), general cargo vessels (50), tankers (40 crude tankers and 50 product tankers), tank barges (36), tugs (89), and the passenger and fishing vessel type (149). From the sparse dataset of 429 incidents, there are zero historical incidents for 883 of the 1,008 scenarios (88%).

Given the sparseness of the dataset it is unreasonable to assume that 88% of the scenarios have zero probability of occurrence. To mitigate the impact of the sparse dataset, scenarios with similar risk profiles are grouped (combined) rather than defining a zero incident rate or an incident rate from only very few incidents. Subareas are grouped into three groups for the underway and maneuvering activity types. All subareas are grouped together for the anchored and docked activity types. Even after combining the subareas into three groups, there are still no historical incidents within the groups upon which to calculate an incident rate for 221 (77%) of the 288 scenario groups.

A zero incident rate is accepted if there is zero probability of the scenario's combination of incident type and activity, or of the scenario's combination of vessel type, activity, and location. For example, vessels that do not carry oil cargo do not have a cargo transfer error. Bulker, general cargo, tug, passenger, and fishing vessels have a zero incident rate for transfer error. A zero incident rate is assigned in 101 of the 228 scenario groups. Additionally, zero incident rates are assigned to specific scenarios, such as a bulker bunker error at dock in Cherry Point (bulkers calling at the Gateway Pacific Terminal will not bunker at dock). The incident rates for the 120 remaining scenario groups with zero historical incidents are adjusted to be non-zero.

The general approach is to assume that 1 incident occurred in 17 years. The assumption behind this approach is that an incident is possible, but that it just had not occurred in the 16 years that were being used to calculate incident rates. Thus the conservative assumption is that an incident would have occurred if 17 years of data had been analyzed. The incident rate adjustment added the equivalent of 18.3 incidents (4.3%) to the dataset of 429 incidents. They contributed uniformly to all analysis cases. Adjusted incident rates do not affect the incremental difference between cases since they apply to all cases equally.

Incident Rates per vessel traffic days are assumed to be independent of traffic density, and do not change in time or with the existence of the BPCP North Wing. It is assumed that the increase in vessel traffic in the forecast year 2030, with cumulative traffic at the BP High Forecast, is within the range that traffic density in local areas can be effectively managed by Vessel Traffic Service (VTS) to prevent an increase in collision frequency rate.

The incident databases are summarized in Sections 6 and presented in Appendix B of this report, and Incident Rates are presented in Section 7. As above, the number of incidents is predicted by combining average annual incident rates per vessel traffic day and the forecast number of traffic days by applying the Poisson distribution. This forecast is discussed as follows.

Vessel Traffic Forecast

The vessel traffic forecast relies heavily upon a commodity-based economic forecast generated by BST Associates, as well as historic trends and patterns of vessel behavior. NEI examined the patterns of traffic and anchorage usage in the study area for the prescribed BP number of calls, for general traffic in 2010, and for general and forecasted traffic in 2030. The vessel traffic forecast is summarized in Section 8 and presented in Appendix D of this report.

Second Wing Wait Time

The forecast for vessel calls at BP is also influenced by the number of wings in operation. Adding the North Wing has two effects: it increases the maximum number of calls that could occur, and reduces tanker wait time for an available berth. Two years of data from before and from after the North Wing began operation showed average wait times of 1.49 days per call and 0.78 days per call, respectively. The second wing reduced wait time by 48% per call. Anchoring time as added in Case 2 without the North Wing compared to Case 3 with both wings is given in Table 5.

Table 5 BP Tanker at Anchor Vessel Traffic Days added for Case 2 without North Wing, versus Case 3 with Both Wings

Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
0	71	0	35	126	0	1	234

Second Wing Added Calls

The single wing maximum number of calls is estimated to be 335. Six calls are added to the actual 329 calls in 2010 to model the Single Wing Max. Eighty-five calls are added to the Single Wing Max to model the “High” forecast. Additional calls are all modeled by scaling up the aggregate transit, docking, and anchoring patterns of past behavior, determined from Marine Exchange data. The typical BP-Tanker will transit through the following subareas: Juan de Fuca West, Juan de Fuca East, Rosario Strait, and Cherry Point. It will dock in Cherry Point. It will anchor at historical active anchorages in the following subareas: Juan de Fuca East, Guemes Channel, Saddlebag, or Cherry Point. The additional tanker wait time is distributed to these subareas in cases modeling a single, South Wing. Keeping other traffic the same, the resulting predicted change in these subareas can be mostly attributed to the additional calls.

Forecast to 2030

Predicted change in General traffic from 2010 to 2030 can be seen by comparing Table 4 and Table 6. Predicted mean values for cumulative traffic added in Cases 6 and 7 are given in Table 7. Four new traffic sources are included in the 2030 cumulative traffic:

1. New oil production from the Alaska Outer Continental Shelf (OCS).

2. Shale oil production from the Alaska North Slope.
3. Expansion of Kinder Morgan's Transmountain pipeline to export oil to Asia.
4. Construction of the Gateway Pacific Terminal (GPT).

There are inherent uncertainties in forecasting vessel traffic 20 years into the future. The closer to the forecast year from when the analysis is performed, the closer modeling of vessel traffic days can be performed, with greater certainty of results. Probability distributions are modeled about the mean, and 10,000 predictions of forecast vessel traffic days are generated for each scenario.

Table 6 Study Area Non-BP, General Vessel Traffic Days (2030)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	172	505	28	478	74	16	80	1,353
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,160	708	260	232	234	14	295	2,902
Cargo	816	488	147	25	621	5	137	2,239
Tug	513	1,846	163	1,529	676	473	1,841	7,041
Passenger & Fishing Vessel	258	1,107	310	1,837	1,762	33	339	5,647

Source: NEI, 2013

Table 7 Study Area Non-BP, Cumulative Vessel Traffic Days (2030)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	204	623	54	174	134	18	124	1,331
Tank Barge	0	0	0	0	0	0	0	0
Bulker	288	365	11	172	402	54	571	1,863
Cargo	0	0	0	0	0	0	0	0
Tug	0	374	280	347	470	203	490	2,165
Passenger & Fishing Vessel	0	0	0	0	0	0	0	0

Source: NEI, 2013

Oil Outflow

Oil outflow for each of the 10,000 scenario predictions is calculated by multiplying: *OP* x *VC* for each spill that is predicted to occur. The integer number of incidents is calculated with the Poisson distribution, as described above. The development of spill probability, outflow percentage, and capacity volumes are expanded on below. The oil outflow model is reported in Section 9 and Appendix D of this report.

Spill Probabilities

The spill probability for each vessel type/incident type combination is based on historical data. There was insufficient data to generate spill probabilities for every vessel type/incident type combination using only incident data from the study area, so national United States and international data were used. Spill probability is also a function of whether the vessel is single or double hulled, with this selection based on forecast year and vessel type.

Spill Outflow Percentages

Where sufficient data was available, outflow percentage curves were developed from study area spill data. Otherwise, national United States and international data were used. Separate outflow percentage curves are used for single- and double-hulled vessels, depending on the sampled hull type. Separate bunker oil outflow percentage and cargo oil outflow percentage are also used, as applicable. Only the tanker and tank barge vessel types have cargo oil.

Vessel Oil Capacities

For 2010, vessel bunker and cargo capacity probability distributions are based on actual capacity distributions of vessels operating in the system in 2010. Most vessel size distributions were obtained from 2010 Marine Exchange of Puget Sound (MX) DWT data. The vessel capacity distribution for 2010 is scaled up for 2030. The scaling factor is the ratio of an average ship size in 2030 compared to 2010. The average size ship for 2030 comes from a forecast capacity demand.

Spill Volume – Impact and Other, Non-Impact Incident Types

Volume of bunker fuel spilled is calculated by multiplying bunker oil capacity with bunker outflow percentage, and volume of cargo oil spilled is calculated by multiplying cargo oil capacity with cargo outflow percentage. Scenario spill volume is the sum of the volumes of bunker fuel and cargo oil spilled.

Spill Volume – Bunker Error and Transfer Error Incident Types

Spill volume, given a spill from a bunker error and transfer error, is not calculated by multiplying OP x VC. Historical data shows that these errors are more frequent, but smaller in size. Spill size was more closely correlated to incident type than vessel type for these types of spills. Therefore, outflow volumes for these two incidents types are sampled directly as spill volumes, independent of vessel size.

Predictions

Representative risk statistics for the seven analysis cases are given in Table 8. The average is presented for the number of incidents and number of spills. Median and 95th percentiles are presented for annual spill volume. Again, they are the statistics of 10,000 attempts to predict the number of incidents, spills, and spill volumes; they should not be interpreted as certain events. They are generated using historical incident and traffic data, supplemented by national and international data, assumptions, and simplifications, which do not affect the incremental risk between cases. Three pairwise comparisons are presented to quantify the incremental risk between each of the seven cases.

Table 8 Predicted Representative Risk Statistics

	Cases						
	1	2	3	4	5	6	7
Year	2010	2010	2010	2030	2030	2030	2030
N. Wing	No	No	Yes	No	Yes	No	Yes
BP Calls	Max. = 335	Actual = 329	Actual = 329	Max. = 335	N+S = 420	Max. = 335	N+S = 420
Traffic	General	General	General	General	General	Gen. + Cumu.	Gen. + Cumu.
Avg. # Incidents	27.78	27.62	27.62	34.35	34.85	46.14	46.66
Avg. # Spills	9.99	9.89	9.88	12.39	12.68	16.58	16.97
50th Spill Vol.	985	975	961	1,109	1,193	2,141	2,396
95th Spill Vol.	90,900	86,172	81,620	62,644	69,617	95,490	114,977

The effect of adding the BP North Wing is isolated by comparing Cases 2 and 3, for which the number of BP calls and General traffic remain the same. The change in number of spills, and thus the change in annual spill volume, is negligible due to the addition of the second wing, as shown in Table 9. The added tanker wait time (Table 5) without the North Wing is a small percentage of the total vessel exposure in the system (Table 3 and Table 4).

Table 9 Case 2 vs. Case 3 – Additional Wing, 2010

	Case 2	Case 3	Change (%)
Average Annual Potential Incidents	27.62	27.62	0.00 (0%)
Average Annual Potential Spills	9.89	9.88	-0.01 (0%)
50th Percentile Potential Spill Volume (gallons)	975	961	-14 (-1%)
95th Percentile Potential Spill Volume (gallons)	86,172	81,620	-4,552 (-5%)

The two effects of adding the BP North Wing, reduced tanker wait time and increased maximum number of calls, are isolated by comparing Cases 4 and 5 (Table 10). There are eighty-five additional calls to BP in Case 5 at the BP “High” forecast as compared to the Single Wing Max. There is no change in General traffic between the two cases. The reduction in BP tanker anchoring time with an increase in BP-Calling tanker and tug underway, maneuvering, and at berth time leads to a small increase in risk, due to the increase in number of BP calls. The change in number of incidents is small. With a small increase in the number of spills, there is a larger increase in annual spill volume.

Table 10 Case 4 vs. Case 5–Additional Wing and 85 Additional BP Calls, 2030

	Case 4	Case 5	Change (%)
Average Annual Potential Incidents	34.35	34.85	0.50 (1%)
Average Annual Potential Spills	12.39	12.68	0.29 (2%)
50th Percentile Potential Spill Volume (gallons)	1,109	1,193	84 (8%)
95th Percentile Potential Spill Volume (gallons)	62,644	69,617	6,973 (11%)

The effect of adding cumulative traffic to the general traffic is isolated by comparing Cases 5 and 7 in Table 11. The increase in risk statistics is large enough to be considered significant and attributable to additional vessel traffic days (Table 7).

Table 11 Case 5 vs. Case 7–Additional Cumulative Projects

	Case 5	Case 7	Change (%)
Average Annual Potential Incidents	34.85	46.66	11.81 (25%)
Average Annual Potential Spills	12.68	16.97	4.29 (34%)
50th Percentile Potential Spill Volume (gallons)	1,193	2,396	1,204 (101%)
95th Percentile Potential Spill Volume (gallons)	69,617	114,977	45,360 (65%)

Validation

Annual historical incidents and total oil outflow were used to validate the oil outflow model 2010 hindcast and 2030 forecast. Incidents in the study area between the years 1995 and 2010 were used to derive incident rates for the outflow model. Total numbers of incidents, numbers of spills, and annual outflow volumes in the study area by year are shown in Table 12.

Table 12 Historical Numbers of Incidents, Numbers of Spills, and Oil Outflow by VTA Vessels in the Study Area

Year	Number of Incidents (*NI*)	Number of Spills (*NS*)	Oil Outflow (gallons)
1995	14	11	362
1996	16	12	14342
1997	19	15	1976
1998	20	15	493
1999	15	11	326
2000	13	12	167
2001	22	17	4113
2002	40	22	3462

Year	Number of Incidents (*NI*)	Number of Spills (*NS*)	Oil Outflow (gallons)
2003	39	11	103
2004	32	11	112
2005	28	13	578
2006	26	10	45
2007	33	9	47
2008	35	9	112
2009	31	4	10017
2010	46	7	46
Median	**27**	**11**	**344**

Case 3 serves as a baseline for model validation, as the model is predicting the number of incidents and total annual oil outflow for a year and traffic combination that actually occurred (2010 actual traffic, with the BP North Wing in operation). Table 13 shows that for 2010, the number of incidents predicted has a median value of 28, and the total oil outflow predicted has a median value of 985. Comparing these predicted values with the actual median values from 1995-2010 (Table 13), shows that the model is in close agreement with number of incidents and number spills and is conservative with regard to oil outflow.

Table 13 Case 3 Median Number of Incidents and Median Total Annual Oil Outflow

	Number of Incidents (*NI*)	Number of Spills (*NS*)	Oil Outflow (gallons)
Median	**28**	**10**	**961**

The conservatism in the total annual oil outflow is primarily attributed to the fact that, over the years investigated (1995-2010), study area spill volumes tended to be less than those of national United States and international data used to develop outflow percentage and outflow volume cumulative distribution functions.

Section 1 Introduction

The US Army Corps of Engineers (USACE) is preparing an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA) to inform its decisions regarding the Department of the Army permit to operate the North Wing of the Cherry Point Marine Terminal (BP Terminal or Terminal). This terminal is associated with the BP Cherry Point Refinery. The North Wing was added to the Terminal in 2001 to supplement the existing South Wing. The North Wing gives the Terminal additional capacity to load or unload refined petroleum products. The North Wing was not designed to transfer crude oil, and has never been used for that purpose.

BP currently holds a Department of the Army Permit (No. 1992-1-00435) issued under Section 10 of the *Rivers and Harbors Act*. At issue are potential modifications to that permit, revocation of the permit, or continuation of the permit in its present form. The primary focus of the USACE in the EIS is the incremental risk of vessel accident and release of crude oil cargo, refined product cargo, or vessel fuel to the environment from operation of the Terminal with two berths (both wings in operation) versus a single wing (South Wing only) by vessels calling at the BP Terminal. A vessel traffic risk study is required to provide the basis for assessing potential environmental impacts from the incremental change in risk related to operation of the second berth.

A previous Vessel Traffic Risk Analysis (VTRA) was completed by George Washington University (GWU) in 2008. This study utilized a simulation modeling approach and used as its baseline vessel traffic data provided by the cooperative US Coast Guard (USCG) and Canadian Coast Guard (CCG) Vessel Traffic Service (VTS), known as the VTOSS data for the year 2005. However, additional analysis is required to provide information needed to complete the environmental impact analysis that is necessary for compliance with NEPA.

1.1 Objective

The scope of work presented in this document is designed to provide the additional information needed by the USACE to complete the Draft EIS. The objective of the work is to characterize the incremental number of incidents, number of oil spills, and the volumes of crude oil cargo, refined product cargo, or vessel fuel spilled. Risk predictions are modeled for 2010 and forecast to 2030. The predictions of the below-listed values are based on historical data from Puget Sound. Due to the scarcity of events in Puget Sound, supplemental national and international data was also used when applicable. The calculated values include:

- Annual vessel traffic days (24 hours) in the study area.
- Annual vessel traffic days – by vessel type and geographic subarea.
- Annual vessel traffic days in the study area – by vessel activity.
- Incident rates – by vessel type, vessel activity, geographic subarea and incident type.
- Probability of a spill when an incident occurs – by vessel type and incident type.
- Annual number marine incidents – total for study area.
- Annual number marine incidents – by geographic subarea and by incident type.
- Annual number of vessel spills – total for study area.

- Annual number of spills – by geographic subarea and by incident type.
- Annual volume of oil outflow – total for study area.
- Annual volume of oil outflow – by subarea, by vessel type and incident type.

It is not possible, however, to predict with perfect certainty incident, spill, and outflow values that are required for the comparisons. This is because of the uncertain quality and scarcity of data, the significant annual variations thereof, and uncertainties in forecasting vessel traffic 20 years into the future. The approach chosen in this comparative risk assessment is to use a Monte Carlo simulation to predict a range of incident, spill, and volume predictions.

The Monte Carlo simulation is an industry standard technique for combining probability distributions of the underlying parameters. It is implemented by choosing thousands of random numbers from the probability distributions of the underlying parameters, and multiplying them together to get thousands of different outcomes. For this project, ten thousand (10,000) random selections were chosen from the underlying probability distributions to produce 10,000 predictions of the values of interest.

Thus, instead of predicting singular incident, spill, and outflow values for the required comparisons, a probability distribution for each value is calculated. The calculated values are plotted as cumulative probability distributions, and statistics of the distributions are tabulated. The average value of the predicted distribution for the number of incidents and spills is reported. The median and 95th percentile of the predicted distribution for the annual spill volumes is also reported.

1.2 Report Organization

This report is organized into eleven sections, and six appendices. Study objectives, context, and analysis cases are in this Section. Section 2 defines the scope of the study. Section 3 introduces project-specific categorizations for incident and traffic data by vessel type, activity type, incident type, and subarea location. The Monte Carlo model, risk assessment method is given in Section 4; model variables are introduced, and a flow diagram is included. The vessel traffic and incident databases are summarized in Sections 5 and 6. These studies are included as Appendices A and B. Incident rate per vessel traffic day statistics are formulated and presented in Section 7. The forecast of future vessel traffic is presented in Section 8 and in Appendix C. The incremental risk assessment model to calculate spill volume is given in Section 9 and in Appendix D, where model variables: spill percentage, vessel capacity, and outflow percentage, are defined. Results and conclusions are given in Sections 10 and 11. Supplementary results are found in Appendix E.

1.3 Definition of Terms

Definitions for the terms used in this study are provided as follows.

Activity Type (a) A scenario parameter. The four (4) project-specific activity categories are:

1. Underway
2. Maneuvering
3. Docked
4. Anchored

BP-Calling Tugboats	Tugboats are defined as BP-calling tugboats during the time they are escorting and/or docking BP-calling vessels.
BP-Calling Tanker	Tankers calling at the BP Terminal to unload or load crude oil or refined product cargos. All calls at the BP Terminal are modeled as tankers and not as tank barges. An expanded definition of traffic days modeled for BP-calling tankers is given in Section 2.1.1 of Appendix B.
BP-Calling Vessel	BP-Calling Vessels are BP-Calling Tugboats and BP-Calling Tankers.
Bunkering	The process of transferring fuel oil to a receiving vessel.
Deadweight Tonnage	The measure of the amount of weight that a ship may carry, including cargo, bunkers (fuel), ballast water, fresh water, dirty water, provisions, crew, etc.
Incident	An event or circumstance deemed by the US Coast Guard and/or the State of Washington Department of Ecology to have the potential for an oil spill. A spill may or may not have occurred. Spills are a subset of incidents.
Incident Rate (IR)	The number of incidents per vessel traffic day. IRs are defined for a given combination of scenario parameters as: vessel type (v), activity type (a), incident type (i), and location (l).
Incident Type (i)	A scenario parameter. The six (6) project-specific incident categories are: 1. Collision 2. Allision 3. Grounding 4. Cargo Transfer Error 5. Bunker Error 6. Other, Non-Impact Incident
Location (l)	A scenario parameter. The seven (7) project-specific subareas, as shown in Figure 6, are: 1. Strait of Juan de Fuca West 2. Strait of Juan de Fuca East 3. Rosario Strait 4. Haro Strait Boundary Pass 5. Cherry Point 6. Saddle Bag 7. Guemes Channel Fidalgo Bay
Location Group (l_group)	The three (3) location groupings are: 1. Juan de Fuca West and East 2. Haro Strait Boundary Pass and Rosario Strait 3. Cherry Point, Saddle Bag, and Guemes Channel Fidalgo Bay

Maneuvering	The time spent maneuvering to and from anchorage or berth. While maneuvering the vessel is either operating at a reduced speed in anticipation of stopping, or is still gaining speed as it moves from an anchored or berthed position. • Deep draft vessels are assumed to require 135 minutes (2.25 hours) maneuvering to and from an anchorage, and 120 minutes (2 hours) maneuvering to and from a berth. • Tug maneuvering time is assumed between 15 (.25 hours) minutes and 75 minutes (1.25 hours), depending on whether or not the tug is maneuvering with or without a tow.
Monte Carlo Simulation	The process of calculating a sufficient number of stochastic results to produce high-resolution probability distributions of cumulative oil outflow for a given set of scenarios.
Parameter	An attribute with a set of prescribed, possible values for selection.
Poisson Distribution	A probability distribution used to describe rare events that occur independent of the time of last occurrence.
Probability Distribution	A function describing the likelihood of each possible outcome of a stochastic process.
R^2	Coefficient of Determination. Quantifies how well data points fit a curve, where $R^2 = 1.0$ when the data points exactly fit the curve.
Random Number	A number in the domain (0, 1) that is generated in order to sample a value of a probability distribution.
Random Variable	A variable that is described as a probability distribution and sampled using a random number.
Regression Analysis	Interpolation of data in order to estimate a value that is not explicitly available or given.
Stochastic Result	One possible oil outflow result; obtained by sampling all 1,008 scenarios (*v,a,i,l* combinations) once each.
Scenario	A combination of parameters present during a particular incident, as defined in Table 17 of this report, which includes: vessel type (*v*), activity type (*a*), incident type (*i*), and location (*l*).
Study Area	The geographic bounds of the area considered in the study. The area covered by all locations (*l*), as shown in Figure 3.
Subarea	See Location.
Study Period	The years during which data on environmental risk were used to develop statistics used in the contaminant outflow model.
Tanker	A self-propelled vessel, articulated tug barge (ATB), or integrated tug barge (ITB) that carries liquid oil products as its primary cargo.
Traffic Day	Twenty-four hours of time in the study area. Traffic days may be further defined with respect to the type of vessel (*v*), the activity (*a*), and/or the location (*l*).

Underway	The activity type in which a vessel is transiting subareas within the study area. While underway, it is assumed that the vessel is operating at a constant speed and is en route to a given point (i.e., not loitering).
Vessel Capacity	The capacity of a given vessel type for a given oil type (cargo or bunker).
Vessel Type (v)	A scenario parameter. The six (6) project-specific vessel categories are: 1. Tanker 2. Tank Barge 3. Bulk Carrier 4. General Cargo Ship 5. Tug 6. Passenger and Fishing Vessel
VTA Vessel	A vessel belonging to one of the project-specific vessel types.

1.4 Acronyms, Abbreviations, Parameters, and Variables

Definitions for the acronyms, abbreviations, parameters, and variables used in this study are provided as follows.

a	Scenario parameter defining activity type
BP-VTA	BP Cherry Point Vessel Traffic Analysis
CCG	Canadian Coast Guard
CDF	Cumulative Distribution Function
DWT	Deadweight Tonnage
ERC	Environmental Research Consulting
c	Case number
i	Scenario parameter defining incident type
IR	Incident Rate
L	Scenario parameter defining location (subarea)
LOA	Length Overall
MX	Marine Exchange of Puget Sound
NEI	Northern Economics, Inc.
NI	Number of Incidents
OP	Outflow percentage
SP	Spill Probability
SV	Spill Volume per Scenario

TD	Traffic Days (1995 - 2010 and 2030)
v	Scenario parameter defining vessel type
VC	Vessel Capacity
VTS	Vessel Traffic Service (collectively USCG and CCG)
VTA	Vessel Traffic Analysis
λ	Mean yearly incident rate

Section 2 Scope of the Study

2.1 Geographic Study Area

The study area includes vessel transit lanes of the north Puget Sound up to the Canadian border and the local maneuvering area at the BP Cherry Point Facility:

- Vessel transit lanes: BP bound vessels are required to operate within the USCG or CCG designated vessel traffic lanes (VTS transit lanes) until they reach the vicinity of the BP Terminal, where they depart from the VTS transit lanes and maneuver to moor at the terminal or move to a local anchorage. Thus, the "geographic study area" for the vessel traffic study consists of the VTS transit lanes used by BP bound vessels, the maneuvering area adjacent to the terminal, the local anchorage areas, and the local transit routes for tugs that are required to assist in maneuvering and mooring. The study does not analyze the risk or impacts of vessel movements outside the above listed areas.

- Local maneuvering area: The local maneuvering area considered in the BP-VTA is that area through which BP bound vessels transit from the point of departure from the transit lanes to the BP Terminal.

The geographic study area and general boundaries of the local maneuvering area are shown in Figure 3 – BP-VTA Study Area.

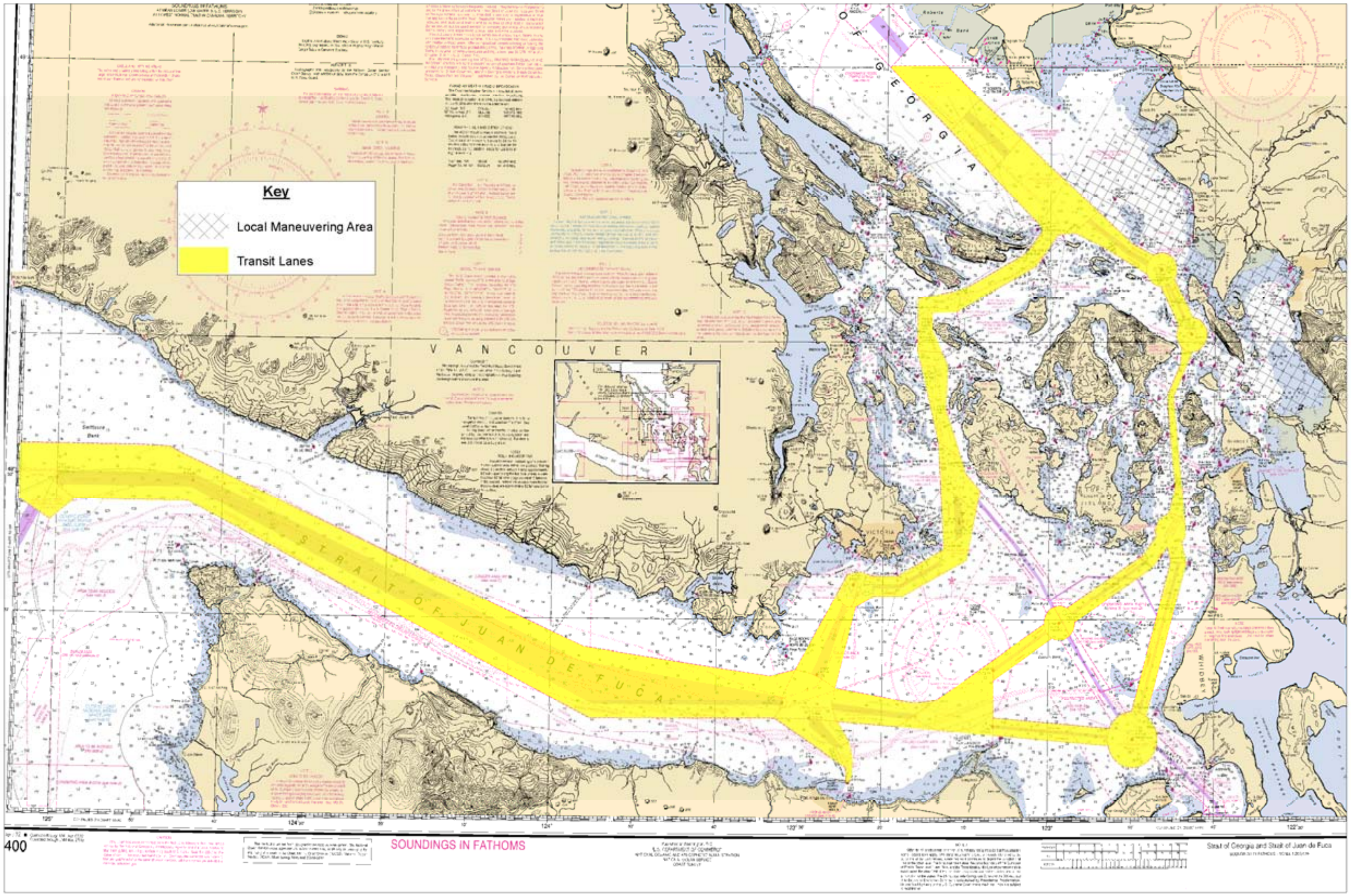

Figure 3 BP-VTA Study Area

2.2 BP Cherry Point

BP's Cherry Point facility is located in Northwest Washington, approximately seven miles south of Blaine and eight miles northwest of Ferndale, WA. BP Cherry Point is the largest refinery in Washington, and specializes in the refinement of Alaska North Slope crude. Currently the refinery produces 2.5 million gallons of jet fuel, 3.5 million gallons of gasoline, 2.2 million gallons of diesel, 360,000 gallons of butane, and 140,000 gallons of propane each day (Reference 21).

The products produced by BP are distributed to market via land and water. BP operates the Olympic pipeline, which is the largest petroleum products pipeline in the Pacific Northwest that connects four of the Puget Sound area refineries to 23 gasoline, diesel, and jet fuel terminals in Washington and Oregon. The Olympic Pipeline provides 300,000 barrels per day of product to major cities such as Seattle, Tacoma, Olympia, and Portland (Reference 22).

Incoming crude not transported via pipeline is delivered via tankers calling at the South Wing of the BP Terminal, shown in Figure 4. BP ships refined products in both tank vessels and tank barges from both wings of the BP Terminal, though barges typically only call at the South Wing.

Figure 4 BP Cherry Point Facility Docks, facing south (Source: NOAA 2013)

The BP Cherry Point docks are referred to as the North Wing and the South Wing, and are located at general position Latitude 480 51.7′N Longitude 1220 44.8′W. There is a deep water anchorage used by calling vessels, located southwest of the BP facility and 1.5 nautical miles due west of Neptune Beach, WA. The single South Wing, as originally constructed, was equipped to handle a maximum of 335 vessels per year. A second berth became available with the addition of the North Wing. This increased the annual maximum number of calls that could be accepted at Cherry Point. According to Marine Exchange of Puget Sound (MX) data, the number of calling vessels for both docks combined ranged from 320 to 400 annually in recent years (Figure 5).

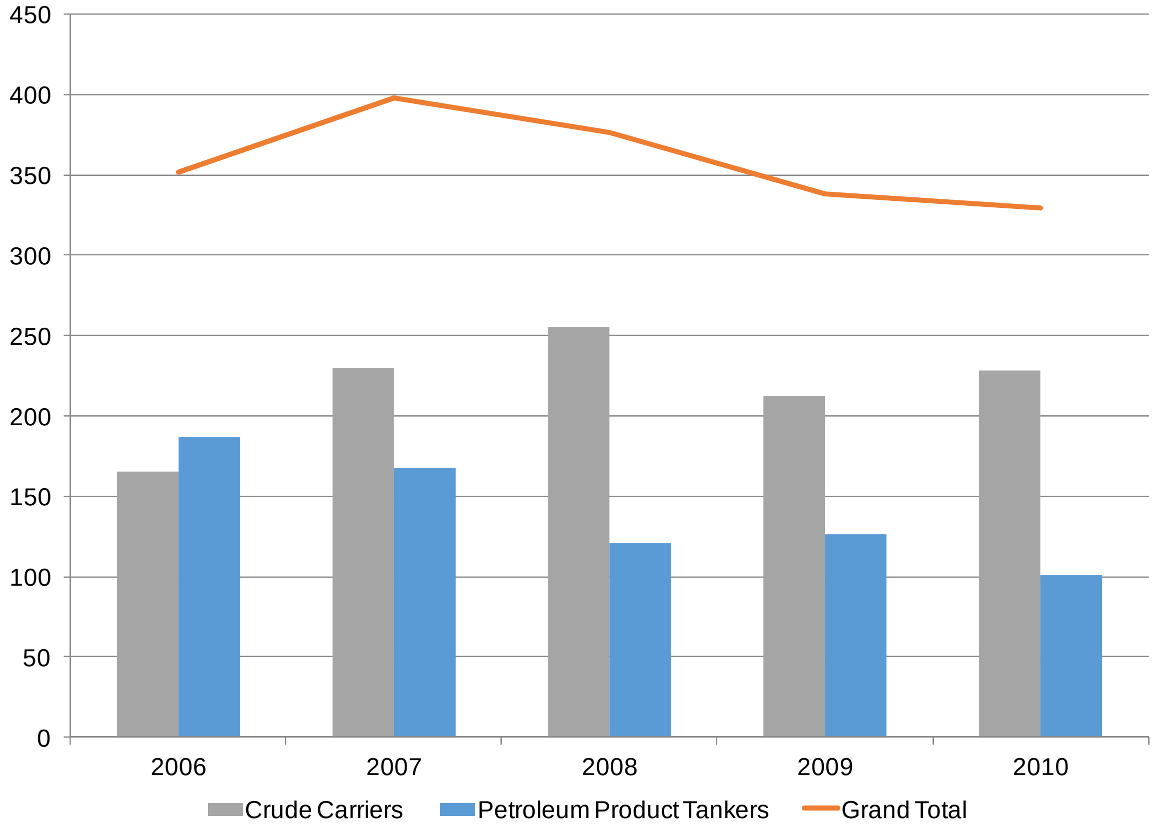

Figure 5 **Vessel Calls to BP Cherry Point, 2006–2010 (Source: NEI. using MX 2012)**

2.3 Case Matrix

The set of seven cases listed in Table 14 are analyzed. The study includes an analysis of past traffic in 2010 (Cases 1 – 3) and forecast traffic in 2030 (Cases 4 – 7).

Table 14 **Case Matrix**

Case	Year	South Wing	North Wing	BP Calls	Traffic Other Than BP
1	2010	Yes	No	Maximum – single wing (335)	2010 Existing
2	2010	Yes	No	2010 actual calls (329)	
3	2010	Yes	Yes	2010 actual calls (329)	
4	2030	Yes	No	Maximum – single wing (335)	General Traffic in 2030
5	2030	Yes	Yes	BP “High” forecast (420)	
6	2030	Yes	No	Maximum – single wing (335)	General Traffic plus Cumulative Traffic in 2030
7	2030	Yes	Yes	BP “High” forecast (420)	

2.4 Study Period

Incident and traffic data used to derive incident rates are from the project study area over the 16-year historical time period between 1995 and 2010. The study period was chosen to maximize reliability in the statistics. It balances the desire to capture more, consistent data, with the need for data that reflects contemporary reality. The farther back in time the study period goes, the more data is captured, which lessens the sensitivity to exceptional years. This is particularly important when relying on a sparse dataset. Where there have been between zero, a few, or more spills each year in a given category, annual statistics are highly variable. It is more informative to take statistics and look for trends over a longer time period. It is not instructive to collect data from further back than 1995 due to the Oil Pollution Act of 1990 (OPA 90). The transition in spill rates and reporting trends from before OPA 90 is considered to be relatively steady by 1995. The closer the study period years are to present day, the more accurately the causes of incidents reflect the behavior of the contemporary world. The end year, 2010, was the last year that the CCG MCTS Near-Real Time and Department of Ecology VTOSS and VEAT traffic data was published in the same, consistent historical format. Incidents and traffic occurring before and after 1995-2010 or outside the study area[1] are informative, but are not inputs to the incident rates[2].

2.5 BP Traffic and Traffic Other Than BP

Modeled traffic is comprised of BP traffic and traffic other than BP (non-BP traffic). The total number of BP vessel calls is prescribed for each case. Non-BP traffic is modeled independently of the prescribed BP traffic. Development of the historical vessel traffic database is discussed in Section 5. Analysis traffic cases for BP traffic and for non-BP traffic are discussed in 7.6. Analysis cases reorganized by traffic components are discussed in Section 4.

Table 15 Traffic Components by Case

	Case						
Traffic Components	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BP Traffic							
BP single wing max: 1 Wing	X			X		X	
BP 2010 actual: 1 Wing		X					
BP 2010 actual: 2 Wings			X				
BP “High”: 2 Wings					X		X
Non-BP Traffic							
Non-BP Existing 2010	X	X	X				
Non-BP General 2030				X	X	X	X
Non-BP Cumulative 2030						X	X

---

[1] There are two notable incidents that occurred just prior and following the study period: In 1972, there was a 21,000 gallon spill at the BP Cherry Point facility; in 2012, there was a bulker allision at the Westshore Terminal, Port Metro Vancouver, BC.

[2] There is currently no bulk commodity terminal in the study area. Data from bulk spills outside the study area was used to formulate the bulker transfer error at dock incident rate. Spill volume distributions, discussed in Section 9, also use data from prior spills outside the study area due to limited data from within the study area.

2.5.1 BP Traffic

2.5.1.1 BP Vessels

BP Traffic is comprised of BP-calling tankers, and the BP-tugs escorting and docking the BP-calling tankers. A tanker in the study area is considered a BP-tanker before, during, and after it calls at the BP Terminal to unload or load crude oil or refined product cargos. A BP-tanker ceases to be considered a BP-tanker when it either a) leaves the study area or b) arrives at another terminal to unload or load cargo, whichever is sooner after its visit to the BP Terminal. Similarly, a tanker becomes a BP-tanker when it either a) enters the study area, or b) departs another terminal for BP, whichever is later in its transit to the BP Terminal. A tug in the study area is a BP-tug when a) assisting during moorage or maneuvering of BP bound vessels in the immediate vicinity of the marine terminal or b) escorting a BP bound vessel during any portion of a transit in the study area.

2.5.1.2 BP Calls

MX data shows total crude and product tanker calls to BP Cherry Point at 329 in 2010. According to figures BP provided to the study team, total tanker calls in 2010 were 332. The 1% discrepancy between the data sets is attributed to reporting error and considered negligible. This analysis was conducted using the MX data for 2010 (228 crude and 101 product calls). This distribution of 69% crude and 31% product is applied to the prescribed number of calls in 2010. Forecast BP tankers in 2030 are 65% crude and 35% product. This distribution is applied to BP tankers for cases in 2030. Table 16 identifies the number of crude, product, and total vessel calls for all BP traffic distributions.

Table 16 BP Crude, Product, and Total Calls by Case

BP Traffic Levels	Number of Calls			Case(s)
	Crude	Product	Total	
BP single wing max: 1 Wing - 2010	232	103	335	1
BP single wing max: 1 Wing - 2030	219	116	335	4 and 6
BP 2010 actual: 1 Wing	228	101	329	2
BP 2010 actual: 2 Wings	228	101	329	3
BP “High”: 2 Wings	274	146	420	5 and 7

2.5.1.3 BP Terminal Queuing Time

Queuing time is the delay between the issuance of the vessel’s Notice of Readiness and the actual docking time at the BP Terminal. Queuing time per vessel call was derived from historical demurrage and vessel call data provided by BP. Demurrage is an hourly fee paid by the terminal to an arriving vessel that is delayed due to lack of berth availability at the fault of the terminal. Two years of data from before and from after the North Wing began operation showed average demurrage rates of 1.49 days per call and 0.78 days per call, respectively. The second wing reduced demurrage, and thus queuing time, by 48%.

Historical Marine Exchange data was used to determine typical BP-calling vessel behavior. A typical BP tanker already anchors during its transit in and out of the study area. Queuing extends time at anchor, but does not add additional vessel moves or additional tug time. Queuing time per BP tanker call is added in all single wing Cases: 1, 2, 4, and 6.

2.5.2 Non-BP Traffic

Three non-BP traffic components are included in the case matrix; one is actual (2010) and two are forecast (2030). Actual 2010 and forecast 2030 BP traffic are subtracted from total traffic to define non-BP existing traffic in 2010 and non-BP general traffic in 2030, respectively. No BP traffic is subtracted from the total forecast cumulative traffic. Future general and cumulative traffic are defined as follows:

- General Traffic – Future general traffic includes forecasted changes in existing commercial deep draft, passenger, and commercial fishing traffic using the routes on which BP bound vessels are expected to operate.
- Cumulative Traffic – Future cumulative traffic includes vessel traffic using the routes on which BP bound vessels are expected to operate that does not currently exist.

Four projects were considered reasonably foreseeable by the study team and are included in forecasting cumulative traffic:

- New oil production from the Alaska OCS beginning in 2024.
- Shale oil production from the North Slope with substantial volumes online by 2016.
- Expansion of Kinder Morgan’s Transmountain pipeline to export oil to Asia in 2016.
- Bulk carrier and tug traffic calling at the Gateway Pacific Terminal Project by 2030.

High-end estimates are made for the cumulative traffic forecast.

Section 3 Description of the System

Each case in the matrix of cases (Table 1) will be evaluated by defining scenarios and determining the quantity of oil spilled in each scenario. A scenario is a combination of vessel type (v), vessel activity (a), incident type (i) and incident location (l); each case in the matrix is defined by forecast year (f), wing configuration (w), BP traffic calls (b), and non-BP traffic condition (t). The proposed analysis has six (6) vessel types, four (4) vessel activities, six (6) incident types and seven (7) locations. Thus, for each case in the matrix there are: $6 \times 4 \times 6 \times 7 = 1{,}008$ scenarios. The 1,008 scenarios are assumed to include all combinations of the scenario parameters that will significantly contribute to the quantity of oil that may possibly be spilled. An example scenario is: a tanker while underway has a collision in the Strait of Juan de Fuca East. The parameters (identified by indices and subscripts in the following sections) for this scenario are:, $v = 1$, $a = 1$, $i = 1$, $l = 2$. The taxonomy of project scenarios is summarized in Table 17.

Table 17 Project Scenario Parameters

Vessel Type (*v*)	Activity Type (*a*)	Incident Type (*i*)	Location (*l*)
1. Tanker	1. Underway	1. Collision	1. Strait of Juan de Fuca West
2. Tank Barge	2. Maneuvering	2. Allision	2. Strait of Juan de Fuca East
3. Bulker	3. At dock	3. Grounding	3. Rosario Strait
4. General Cargo	4. At Anchor	4. Transfer Error	4. Haro Strait and Boundary Pass
5. Tugboat		5. Bunker Error	5. Cherry Point
6. Passenger or Fishing Vessel		6. Other Non-Impact Incident	6. Saddlebag (including Vendovi Anchorages)
			7. Guemes Channel and Fidalgo Bay

3.1 Geographic Subareas (*l*)

The geographic study area is divided into seven subareas: Strait of Juan de Fuca West, Strait of Juan de Fuca East, Rosario Strait, Haro Strait and Boundary Pass, Cherry Point, Saddlebag, and Guemes Channel and Fidalgo Bay, Figure 6.

The Strait of Juan de Fuca is an international waterway that separates the south shore of Vancouver Island in British Columbia (BC), and the north shore of the United States Olympic Peninsula in Washington State. The entrance of the Strait lies between Cape Flattery, Washington (48°23′43″N, 124°44′11″W) to the south, and Carmanah Point, Vancouver BC (48°36′38″N, 124°45′00″W) to the north, and is an important waterway that connects the Pacific Ocean to passages in Puget Sound, BC, and Southeastern Alaska via the Inside Passage.

The vessel traffic through this area is extensive, both domestic and foreign, serving the lumber, fishing, rail, grain, cruise, oil, coal, and containerized cargo industries. In addition, both the United States and Canadian militaries have bases in the region and use several areas for the training and testing of weapons.

From the mouth to 50 nm east at Race Rocks, the Strait is generally about 12 nm wide, then widens to almost 16 nm for the next 30 nm east to Whidbey Island on the eastern boundary. The Strait is deep to the near shoreline as a rule, with very few outlaying dangers except in the eastern part.

Navigating these waters is relatively easy in clear weather using the numerous and well-placed navigational aids. During fog, however, caution must be used due to the strong and irregular currents that influence the set and drift of the ship and the detection of other traffic, especially in the eastern part (Reference 2).

The IALA Buoyage System – B (International Association of Lighthouse Authorities - Region B) is used for the Strait of Juan de Fuca, Haro, Georgia Strait, and Rosario Strait. This system is also used in the Eastern Pacific, Atlantic and Pacific Coasts of North and South America, the Great Lakes, the Caribbean, Japan, Philippines, and the Republic of Korea (Reference 3). The *International Regulations for Preventing Collisions at Sea*, 1972 (‘72 COLREGS, Reference 4) apply to all waters of the Strait of Juan De Fuca, Haro Strait, Strait of Georgia, Rosario Strait, and Puget Sound.

For the purposes of this study, Haro Strait is defined as the waters north of a line between Discovery Island, which is located just east of Victoria, to Cattle Point at the southern tip of San Juan Island. The Strait’s northern boundary is a line that runs between Point Fairfax on Mosby Island to Turn Point on Stuart Island, where it then turns into Boundary Pass and then turns into the Strait of Georgia.

Haro Strait is a major shipping waterway that connects the Strait of Juan de Fuca to Boundary Pass and the Strait of Georgia, and is mainly used by vessels transiting to and from Vancouver BC and Alaska through the Inside Passage. The 30 nm passage, from the southern end at Discovery Island to the northern end abeam Patos Island where the passage opens into the Strait of Georgia, straddles the international boundary between the United States and Canada. Depths in the Strait range from 160 fathoms in the deepest areas, to 20 fathoms in the shoal areas.

Pilotage for Canadian vessels transiting Haro Strait is required for every ship over 350 gross tons that is not a pleasure craft and every pleasure craft over 500 gross tons (Reference 5). For US-bound ships, pilotage is compulsory for all foreign vessels and US vessels engaged in foreign trade. Pilotage is optional for US vessels engaged in the coastwise trade with a federally licensed pilot on board (Reference 2).

Rosario Strait is the easternmost channel leading from the Strait of Juan de Fuca to the Strait of Georgia. The Strait’s southern end begins abeam of Davidson Rock and runs north 16 nm to Lawrence Point on Orcas Island. Its widest point is 5 nm between Davidson Rock and Deception Island, which narrows to 1.5 nm between Blakely Island and Strawberry Island. The depths range between 13 fathoms in the south end to 53 fathoms in the north end, with an average depth of approximately 30 fathoms.

Rosario Strait is regularly used by tankers calling at refineries at Cherry Point and Anacortes, and by vessels transiting to Bellingham. It is sometimes used by vessels headed to or from Vancouver and Alaska when there is a tidal current advantage compared to those in Haro Strait (Figure 6).

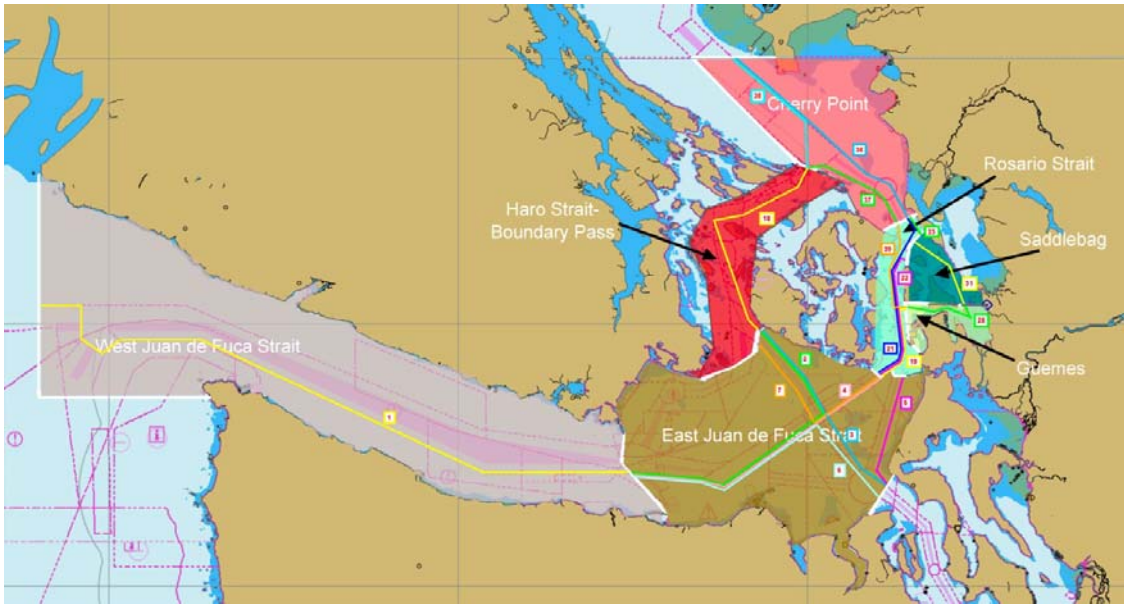

Figure 6 BP-VTA Study Area

3.2 Vessel Type Classification (*v*)

Six vessel types are analyzed: Tanker, Tank Barge, Bulker, General Cargo, Tug, and Fishing and Passenger Vessels. Capacities and traffic patterns for crude carriers and product tankers are modeled separately. Grain and non-grain bulkers are studied separately for their traffic patterns, but are grouped in presentation and in the analysis. Container ships and general cargo ships are also studied separately and grouped as general cargo ships. Fishing vessels, cruise ships, and ferries are also studied separately and grouped as the "Fishing and Passenger Vessel" vessel type. Only tankers and tank barges are considered to carry and have the potential to spill cargo oil. All vessel types are considered to carry and have the potential to spill bunker oil. A bunkering tank barge may spill bunker fuel in a bunkering error. Otherwise, the onboard oil is considered cargo oil. Vessel traffic days and incidents statistics as modeled in this risk assessment are categorized into these six types.

Small fishing, charter, and recreational watercraft were not included in the statistical analysis because their movements and behavior could not be accurately tracked with the data sources available, and they are assumed to represent insignificant quantities of oil outflow. Military vessels are active in the study area, but data regarding their movements are not available, for obvious reasons.

3.3 Vessel Activity Classification (*a*)

The four project-specific activity categories are: Underway, Maneuvering, Docked, and Anchored. A vessel is categorized as underway when transiting subareas within the study area. While underway, it is assumed that the vessel is operating at a constant speed and is en route to a given point (i.e., not loitering). The time spent maneuvering to and from anchorage or berth is categorized as maneuvering. While maneuvering the vessel is either operating at a reduced speed in anticipation of stopping, or is still gaining speed as it moves from an anchored or berthed position. Large vessels, such as tankers, container vessels and bulkers, are expected to require 135 minutes (2.25 hours) maneuvering to and from an anchorage, and

120 minutes (2 hours) maneuvering to and from a berth. For tugs maneuvering time is significantly less, and is estimated as somewhere between 15 minutes (.25 hours) and 75 minutes (1.25 hours), depending on whether or not the tug is maneuvering with or without a tow. Time in these four activity times, when summed, equal the total exposure time in the system. With the four activities delineated, their relative risk can be assessed. Vessel traffic days and incidents statistics are categorized into these four activity types.

3.4 Incident Type Classification (*i*)

The six (6) incident types are collision, allision, grounding, transfer error, bunker error, and other non-impact incident. Collisions, allisions, and groundings are impact incidents. A collision occurs when two vessels are in the same place at the same time. Collision records only necessarily report the larger of the vessels involved. Allisions occur when a moving object makes contact with a stationary object, such as when a moving vessel hits a pier, or a stationary vessel is hit by another vessel. Drift and powered groundings are included as they occurred historically, but they are not differentiated in the incident rates. Transfer errors, bunker errors, and other non-impact incidents are non-impact incidents. Internal transfer errors are not included. Only over water transfers are included. The other non-impact incident type includes the following causes: equipment failures, fires, explosions, operator errors, and structural failures. Historical incidents with unknown cause are also assigned to the other non-impact incident type.

A vessel "incident" is an event or circumstance deemed by the US Coast Guard or Washington Department of Ecology to have the potential for an oil spill. A spill may or may not have occurred. "Spills" are a subset of incidents.

Section 4 Incremental Risk Assessment Model

The objective of the Incremental Risk Assessment Model is to predict the locations and quantities of incidents, spills, and volumetric oil outflow for the seven cases. The model uses historical incident and traffic data to predict the annual rate at which incidents occur that may result in oil outflow. The results can then be compared to quantify the incremental risk between each of the seven cases. Traffic volumes by vessel type are forecasted for different geographic regions throughout the system. Forecasted traffic is categorized by size and by number of hulls (i.e., single or double hulled). Because of uncertainty in projections and variability in historical data, a Monte Carlo simulation is employed to generate a probabilistic set of potential outcomes. Section 4.1 describes the process used to generate a single outcome. Section 0 describes how the Monte Carlo simulation method is used to predict the entire set of potential outcomes and the probability that each outcome will occur. Section 4.2 describes the programming environment in which the incremental risk assessment algorithm was implemented. A flow diagram is presented to illustrate the Monte Carlo simulation method, Figure 8.

4.1 Scenario Spill Volumes ($SV_{c,v,a,i,l}$)

Total oil outflow for a given case is determined by summing all the individual spills that occur in that case. Determination of the quantity and volume of individual spills is accomplished by breaking the system into scenarios that represent each potential occurrence of oil outflow, and sampling each scenario to determine if that scenario results in any spills of oil cargo, bunker fuel, or some combination thereof. Scenarios are defined by six (6) vessel types (v), four (4) activity types (a), six (6) incident types (i), and seven (7) locations (l), as defined in Section 7. Thus there are 6 × 4 × 6 × 7 = 1,008 scenarios for each analysis case.

These 1,008 scenarios are assumed to include all combinations of the scenario variables that may significantly contribute to the quantity of oil spilled. Other vessel types that are not included in the scenario set, such as pleasure boats, do have spills, but the sizes of their spills are small enough that their inclusion in the model would result in an immeasurable difference in the outcome, and therefore not affect the results. Total annual oil outflow for a given case is defined by the summation of spill volume for each scenario ($SV_{c,v,a,i,l}$), as shown in Equation 1.

$$\textit{Total Annual Outflow(c)} = \sum_{v=1}^{6}\sum_{a=1}^{4}\sum_{i=1}^{6}\sum_{l=1}^{7} SV_{c,v,a,i,l} \qquad 1$$

Spills may occur as the result of incidents that have the potential to result in a spill. It is necessary, therefore, to determine the rate at which incidents occur and the probability that a spill occurs, given an incident, for each scenario. Historical traffic and incident counts are used to derive incident rates. The historical baseline is the 16 years between 1995 and 2010. The vessel traffic and incident databases are summarized in Sections 5 and 6.

Incident Rates (*IR*) in units of incidents per vessel traffic day are calculated by dividing the number of incidents by the number of vessel traffic days. Incident and traffic data are from the same time period, vessel type, activity, and subarea or from the same grouping of these parameters. Incident rate statistics are formulated and presented in Section 7. Vessel traffic modeled and forecast for each given case is presented in Section 8.

Since the model is concerned with oil outflow for a given future year, it is necessary to determine the forecasted mean yearly incident rate ($\lambda_{c,v,a,i,l}$). This is accomplished by multiplying the historical incident rate by the forecast number of traffic days for the given scenario, as defined by Equation 2.

$$\lambda = IR \times TD \qquad 2$$

To determine the number of incidents that occur for a given scenario, it is assumed that the number of incidents that occur each year for each scenario follow the Poisson distribution. A Poisson distribution is used to describe the probability of an event for which the average rate of occurrence is known and the events occur independently of the time since the last event (the occurrence of an event has no bearing on the time before the event occurs again). It is often used to describe very rare events. Shipping incidents that might result in contaminant release are considered very rare events, and it is assumed that an event occurring on one vessel will not affect the time before another event occurs on another vessel. Therefore, the Poisson distribution is assumed to be a representative distribution of, and is used to sample, the number of incidents that occur for each scenario. Equation 3 defines the Poisson distribution probability that the number of incidents ($NI_{v,a,i,l}$) will occur for a given forecasted mean yearly incident rate ($\lambda_{v,a,i,l}$).

$$P(NI) = \frac{\lambda^{(NI)} e^{-\lambda}}{(NI)!} \qquad 3$$

By defining $P(NI_{v,a,i,l})$ as a random number between 0 and 1 and solving for $NI_{v,a,i,l}$, the number of incidents for the given scenario is determined. For each incident that occurs, the probability that it results in a spill is given by the Spill Probability ($SP_{c,v,i}$). By generating a random number between 0 and 1 and comparing it with ($SP_{c,v,i}$), it is determined whether or not a spill occurs.

When a spill does occur, it is necessary to determine the spill volume ($SV_{c,v,a,i,l}$). Spill volume is sampled directly for bunker and transfer errors. For impact and other non-impact incident types, spill volume is the product of Outflow Percent ($OP_{v,i}$) and Vessel Capacity ($VC_{c,v}$), as defined in Equation 4.

$$SV = OP \times VC \qquad 4$$

Spill probabilities ($SP_{c,v,i}$) are presented in Section 9.1 and Outflow percentages ($OP_{v,i}$) for each combination of vessel type and incident type are presented in Section 9.2 and Appendix D. Vessel Capacities ($VC_{c,v}$) are described in Section 9.3. For bunker and transfer errors, spill volume is sampled directly. Spill probabilities and outflow percentages are from historical data. The vessel's capacity is either the actual 2010 fleet capacity or the forecasted (2030) fleet capacity.

4.1.1 Example of Random Variable Sampling

Figure 7 shows an example of a graphed outflow percentage cumulative distribution function. To sample this cumulative distribution function, a random number is generated between 0 and 1 and is designated as the sampled probability. The outflow percentage is then found by interpolating between points on the outflow percentage curve at this sampled probability. In the case of the example in Figure 7, the random number generated was 0.7, resulting in a sampled outflow percentage of 0.0001%.

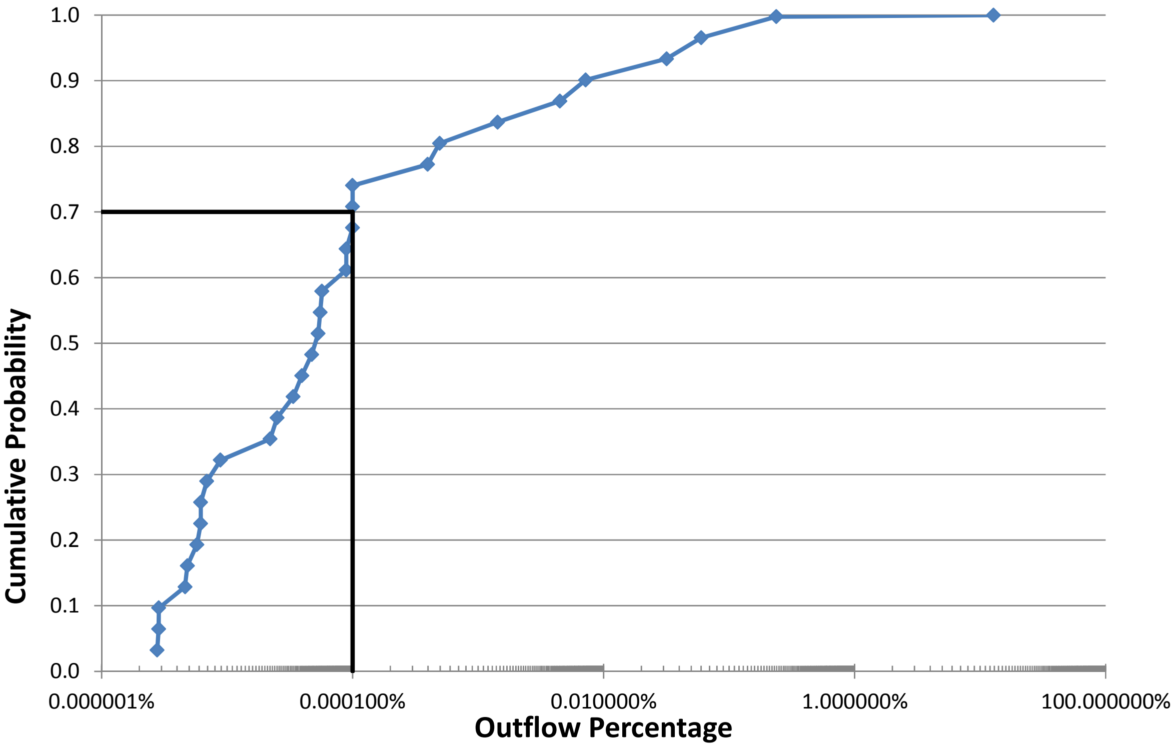

Figure 7 Example Outflow Percentage Cumulative Distribution Function – Monte Carlo Simulation

The variables used to determine total oil outflow have variability and uncertainty. The uncertainties are due to the errors in the historical record, sampling errors introduced by the small population of the data set, and uncertainties in the extrapolation to forecasted values. *IR, TD, SP, OP, VC,* and *SV* are not deterministic and are thus probabilistically distributed, meaning that each stochastic sample for each variable will return a different value, within bounded ranges and with probabilities defined by distribution parameters[3]. There is one exception to this rule: vessel traffic in 2010 is deterministic.

Distributions are written as cumulative distribution functions. An analytic inverse cumulative distribution function or a lookup function is implemented to take a random number (0,1) as input and return a sampled value. Because one or more of these variables are probabilistically distributed, one summation across all scenario outflows ($\sum SV_{c,v,a,i,l}$) will result in *one stochastic result* of total annual oil outflow volume. In order to understand the uncertainty inherent in the prediction of potential outflow volumes and the likelihood that each outflow volume will occur, it is necessary to calculate total oil outflow many times. The Monte Carlo method is thus employed to build a probability distribution of possible solutions of total annual oil outflow.

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[3] For example, Outflow Percentage ($OP_{v,i}$) is bounded by 0% to 100%, with a mean typically skewed towards the lower end of the bounds, since only on rare occasion does a spill result in the outflow of a majority of the total vessel capacity.

Each solution of total oil outflow is called a stochastic result. Each of the 1,008 scenarios are calculated for 10,000 stochastic results, for a total of 1,008 x 10,000 = 10,080,000 (10.08 million) calculations of scenarios potentially resulting in spills, for each case The Monte Carlo simulation cycles through each case parameter and scenario parameter, building a database of incidents and spills identified by these parameters, as detailed in Figure 5. For each scenario in each case, the Monte Carlo simulation generates random numbers within the range of possible values for each variable to determine the sample values summarized in Table 18.

Table 18 Variables Generated by Monte Carlo Simulation

Traffic Days (*TD*)	The unit of time describing the number of days per year a vessel is engaged in a given activity type (*a*) in a given location (*l*).
Number of Incidents (*NI*)	The number of annual incidents that occur for a given scenario incident rate (*IR*) and traffic days (*TD*).
Vessel Capacity (*VC*)	The capacity of the vessel for a given forecast year (*f*) and vessel type (*v*). Several other random numbers are sampled to determine the vessel capacity, depending on vessel type (*v*), as detailed in Section 9.3.
Vessel Hull Type (*SH/DH*)	For a given vessel type (*v*), whether the vessel is single-hulled or doubled hulled.
Spill Probability (*SP*)	For a given incident, whether a spill occurs.
Outflow Percentage (*OP*)	For a given spill, the percentage of the vessel capacity spilled.

The final product for each case is an array of summed spill volume (gallons) corresponding to 1/10,000 probability increments. Spill volumes for the ten thousand samples are sorted and plotted as cumulative probability distributions. A comparison between the seven matrix cases can be made by comparing the cumulative probability distribution functions of number of incidents, number of spills, and spill volumes. Further discussion on generating and interpreting results is given in the results section, Section 10.

4.2 Programming Environment

The Monte Carlo simulation is programmed using the Python(X,Y) distribution of the Python programming language, as given by Reference 24. Python is an object-oriented, interpretive language often used by scientists and engineers to perform computationally intensive calculations, due to its simplicity, robustness, and expansive open-source software library. Input data from Microsoft Excel is read into the program with xlrd, as given by Reference 25. Random numbers are generated and cumulative distribution functions are interpolated using SciPy, as given by Reference 26. Results are plotted using MatPlotLib, as given by Reference 27.

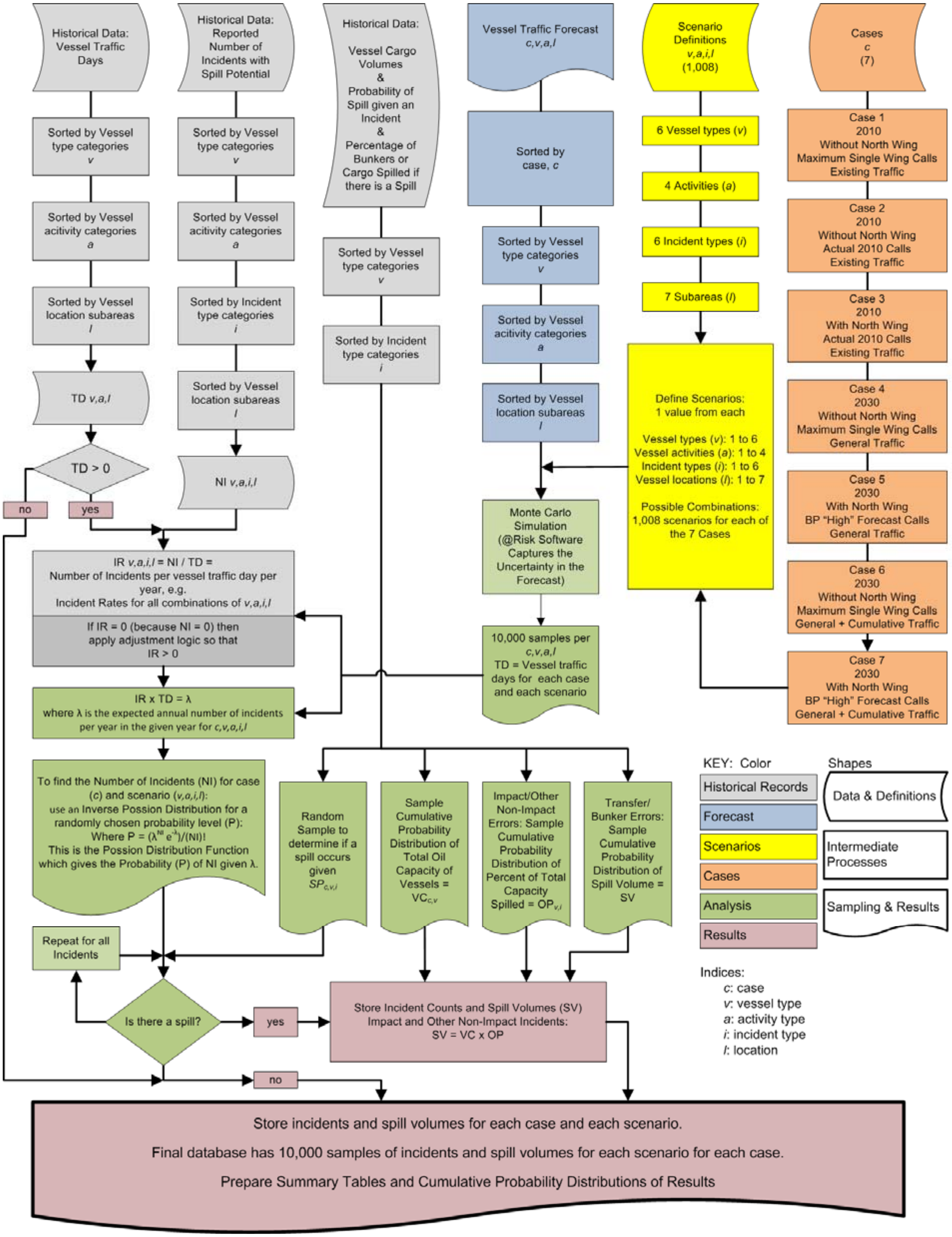

Figure 8 Monte Carlo Simulation Flow Diagram

Section 5 Vessel Traffic Database

NEI examined the historic and current patterns of traffic and anchorage usage in the Study Area. Their report summarizes the vessel traffic database and analysis methodology. The analysis is based on vessel traffic volumes from 1995-2010, presented in units of traffic days. Traffic days spent in each subarea by deep draft vessels remained somewhat consistent through this time period. The three sections of the vessel traffic database report are summarized as follows, and the report is included as Appendix A.[4]

5.1 Transits and Calls

The "Transits and Calls" section of Appendix A describes the basic activities and transit patterns of non-BP tankers, BP tankers, bulkers, container vessels, general cargo vessels, tugs, cruise vessels, ferries, and large fishing vessels. Tugs, passenger vessels, and large fishing vessels are grouped into one vessel category called "Other" in Appendix A. As an example, two typical tanker itineraries are shown in Figure 9.

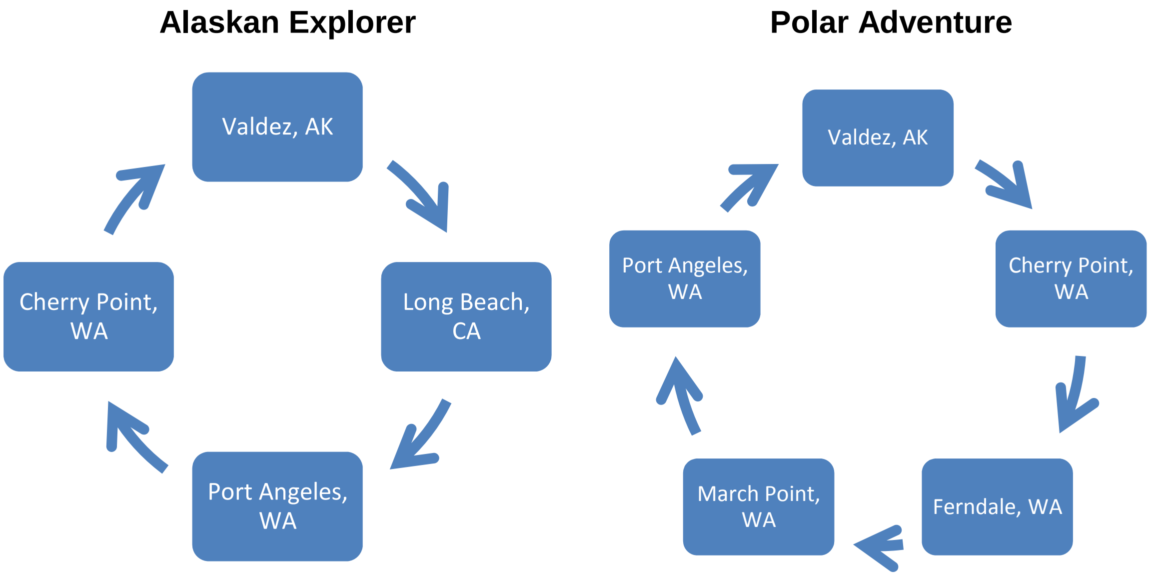

Figure 9 Sample Tanker Itineraries, 2010

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[4] The Section 5 Vessel Traffic Database is an input to the Section 8 Traffic Forecast and to the Section 7 Incident Rates (IRs). The Forecast is based on the final data presented in Appendix A. The Incident Rates are based on the data presented in the draft report, delivered 15 May 2013. Summary traffic data presented in this section report is also based on the earlier hindcast. The differences between the two versions are small.
The main differences are in the tug vessel traffic days and in the maneuvering vessel traffic days. There are more tug days in the final hindcast. Tug homeports were revised when new data became available. Assumptions on required maneuvering time were revised to be longer. An increase in historical traffic would lower the IRs. Higher IRs are conservative for predicting risk. The incremental risk between cases is not affected.

5.2 Vessel Traffic Data

The "Vessel Traffic Data" section of Appendix A summarizes the vessel traffic by vessel type, subarea, and activity type. This section includes a description of the data sources and modeling methods used in producing the results. Average (1995 - 2010) traffic days by subarea and vessel type are shown in Figure 10. Average traffic days by subarea, vessel type, and activity type are shown in Table 7a. The appendix results include charts of average traffic days by activity type, bar graphs of average traffic days by subarea, and tables of traffic days by subarea by year for each vessel type.

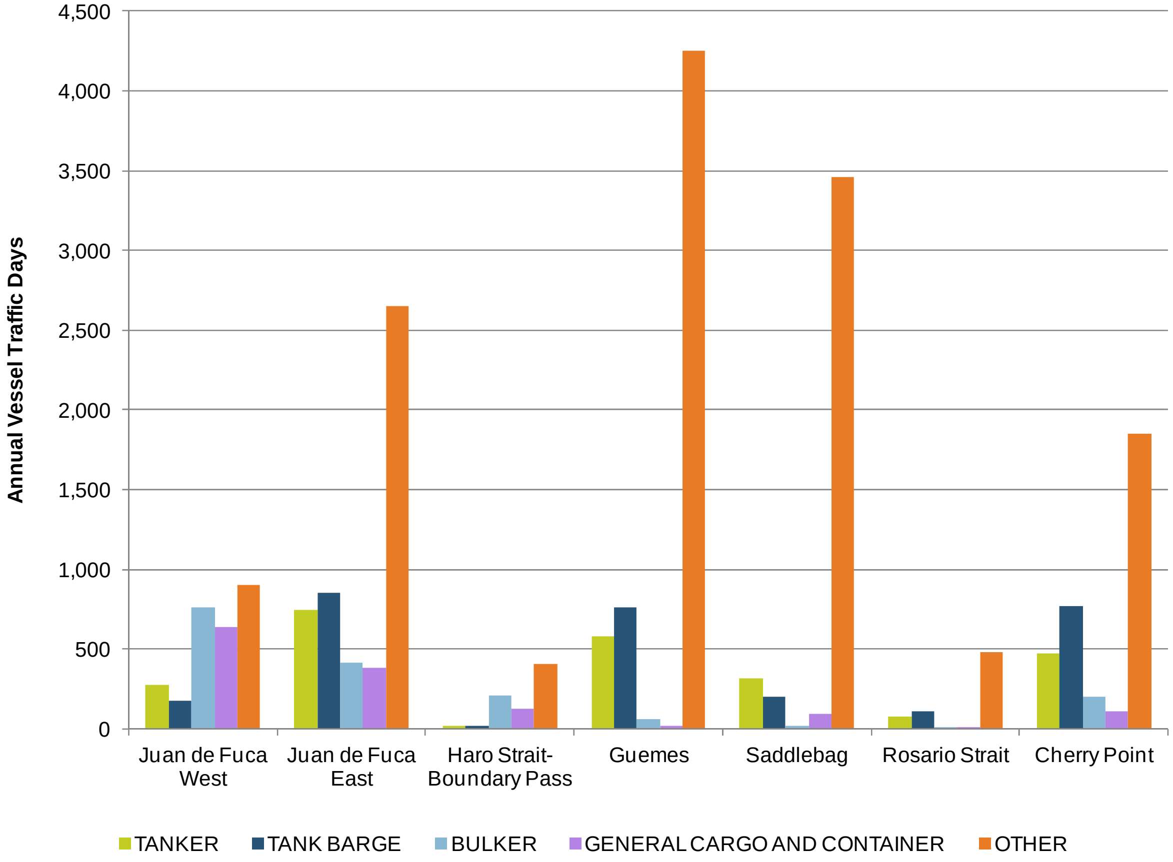

Figure 10 Traffic Days by Subarea and Vessel Type, Average (1995–2010) (Source: NEI, 2013)

Table 7a Average Vessel Traffic Days (1995–2010) by Subarea, Vessel Type and Activity Type (source: Northern Economics, Inc. 2013).

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Underway							
Tanker	277.4	152.1	20.0	24.9	4.1	74.1	67.1
Tank Barge	173.8	210.1	16.6	22.6	3.1	124.4	182.2
Bulker	760.0	372.3	210.7	1.4	0.1	2.9	161.5
Cargo	641.5	347.4	125.6	0.5	0.03	3.4	106.9
Tug	486.7	668.9	79.3	64.7	42.20	403.3	565.5
Passenger and Fishing	427.5	338.3	82.3	124.3	17.9	36.3	143.1
Maneuvering							
Tanker	0.0	22.6	**0.0**	25.3	6.2	**0.0**	32.4
Tank Barge	0.2	27.7	0.3	47.1	9.8	**0.0**	52.0
Bulker	**0.0**	4.5	**0.0**	1.0	0.3	**0.0**	1.4
Cargo	**0.0**	2.5	**0.0**	0.5	0.1	**0.0**	**0.0**
Tug	0.3	33.8	0.8	57.3	15.89	0.8	59.5
Passenger and Fishing	**0.0**	0.3	**0.0**	0.7	2.1	**0.0**	**0.0**
Anchored							
Tanker	**0.0**	428.0	**0.0**	300.5	305.8	**0.0**	12.1
Tank Barge	**0.0**	602.3	**0.0**	292.2	110.7	**0.0**	**0.0**
Bulker	**0.0**	32.5	**0.0**	4.2	0.6	**0.0**	1.4
Cargo	**0.0**	22.0	**0.0**	2.6	0.1	**0.0**	**0.0**
Tug	**0.0**	779.8	**0.0**	383.6	124.65	**0.0**	**0.0**
Passenger and Fishing	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Docked							
Tanker	**0.0**	140.0	**0.0**	232.6	**0.0**	**0.0**	364.0
Tank Barge	2.0	14.8	3.6	403.8	73.5	**0.0**	558.1
Bulker	**0.0**	6.9	**0.0**	51.7	21.2	**0.0**	39.8
Cargo	**0.0**	12.6	**0.0**	13.2	96.0	**0.0**	**0.0**
Tug	7.3	87.4	24.6	787.3	348.90	37.2	901.1
Passenger and Fishing	**0.0**	749.7	220.5	2833.9	2911.9	**0.0**	179.0

5.3 Anchorages

The "Anchorages" section of Appendix A presents utilization at the eight primary anchorages in the study area, located at Cherry Point, Bellingham Bay, Vendovi Island, Anacortes, and Port Angeles. The Bellingham Bay and Vendovi Island anchorages are in the Saddlebag subarea. The Anacortes anchorages are in the Guemes subarea. The Port Angeles anchorages are in the Juan de Fuca East subarea. Traffic days at anchor by subarea are shown in Figure 8.

Anchor times by vessel type, year 2006-2010, and subarea are included as Table 13 of the appendix.

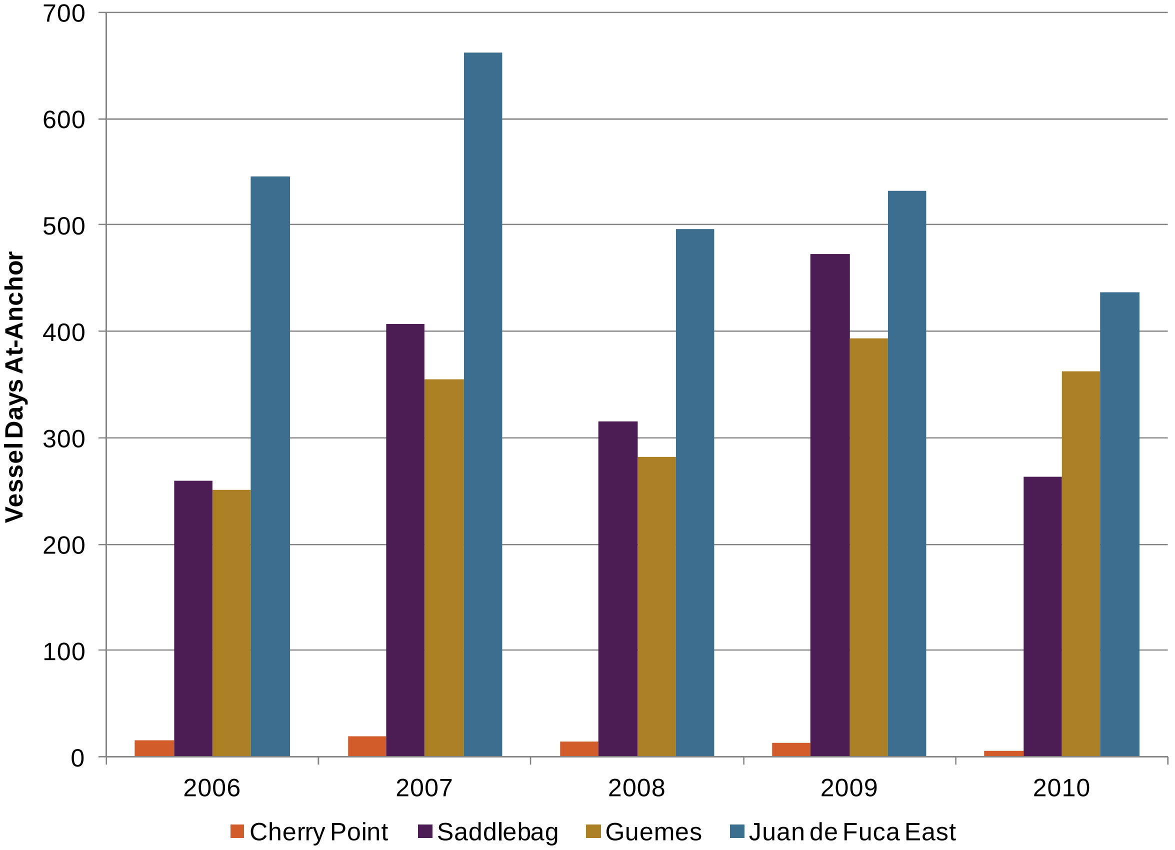

Figure 11 **Vessel Traffic Days at Anchor by Subarea by year (2006–2010) (Source: NEI using USCG 2012)**

5.4 Vessel Transit Speed

Underway vessel transit speeds are modeled by vessel type and by subareas in Table 7b. Transit speeds are averages for all vessels within a vessel type category in the study area. There are two reasons for average tug transit speeds being slower than tanker transit speeds. First, a tug pulling a tow (such as a load of logs) will transit at a much slower speed than an escort tug. This means that the average speed of tugs during all modes of transit is less than the speed of tugs just during escorting. Secondly, tankers have higher top speeds than tugs. When tankers pick up an escort tug, they reduce speed to match their escort tug(s). In all other transiting situations, they have a higher average speed. Thus, the average transit speed of tankers in all modes of transit is higher than the average transit speed of tankers during escorting.

Table 7b Vessel Transit Speeds (in nautical miles per hour)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
Tanker	13.29	12.81	13.82	8.24	9.01	11.52	12.72
Bulker	13.00	12.18	13.69	5.43	10.96	11.95	13.42
Container	18.17	18.76	20.25	15.36	15.36	15.36	18.32
Gen Cargo	16.09	15.29	16.01	4.34	10.57	10.56	13.79
Cruise Vessels	19.16	16.29	15.85	3.53	14.75	10.92	7.98
Tug	8.65	8.51	7.71	6.37	8.93	8.20	8.20

5.5 Data Sources

NEI obtained data on vessels calling at ports in the State of Washington and the relevant ports in British Columbia. The geographic scope of the analysis includes the major waterways between Cherry Point and Buoy J, including the Strait of Juan de Fuca, Rosario Strait, the Strait of Georgia, and alternate routes used for accessing the ports of northern Washington.

Vessel traffic volumes were requested for the most recent year available and the five years previous to this year, by month. This analysis is based on vessel traffic volumes from 1995-2010.

Data on the State of Washington’s piloted, deep draft vessels was accessed through the Marine Exchange of Puget Sound. The primary role of the Marine Exchange is to track and monitor vessel movement activity and share this activity information with the membership in a timely manner to support safe, secure, efficient, and environmentally responsible maritime operations. Their tracking capability is heavily based on region-wide shore-based Automatic Identification System (AIS) capability. The Marine Exchange is able to provide vessel volumes for the State of Washington by current port of call, last port of call, next port of call, vessel type and arrival and departure dates, among other variables.

Data on vessels in British Columbia is supplied by the Canadian Coast Guard’s Victoria Marine Communications and Traffic Services (MCTS). Located on Vancouver Island, Victoria MCTS provides Coast Guard Radio and Vessel Traffic coverage to British Columbia’s southern inside waters; specifically, all waters between Juan de Fuca Strait to the south and Ballenas Island to the north.

Vessel traffic volumes obtained from the aforementioned sources were compared to The State of Washington’s Department of Ecology Vessel Entries and Transits annual report (VEAT). VEAT summarizes commercial vessel traffic in Washington waters on an annual basis, and adds value to our analysis by providing a greater level of detail on the routes taken by the various commercial vessels. VEAT provides the volume of entering transits and individual vessels bound for Washington ports in Puget Sound via the Strait of Juan de Fuca, Strait of Georgia, and Haro Strait.

5.6 Bunkering Demand

The additional berth at BP Cherry Point may change bunkering demand due to additional vessel calls. Additional vessels calling at BP Cherry Point will have a commensurate additional demand for bunker fuel. BP Calling vessels may bunker at Anacortes, Bellingham, Everett, and Ferndale. They will most likely bunker at Port Angeles.

Section 6 Historical Incidents and Spill Statistics

6.1 Incident Data Sources

Historical incidents are reported in ERC's report, *Characterization of Historical Vessel Incidents*, which is included as Appendix B. ERC has developed proprietary databases of oil spill and vessel casualty (and other incident) incidents. A variety of the best available public and proprietary primary reporting sources and existing databases have been used for developing ERC case records, including:

- National Response Center Incident Reports.
- US Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) Marine Casualty and Pollution Database.
- US Coast Guard CASMAIN Database [VCAS (Vessel Casualty) and PCAS (Pollution Case)].
- US Coast Guard Marine Safety Information System, Lloyd's Maritime Casualty Database.
- Emergency Response Notification System.
- International Tanker Owners Pollution Federation Database.
- US Coast Guard Compendium Database.
- US Coast Guard Pollution Incident Reporting System.
- International Oil Spill Database, Office of Pipeline Safety (now Pipeline and Hazardous Material Safety Administration) databases.
- Approximately 36 state-specific databases, including Washington Emergency Response Tracking System (ERTS).

Each incident may appear in numerous databases. ERC creates a single record for each incident based on the comparison of data from the various sources and incorporating de-duplication, corrections, validation, cross-checking, and other quality control measures to derive the most complete record possible.

6.2 Number of Incidents (*NI*) Database

A customized database was developed by ERC to include only records relevant to the BP-VTA. Incidents were categorized by the project-specific scenario parameters to allow for matching with the vessel traffic database, as described in Section 5.

A total of 1,116 vessel incidents that occurred in the study area during the years 1995 through 2010 were categorized and analyzed. The largest percentage (62%) of vessels involved in these incidents do not fall into any of the vessel types defined in this study. Those not included in the study are: fishing vessels less than 60 feet in length, pleasure craft, workboats, freight barges of any size, and vessels for which there is no traffic data available. The vessels for which there is no traffic data include: research vessels, military (public) vessels, passenger vessels other than regularly-scheduled ferries and cruise ships, offshore supply vessels, oil recovery vessels, industrial vessels, anchor handlers, and workboats.

The remaining 429 vessel incidents include those involving bulkers (15), general cargo vessels (50), tankers (40 crude tankers and 50 product tankers), tank barges (36), tugs (89), and the

‘Passenger and Fishing Vessel’ vessel type (149). The ‘Passenger and Fishing Vessel’ type includes cruise ships, ferries, and fishing vessels longer than 60'. Vessels within these six types are considered VTA vessels for the purposes of this study.

Each of the 429 incidents involving VTA vessels are categorized by the project-specific scenario parameters and by historical year y, $I_{v,a,i,l,y}$. The numbers of incidents (NI) are tabulated by year (NI_y), scenario parameter (NI_v, NI_i, NI_l), combinations of scenario parameters ($I_{v,i}$, $I_{v,a}$, $I_{v,a,i}$, $I_{i,l}$), and scenario parameter and year ($NI_{l,y}$, $NI_{v,l,y}$). ERC used various geographic information system databases to identify and classify incident locations. Figures in *Characterization of Historical Vessel Incidents* (Appendix B) show incident locations within subareas by incident type and vessel type on subarea maps. The incident database is organized by the project-specific scenario parameters to align with the organization of the traffic database. Incident rates herein are based on this database of 429 incidents.

Each vessel incident was also analyzed with regard to whether a spill occurred or did not occur within Appendix B. Spill probability and outflow percentage is discussed further in Section 9.

Section 7 Incident Rates

Risk is interpreted in this report as the probability of an incident, a spill, and volume of spill outflow. This section addresses the probability of an incident. Incident rates are a numerical representation of the likelihood of an incident for a given scenario. Incident rates are in the units of number of incidents per vessel traffic day.

Section 7.1 of this report describes the formulation of incident rates from historical data. Section 7.2 addresses scenarios that do not occur or have no potential for an incident and, thus, have a zero incident rate. Section 7.3 addresses scenarios that have zero historical incidents but can result in incidents, and formulates an adjusted, non-zero incident rate. Resultant incident rates are presented in Section 7.4. Additional incident rate summaries and validation are discussed in Sections 7.5 and 7.6.

7.1 Incident Rate (IR) Approach

Incident probability statistics are formulated and presented as incident rates. Incident rates are numerical representations of the likelihood of incidents. Historical incident counts and historical traffic are used to derive incident rates. The historical baseline is the 16 years between and including 1995 and 2010. Incident Rates (*IR*) are calculated by dividing the number of incidents (*NI*) by the number of vessel traffic days (*TD*). Symbolically, $IR = NI / TD$, where incident and traffic data are from the same time period, vessel type, activity, and subarea or from the same grouping of these parameters.

Incident rates are developed for every scenario. Scenarios are defined by four scenario parameters: six (6) vessel types (v), four (4) activity types (a), six (6) incident types (i), and seven (7) locations (l). The set of selected values for each parameter is defined in Section 7.1.1. The exhaustive enumeration of scenario parameter combinations is $6 \times 4 \times 6 \times 7 = 1{,}008$ scenarios. These 1,008 combinations are assumed to include all scenarios that could significantly contribute to the quantity of oil that may be spilled.

7.1.1 Incident and Traffic Baseline

Incident and traffic data used to derive incident rates are from the project study area over the 16-year historical time period between and including 1995 and 2010. It is necessary to align incident data with traffic data to define an incident rate with respect to vessel traffic, as opposed to a temporal rate. Both the incident data and the traffic data are categorized by the same scenario parameters and by the same set of possible values within each parameter.

The four project-specific parameters and parameter values that combine to form all possible scenarios are summarized in Table 17. The number of incidents is categorized by vessel type (v), activity type (a), incident type (i), and locations (l), $NI_{v,a,i,l}$. The incident study introduced in Section 6 obtained values of $NI_{v,a,i,l}$ for every v,a,i,l combination (scenario). Traffic days are categorized by vessel type (v), activity type (a), and locations (l), $TD_{v,a,l}$. A vessel traffic study, as introduced in Section 5, was performed to obtain values of $TD_{v,a,l}$ for every v,a,l combination. These aligned inputs allow for the formulation of incident rates in terms of number of incidents per traffic day.

7.1.2 IR Incident Rate Formulation

Incident rates are calculated by dividing number of incidents by number of vessel traffic days. Symbolically, $IR = NI / TD$, where incident and traffic data share the same time period, vessel type, activity, and subarea. Equation 5 shows this formulation with subscripts indicating scenario parameters, summed over the 16-year baseline. Each incident rate is with respect to the selected scenario combination of parameter values: *v*, *a*, *i*, and *l*.

$$IR_{v,a,i,l} = \frac{\sum_{y=1995}^{2010} NI_{v,a,i,l,y}}{\sum_{y=1995}^{2010} TD_{v,a,l,y}} \qquad 5$$

Incident Rates may also be calculated for a group of scenarios. While an incident rate is needed for each of the 1008 scenarios, there are relatively few historical incidents over the 16 year baseline. From the sparse dataset of 429 incidents, there are zero historical incidents for 883 of the 1008 scenarios (88%). Some of these scenarios should, in fact, have zero incidents, because they do not occur in the study area. For example, there are no bulk carrier berths in the Strait of Juan de Fuca West, so incident rates for bulk carriers docked in Juan de Fuca West should be zero. After zeroing these no traffic scenarios, however, scenarios still remain that pose an incident risk to the system, but that do not have historical data to assign them their own unique incident rate.

Scenarios with similar risk profiles are grouped, rather than defining a zero incident rate or an incident rate from only very few incidents. The numbers of incidents are summed in the numerator, and the corresponding numbers of vessel traffic days are summed in the denominator. This maintains alignment between incidents and traffic. The incident rate calculated for a group of scenarios can be applied to all of the individual scenarios in the group.

Scenarios with sufficiently dissimilar risk profiles or of specific interest (for example, tankers) are explicitly left ungrouped. All vessel types, activity types, and incident types are maintained ungrouped. Incident rates are only grouped over subarea. Grouping over subarea is done by activity.

7.1.3 Grouping by Subarea for Underway and Maneuvering

Subareas with similar geography and traffic patterns are grouped. Traffic activity by subarea is discussed in Appendix A. For underway and for maneuvering scenarios, three subarea groups (*l_group*) are defined:

- Strait of Juan de Fuca West and Strait of Juan de Fuca East.
- Haro Strait Boundary Pass and Rosario Strait.
- Guemes Channel, Fidalgo Bay, Saddlebag, and Cherry Point.

The incident rate formulation for underway scenarios is given as Equation 6. The incident rate formulation for maneuvering scenarios is equivalent and given as Equation 7.

$$IR_{v,a=underway,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_group} NI_{v,a=underway,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_group} TD_{v,a=underway,l,y}} \qquad 6$$

$$IR_{v,a=maneuvering,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_group} NI_{v,a=maneuvering,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_group} TD_{v,a=maneuvering,l,y}} \qquad 7$$

7.1.4 Grouping by Subarea for Anchored and Docked

Anchored and docked scenarios are grouped over all seven subareas. The incident rate at an anchorage is independent of where the anchorage is located[5]. Similarly, the incident rate at a dock is assumed to be independent of where the dock is located. Equations 8 and 9 give the incident rate formulation for the anchored and docked activity types, respectively.

$$IR_{v,a=anchored,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} NI_{v,a=anchored,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} TD_{v,a=anchored,l,y}} \qquad 8$$

$$IR_{v,a=docked,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} NI_{v,a=docked,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} TD_{v,a=docked,l,y}} \qquad 9$$

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[5] In reality, some docks and anchorages are more susceptible to weather influence, tight maneuvering room, potential for anchor dragging or other factors. These would be expected to have a higher incident rate than other sheltered docks or anchorages. The incident rate applied uniformly to all subareas is the average from the whole study area.

7.1.5 Formulation Refinements

The total number of unique incident rates to derive is reduced from 1008 to 288 by grouping. There are 6x2x6x3 = 216 unique incident rates for underway and maneuvering scenarios, and 6x2x6x1 = 72 unique incident rates for anchored and docked scenarios.

The resultant 288 incident rates are reviewed and adjusted for insufficient historical data, statistical anomalies, and appropriate conservatism. These incident rate formulations still produce incident rates of zero incidents per traffic day where there are zero historical incidents for the subarea group (for underway and maneuvering), and for all subarea locations (for anchored and docked) of a particular combination of vessel type, activity type, and incident type. After grouping subareas, there are still zero historical incidents for 221 (77%) of the 288 scenario groups.

A zero incident rate is accepted if there is zero probability of the scenario's combination of incident type and activity; for example, a transfer error while underway for all vessel types (transfer errors are assumed to occur only at dock or at anchor).

When there are zero traffic days in a particular subarea, an incident rate of zero is assumed. The incident rate formulations used in the study, however, do not result in zero for zero traffic day subareas when they are grouped in with other, non-zero subareas. This is because these formulas average the incident rates of all the subareas together. Consequently, the incident rates for zero traffic day subareas are explicitly defined as zero. These accepted and adjusted zero incident rates are further described in Section 7.2.

Where a combination of vessel type, activity type, incident type, and subarea group (or entire study area, for anchored and docked) has a zero historical incidents, but can physically occur and has non-zero historical traffic, the incident rate is adjusted to be non-zero. This is necessary to capture the non-zero probability of an incident that did not occur during the 16-year study period. These adjustments to define non-zero incident rates are described in Section 7.2.

7.2 Zero Incident Rates

A zero incident rate is accepted if there is zero probability of the scenario's combination of incident type and activity or of the scenario's combination of vessel type, activity, and location. A scenario's incident rate may be zero for one or more of the described zero probability combinations following. A zero incident rate is assigned in 102 of the 228 scenario groups. There is overlap in the given number of scenarios applicable within following subsections.

7.2.1 Zero Incident Rates from Zero Probability of Incident Type and Activity Type Combination

Vessels do not transfer cargo or bunker while moving in the study area. This is validated in the incident database. There were no historical incidents of transfer error or bunker error while underway or maneuvering. For all vessel types in all subareas, scenarios of transfer or bunker error while underway or maneuvering have a zero incident rate. This applies to 7x2x2x7 = 196 scenarios.

7.2.2 Zero Incident Rates from Zero Probability of Incident Type and Vessel Type Combination

Vessels that do not carry cargo do not have a cargo transfer error. Transfer error contributing to spilled oil volume is only relevant for tankers and for tank barges. Bulker, general cargo, tug, passenger, and fishing vessels have a zero incident rate for transfer error. This applies to 4x4x1x7 = 112 scenarios.

7.2.3 Zero Incident Rates from Zero Traffic

There is no chance of an incident when there is no traffic. This is validated in the incident database. Of the 429 incidents, 99% occurred for a vessel type, activity type, and subarea combination with nonzero historical traffic (Source: Environmental Research Consulting Databases). Where there is zero historical traffic in the formula denominator, the incident rate is undefined. These scenarios are assigned an incident rate of zero.

Zero traffic scenarios add zero incidents to the calculated incident rate when grouped with nonzero traffic scenarios. The incident rate for the group of scenarios is still valid for the other nonzero traffic scenarios. For, example, there is zero anchoring traffic in Juan de Fuca West, but there is anchoring around Port Angeles in Juan de Fuca East. The incident rate calculated by Equation 4 for anchoring in the subarea group is still valid and applied to scenarios in Juan de Fuca East, while all scenarios with anchoring in Juan de Fuca West are assigned an incident rate of zero.

An average number of annual traffic days from the 1995-2010 is shown in Table 7a for all 6 x 4 x 7 = 168 combinations of vessel type, activity type, and subarea, with zero traffic combinations bolded. All vessel types spend time underway in all subareas. The majority of zero traffic combinations are for anchoring or docking in a subarea without anchorages or terminals for docking. There are 54 combinations for vessel type, activity type, and location with zero traffic; with 6 incidents types, the zero incident rate applies to 324 scenarios (including 15 combinations for maneuvering which are assumed zero incident rates for the 90 scenarios with transfer and bunker error, as described in Section 7.2.1).

7.3 Adjusted Incident Rates

The dataset of 429 incidents distributes into 125 scenarios. There are zero historical incidents for the remaining 883 (88%) of the exhaustive enumeration of 1,008 scenarios. After grouping subareas there are still zero historical incidents for 221 (77%) of the 288 scenario groups. The zero IR is accepted in 102 of the 228 scenario groups, as discussed in Section 7.2. The incident rates are adjusted to be non-zero in the 120 remaining scenarios with zero historical incidents. Adjustment is necessary to capture the non-zero risk of an incident occurring in the scenario. The incident rates for the 120 scenario groups with zero historical incidents are adjusted.

This section presents the approach to adjust the incident rates for these scenarios to be non-zero. The general approach is to assume that 1 incident occurred in 17 years. The sum traffic days over the 16-year database is multiplied by 17/16 to add a year of average traffic days to the denominator. This approach introduces an acceptable percentage (4.3%) of artificial incidents to the dataset of 429, as per discussion in Section 7.4.5. It is selected for its acceptable conservatism and simplicity.

7.3.1 Adjustment for Underway and Maneuvering

There are 44 remaining incident rates of zero for underway, and 55 remaining incident rates of zero for maneuvering, after subtracting out transfer and bunker errors from of the 144 incident rates calculated for the combinations of six (6) vessel types, 2 activities, 4 incident types, and 3 subarea groups. These zeros and the adjusted incident rates (AIRs) are noted in the tables presented in Section 7.4.

The AIR method for underway scenarios is to add one incident over the total number of underway traffic days by that vessel type in the entire study area. The total underway traffic is scaled from 16 to 17 years. This IR is then factored by the proportion of vessel traffic days of that vessel type in the scenario subarea group to the total number of traffic days by that vessel type in the entire study area. This formulation is shown numerically with Equation 10. The formulation for maneuvering is equivalent and shown in Equation 11.

$$AIR_{v,a=underway,i,l} = \frac{1}{\frac{17}{16}\times\sum_{y=1995}^{2010}\sum_{l=1}^{l\_all} TD_{v,a=underway,l,y}} \times \frac{\sum_{y=1995}^{2010}\sum_{l=1}^{l\_group} TD_{v,a=underway,l,y}}{\sum_{y=1995}^{2010}\sum_{l=1}^{l\_all} TD_{v,a=underway,l,y}} \tag{10}$$

$$AIR_{v,a=maneuvering,i,l} = \frac{1}{\frac{17}{16}\times\sum_{y=1995}^{2010}\sum_{l=1}^{l\_all} TD_{v,a=manuevering,l,y}} \times \frac{\sum_{y=1995}^{2010}\sum_{l=1}^{l\_group} TD_{v,a=maneuvering,l,y}}{\sum_{y=1995}^{2010}\sum_{l=1}^{l\_all} TD_{v,a=maneuvering,l,y}} \tag{11}$$

Incident rates while underway, including adjustments, for tankers, tank barges, bulkers, cargo ships, tugs, and the passenger and fishing vessel type, are given in Section 7.4.1, Table 19 through Table 24. Maneuvering incident rates are given in Section 7.4.2, Table 25 through Table 30.

7.3.2 Adjustment for Anchoring and Docked

7.3.2.1 Adjustment for Impact Incidents

There were zero historical incidents for the 5x2x3x7 = 210 scenarios with allisions, collisions, or groundings (i = impact) at an anchor or at dock. Note that impact incidents while at anchor or at dock *are* possible due to a dragged anchor or a breakaway.

The AIR method for anchored scenarios is to add one incident for the scenario over the total number of anchored traffic days by all vessels in the entire study area. The total anchored traffic days is scaled from 16 to 17 years. This IR is then factored by the proportion of vessel traffic days of that vessel type in all subareas to the total number of anchored traffic days by all vessels in the entire subarea. This formulation is shown numerically with Equation 12. The formulation for docked is equivalent and shown in Equation 13.

$$AIR_{v,a=anchored,i=impact,l} = \frac{1}{\frac{17}{16}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} TD_{v,a=anchored,l,y}}{\left(\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} \sum_{v=1}^{v\_all} TD_{v,a=anchored,l,y} \right)^2} \tag{12}$$

$$AIR_{v,a=docked,i=impact,l} = \frac{1}{\frac{17}{16}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} TD_{v,a=docked,l,y}}{\left(\sum_{y=1995}^{2010} \sum_{l=1}^{l\_all} \sum_{v=1}^{v\_all} TD_{v,a=docked,l,y} \right)^2} \tag{13}$$

7.3.2.2 Adjustment for Cargo Transfer Error

Transfer error is only relevant for tankers and tank barges, as described in Section 7.2.2. Tankers and tank barges may transfer cargo at anchor or at dock. Typically the larger vessel is reported for the error between a larger and a smaller vessel. There may be no further narrative in the incident report mentioning the smaller vessel. There were zero transfer errors from tank barges at an anchorage. Thus, the incident rate for tankers at anchor was assigned to tank barges.

The incident rates for tankers, tank barges, bulkers, cargo ships, tugs, and the passenger and fishing vessel type while anchored and docked including adjustments are given in Table 31 and Table 32, respectively.

7.3.3 Adjustment for Bunker Error at Anchor

Incident rates for bunker error are calculated for the anchoring and docked activities grouped over all subareas. All vessel types had at least one prior bunker error at dock; there was no adjustment needed to define a nonzero bunkering error rate at dock. There were only two vessel types with zero historical bunker errors at anchor. The incident rate for bunker error at anchor is adjusted for tankers and for bulkers as per Equation 8.

7.4 Incident Rate Results

Number of incidents, number of traffic days, and the adjusted incident rates are presented below in Table 19 through Table 35. Data is shown grouped, calculated, and adjusted, as discussed in previous sections, with an exception. Incident rates are presented per 10,000 vessel traffic days rather than per vessel traffic day. This is for presentation purposes only. Adjusted incident rates are italicized with light grey highlight.

7.4.1 Underway

Number of incidents by incident type, number of traffic days, and the adjusted incident rates for the underway activity type are presented below in Table 19 through Table 24, for the six vessel types. Underway incident rates are calculated by Equation 6. Adjusted underway incident rates are calculated by Equation 10 and are shown italicized with light grey highlight.

Table 19 Tanker Underway Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Tanker Underway (incidents)			
Collision	1	0	0
Grounding	1	0	1
Allision	0	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	15	1	12
Sum (incidents)	17	1	13
Traffic Days 1995-2010 - Tanker Underway (days)			
	6,872	1,505	1,537
Incident Rates - Tanker Underway (incidents / 10,000 traffic days)			
IR Collision	1.46	*0.14*	*0.15*
IR Grounding	1.46	*0.14*	6.51
IR Allision	*0.66*	*0.14*	*0.15*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	21.83	6.65	78.07
Sum	25.39	7.08	84.87

Table 20 Tank Barge Underway Incident Rates

Incident Type	**Juan de Fuca**	**Haro Strait Boundary Pass Rosario Strait**	**Guemes Channel Saddlebag Cherry Point**
Number of Incidents 1995-2010 – Tank Barge Underway (incidents)			
Collision	1	0	1
Grounding	0	0	0
Allision	0	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	2	0	3
Sum (incidents)	3	0	4
Traffic Days 1995-2010 – Tank Barge Underway (days)			
	6,143	2,257	3,325
Incident Rates ‑ Tank Barge Underway (incidents / 10,000 traffic days)			
IR Collision	1.63	*0.15*	3.01
IR Grounding	*0.42*	*0.15*	*0.23*
IR Allision	*0.42*	*0.15*	*0.23*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	3.26	*0.15*	9.02
Sum	*5.72*	*0.62*	*12.48*

Table 21 Bulker Underway Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Bulker Underway (incidents)			
Collision	1	0	0
Grounding	0	0	0
Allision	1	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	3	0	3
Sum (incidents)	5	0	3
Traffic Days 1995-2010 - Bulker Underway (days)			
	18,116	3,418	2,609
Incident Rates - Bulker Underway (incidents / 10,000 traffic days)			
IR Collision	0.55	*0.06*	*0.04*
IR Grounding	*0.29*	*0.06*	*0.04*
IR Allision	0.55	*0.06*	*0.04*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	1.66	*0.06*	11.50
Sum	*3.05*	*0.22*	*11.62*

Table 22 Cargo Underway Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Cargo Underway (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	0	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	29	0	4
Sum (incidents)	29	0	4
Traffic Days 1995-2010 - Cargo Underway (days)			
	15,823	2,064	1,719
Incident Rates - Cargo Underway (incidents / 10,000 traffic days)			
IR Collision	*0.39*	*0.05*	*0.04*
IR Grounding	*0.39*	*0.05*	*0.04*
IR Allision	*0.39*	*0.05*	*0.04*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	18.33	*0.05*	23.28
Sum	*19.49*	*0.20*	*23.40*

Table 23 Tug Vessels Underway Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Other Vessels Underway (incidents)			
Collision	0	0	0
Grounding	2	0	0
Allision	1	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	23	4	14
Sum (incidents)	26	4	14
Traffic Days 1995-2010 – Tug Vessels Underway (days)			
	18,490	7,722	10,758
Incident Rates – Tug Vessels Underway (incidents / 10,000 traffic days)			
IR Collision	*0.13*	*0.05*	*0.07*
IR Grounding	1.08	*0.05*	*0.07*
IR Allision	0.54	*0.05*	*0.07*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	12.44	5.18	13.01
Sum	*14.19*	*5.34*	*13.24*

Table 24 Passenger and Fishing Vessels Underway Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Passenger and Fishing Vessels Underway (incidents)			
Collision	1	0	0
Grounding	7	0	4
Allision	0	0	1
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	19	7	27
Sum (incidents)	27	7	32
Traffic Days 1995-2010 – Passenger and Fishing Vessels Underway (days)			
	12,252	1,897	4,566
Incident Rates – Passenger and Fishing Vessels Underway (incidents / 10,000 traffic days)			
IR Collision	0.82	*0.05*	*0.12*
IR Grounding	5.71	*0.05*	8.76
IR Allision	*0.33*	*0.05*	2.19
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	15.51	36.89	59.14
Sum	*22.37*	*37.04*	*70.21*

7.4.2 Maneuvering

Number of incidents by incident type, number of traffic days, and the adjusted incident rates for the maneuvering activity type are presented below in Table 25 through Table 30, for the six vessel types. Maneuvering incident rates are calculated by Equation 7. Adjusted maneuvering incident rates are calculated by Equation 11 and are shown italicized with light grey highlight.

Table 25 Tanker Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Tanker Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	1	0	1
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	5	0	2
Sum (incidents)	6	0	3
Traffic Days 1995-2010 - Tanker Maneuvering (days)			
	362	0	1,022
Incident Rates - Tanker Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*1.78*	0.00	*5.02*
IR Grounding	*1.78*	0.00	*5.02*
IR Allision	27.62	0.00	9.78
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	138.10	0.00	19.56
Sum	*169.28*	0.00	*39.38*

Table 26 Tank Barge Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Tank Barge Maneuvering (incidents)			
Collision	0	0	2
Grounding	0	0	0
Allision	0	0	1
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	0	0	1
Sum (incidents)	0	0	4
Traffic Days 1995-2010 – Tank Barge Maneuvering (days)			
	445	5	1,743
Incident Rates – Tank Barge Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*0.87*	*0.01*	11.48
IR Grounding	*0.87*	*0.01*	*3.41*
IR Allision	*0.87*	*0.01*	5.74
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	*0.87*	*0.01*	5.74
Sum	*3.49*	*0.04*	*26.36*

Table 27 Bulker Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Bulker Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	0	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	0	0	0
Sum (incidents)	0	0	0
Traffic Days 1995-2010 - Bulker Maneuvering (days)			
	72	0	43
Incident Rates - Bulker Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*51.29*	0.00	*30.58*
IR Grounding	*51.29*	0.00	*30.58*
IR Allision	*51.29*	0.00	*30.58*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	*51.29*	0.00	*30.58*
Sum	*205.16*	0.00	*122.31*

Table 28 Cargo Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Cargo Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	1	0	0
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	4	0	1
Sum (incidents)	5	0	1
Traffic Days 1995-2010 - Cargo Maneuvering (days)			
	40	0	9
Incident Rates - Cargo Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*155.29*	0.00	*35.34*
IR Grounding	*155.29*	0.00	*35.34*
IR Allision	248.64	0.00	*35.34*
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	994.56	0.00	1092.50
Sum	*1553.78*	0.00	*1198.53*

Table 29 Tug Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Tug Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	0	2	2
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	3	0	3
Sum (incidents)	3	2	5
Traffic Days 1995-2010 - Tug Maneuvering (days)			
	546	25	2,123
Incident Rates - Tug Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*0.71*	*0.03*	*2.75*
IR Grounding	*0.71*	*0.03*	*2.75*
IR Allision	*0.71*	807.39	9.42
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	54.92	*0.03*	14.13
Sum	*57.04*	*807.48*	*29.06*

Table 30 Passenger and Fishing Vessels Maneuvering Incident Rates

Incident Type	Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Passenger and Fishing Vessels Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	0	0	7
Transfer Error	0	0	0
Bunker Error	0	0	0
Other Non-Impact Incident	1	0	7
Sum (incidents)	1	2	14
Traffic Days 1995-2010 - Passenger and Fishing Vessels Maneuvering (days)			
	4	0	46
Incident Rates - Passenger and Fishing Vessels Maneuvering (incidents / 10,000 traffic days)			
IR Collision	*16.48*	0.00	*171.55*
IR Grounding	*16.48*	0.00	*171.55*
IR Allision	*16.48*	0.00	1532.85
IR Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	2279.08	0.00	1532.85
Sum	*2328.53*	0.00	*3408.79*

7.4.3 Anchored

Number of incidents by incident type, number of traffic days, and the adjusted incident rates for the anchored activity type are presented below in Table 31. Anchored incident rates are calculated by Equation 8. The incident rate for tank barge transfer errors at anchor is adjusted to be equal to the tanker transfer error rate, as per Section 7.3.2.2. Other adjusted anchored incident rates are calculated by Equation 12. Adjusted rates are shown italicized with light grey highlight.

Table 31 Anchored Incident Rates

Incident Type	Tanker	Tank Barge	Bulker	Cargo	Tug	Pass & FV
Number of Incidents 1995-2010 –Anchored (incidents)						
Collision	0	0	0	0	0	0
Grounding	0	0	0	0	0	0
Allision	0	0	0	0	0	0
Transfer Error	3	0	0	0	0	0
Bunker Error	0	0	0	1	2	0
Other Non-Impact Incident	3	2	1	2	2	0
Sum (incidents)	6	2	1	3	4	0
Traffic Days 1995-2010 ‐ Anchored (days)						
	16,742	16,082	618	395	20,610	0
Incident Rates ‐ Anchored (incidents / 10,000 traffic days)						
IR Collision	*0.0532*	*0.0511*	*0.0020*	*0.0013*	*0.0654*	0.0
IR Grounding	*0. 0532*	*0.0511*	*0.0020*	*0.0013*	*0. 0654*	0.0
IR Allision	*0. 0532*	*0.0511*	*0.0020*	*0.0013*	*0. 0654*	0.0
IR Transfer Error	1.7919	*1.7919*	0.0	0.0	0.0	0.0
IR Bunker Error	*0. 0532*	*0.00001*	*0.0020*	25.2996	0.9704	0.0
IR Other Non-Impact Incident	1.7919	1.2436	16.1792	50.5992	0.9704	0.0
Sum	*3.7533*	*3.1887*	*16.1870*	*75.9026*	*2.1371*	0.0

7.4.4 Docked

Number of incidents by incident type, number of traffic days, and the adjusted incident rates for the docked activity type are presented below in Table 32. Docked incident rates are calculated by Equation 9. Other adjusted anchored incident rates are calculated by Equation 13. Adjusted rates are shown italicized with light grey highlight.

Table 32 Docked Incident Rates

Incident Type	Tanker	Tank Barge	Bulker	Cargo	Tug	Pass & FV
Number of Incidents 1995-2010 – Docked (incidents)						
Collision	0	0	0	0	0	0
Grounding	0	0	0	0	0	0
Allision	0	0	0	0	0	0
Transfer Error	23	9	0	0	0	0
Bunker Error	1	3	2	2	15	15
Other Non-Impact Incident	20	11	4	6	16	53
Sum (incidents)	44	23	6	8	31	68
Traffic Days 1995-2010 ‑ Docked (days)						
	11,785	16,893	1,914	2,982	35,102	110,319
Incident Rates ‑ Docked (incidents / 10,000 traffic days)						
IR Collision	*0.0035*	*0.0050*	*0.0006*	*0.0009*	*0.0103*	*0.0324*
IR Grounding	*0.0035*	*0.0050*	*0.0006*	*0.0009*	*0.0103*	*0.0324*
IR Allision	*0.0035*	*0.0050*	*0.0006*	*0.0009*	*0.0103*	*0.0324*
IR Transfer Error	19.5159	5.3278	0.0000	0.0000	0.0000	0.0000
IR Bunker Error	0.8485	1.7759	10.4497	6.7059	4.2733	1.3597
IR Other Non-Impact Incident	16.9703	6.5117	20.8995	20.1177	4.5582	1.3597
Sum	*37.3451*	*13.6303*	*31.6089*	*26.8262*	*8.8624*	*6.2612*

7.4.5 Incidents Added from Adjusted Incident Rates (IRs)

The incident rate adjustment adds the equivalent of 18.3 incidents (4.3%) to the dataset of 429 incidents. Adjusted incident rates contribute uniformly to all analysis cases. They do not affect the incremental difference between cases. The distribution of these 18.3 incidents by activity type, incident type, and vessel type is given in Table 33, Table 34, and Table 35, respectively.

Table 33 Incidents Added from AIRs by Activity Type

Activity	Historical Incident Count	Incidents added from the adjusted historical rates	Sum Number of Incidents
Underway	189	5.00	194.00
Maneuver	44	8.13	52.13
Anchor	16	3.89	19.89
Docked	180	1.27	181.27
Sum	**429**	**18.28**	**447.28**

Table 34 Incidents Added from AIRs by Incident Type

Incident Type	Historical Incident Count	Incidents added from the adjusted historical rates	Sum Number of Incidents
Collision	7	5.06	12.06
Grounding	15	6.21	21.21
Allision	18	3.39	21.39
Cargo Transfer Error	35	2.93	37.93
Bunker Error	41	0.09	41.09
Other, Non-Impact	313	0.60	313.60
Sum	**429**	**18.28**	**447.28**

Table 35 Incidents Added from AIRs by Vessel Type

Vessel Type	Historical Incident Count	Incidents added from the adjusted historical rates	Sum Number of Incidents
Tanker	90	2.09	92.09
Tank Barge	36	4.71	40.71
Bulker	15	2.69	17.69
Cargo	50	3.25	53.25
Tug	89	2.40	91.40
Pass & FV	149	3.15	152.15
Sum	**429**	**18.28**	**447.28**

7.5 Incident Rate Summaries

A summary of number of incidents, traffic days, and incident rates presented. Statistics by vessel type, activity type, and location are presented in Table 36, Table 37, and Table 38, respectively. Incident rates in these tables are a simple division of the number of incidents by traffic days.

Table 36 Average IR by Vessel Type

	Tanker	Tank Barge	Bulker	Cargo	Tug	Pass & FV
Number of Incidents	90	36	15	50	89	149
Traffic Days	39,826	46,893	26,790	23,033	95,376	129,084
Incident Rate x10,000	22.60	7.68	5.60	21.71	9.33	11.54

Table 37 Average IR by Activity Type

	Underway	Maneuvering	Anchored	Docked
Number of Incidents	189	44	16	180
Traffic Days	121,074	6,486	54,447	178,995
Incident Rate x10,000	15.61	67.84	2.94	10.06

Table 38 Average IR by Subarea

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
Number of Incidents	53	103	4	108	67	11	83
Traffic Days	44,426	80,916	12,548	90,815	66,548	10,920	54,830
Incident Rate x10,000	11.70	12.73	3.19	11.89	10.07	10.07	15.14

See Appendix B for the distribution of incidents by incident type.

A summary of number of incidents, traffic days, and incident rates grouped by two parameters is presented. Statistics by area and activity are presented in Table 39. Statistics by vessel type and activity are presented in Table 40.

Table 39 Unadjusted Average Incident Rates by Activity Type and Subarea

Subarea	Underway	Maneuvering	Anchored	Docked
Number of Incidents 1995-2010 – by Activity Type (incidents)				
Juan de Fuca West	48	0	1[6]	4
Juan de Fuca East	59	15	8	21
Haro Strait-Boundary Pass	3	0	0	1
Guemes	25	8	2	73
Saddlebag	21	12	3	31
Rosario Strait	9	2	0	0
Cherry Point	24	7	2	50
Traffic Days 1995-2010 – by Activity Type (days)				
Juan de Fuca West	44,270	8	0	148
Juan de Fuca East	33,427	1,463	29,835	16,191
Haro Strait-Boundary Pass	8,551	18	0	3,979
Guemes	3,815	2,109	15,730	69,161
Saddlebag	1,080	552	8,668	56,248
Rosario Strait	10,312	12	0	595
Cherry Point	19,620	2,324	215	32,672
Unadjusted Incident Rate – by Activity Type (incidents / 10,000 traffic days)				
Juan de Fuca West	10.84	0.00	0.00	269.97
Juan de Fuca East	17.65	102.55	2.68	12.97
Haro Strait-Boundary Pass	3.51	0.00	0.00	2.51
Guemes	65.54	37.93	1.27	10.56
Saddlebag	194.48	217.44	3.46	5.51
Rosario Strait	8.73	1612.91	0.00	0.00
Cherry Point	12.23	30.12	93.01	15.30

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[6] A tank barge was recorded for a Other Non-Impact Incident while anchored at Neah Bay (Juan de Fuca West). This incident was one of the 1% of the 429 historical incidents that occurred without corresponding historical data or hindcast traffic.

Table 40 Unadjusted Average Incident Rates by Activity Type and Vessel Type

Vessel Type	Underway	Maneuvering	Anchored	Docked
Number of Incidents 1995-2010 – by Activity Type (incidents)				
Tanker	31	9	6	44
Tank Barge	7	4	2	23
Bulker	8	0	1	6
Cargo	33	6	3	8
Tug	44	10	4	31
Pass & FV	66	15	0	68
Traffic Days 1995-2010 – by Activity Type (days)				
Tanker	9,914	1,384	16,742	11,785
Tank Barge	11,725	2,193	16,082	16,893
Bulker	24,143	115	618	1,914
Cargo	19,606	49	395	2,982
Tug	36,970	2,694	20,610	35,102
Pass & FV	18,715	50	0	110,319
Unadjusted Incident Rate – by Activity Type (incidents / 10,000 traffic days)				
Tanker	31.27	65.01	3.58	37.33
Tank Barge	5.97	18.24	1.24	13.62
Bulker	3.31	0.00	16.18	31.35
Cargo	16.83	1215.27	75.90	26.82
Tug	11.90	37.12	1.94	8.83
Pass & FV	35.27	2996.74	0.00	6.16

7.6 Incident Rate (IR) Discussion and Validation

Yearly and overall statistics from the 16-year baseline were studied. Traffic was relatively steady over the 16 year baseline, while the number of incidents varied widely from year to year. Yearly statistics for number of traffic days and incident rates were compared to look for a correlation between increased traffic and increased incident rates. This would indicate that the number of incidents increases nonlinearly with increasing traffic days, or that there was congestion that caused more incidents in the system. Behavior in individual subareas and in the overall study area was studied. Guemes Channel, Cherry Point, and Port Angeles (Juan de Fuca East) were identified as subareas with potential higher levels of congestion. No discernible trends were found in the data for increasing incident rates per vessel traffic day with increased traffic days. Therefore, number of incidents is assumed to increase in direct, linear proportion with increased number of traffic days.

Increased traffic could result in congestion from higher traffic density. Congestion would primarily affect collision rates while underway. Other impact incident types may also be affected. There were seven (7) collisions in the baseline records: two (2) in Juan de Fuca West, two (2) in Juan de Fuca East, one (1) in Guemes Channel, and two (2) in Cherry Point. All seven (7) were in different years. Five (5) of the collisions occurred while underway; two (2) were maneuvering. Only the larger of the vessels involved in a collision is necessarily recorded. The other vessel involved in the incident is not always recorded. Four (4) collisions involved a tank barge, and factory fishing vessels accounted for one (1) collision. One (1) collision involved a tanker; one (1) collision involved a bulker. There are too few data points to interpret a trend.

The available data does not show whether these collisions occurred at a time when the waterway was congested. Overall, the annual traffic levels for the year and subarea of these seven collisions were not higher than in other year and subarea combinations without collisions. Annual traffic days, however, are not an indication of ‘instantaneous’ congestion that may have occurred in the hours or moments before a collision between two vessels. Traffic variations over season and throughout the day would affect traffic density.

Other methods to model the effect of congestion on incident probability were considered. A time-domain simulation over a fine spatial grid is a common approach, if there is a correlation between interactions and incidents that is dependent on traffic density. The papers on the modeling and effect of traffic congestion listed in the Bibliography (Appendix F) were reviewed for this study. The alternative methods described, however, were not applicable with the approach presented and data available for this project.

The increase in vessel traffic in the forecast year 2030 with cumulative traffic at the BP High Forecast is within the range that traffic density in local areas can be effectively managed by Vessel Traffic Service (VTS) to prevent an increase in collision frequency rate. Incident Rates per vessel traffic days are assumed to be independent of traffic density, and do not change in time or with the existence of the BPCP North Wing.

Other contributing factors may have been present at the time of the historical incidents, such as high wind speed, low visibility, or high vessel speed. These factors are not explicitly modeled, but are implicit in the incident rates as they contributed to the historical incidents in the 16-year study period. The available data makes it possible to quantify the annual probability of an incident with respect to the available, selected parameters (vessel type, activity type, incident type, and location).

The incident rates presented were compared to worldwide statistics for validation. Historical Accident Frequencies for Oslofjord, Norway, the North Sea area, and worldwide, were aligned to comparable units for tankers, bulkers, and general cargo ships with collisions, groundings, and Other Non-Impact Incidents (Reference 3). Incident rates between regions were within a wide but acceptable range.

The historical incident database was developed and checked as described in Section 6.1. Yet, the primary sources and processed data may still have human errors from transcription and interpretation. All quoted traffic days are predicted mean values. There is a range of variability about the mean. This variance is modeled in the Monte Carlo Risk Assessment Model, as described in Section 4.

Section 8 Traffic Forecast

NEI examined the patterns of traffic and anchorage usage in the study area for the prescribed BP number of calls, baseline traffic in 2010, and forecasted traffic in 2030. Their report, Appendix C, summarizes the methodology to model vessel traffic days in 2010 (Cases 1-3) and in 2030 (Cases 4-7). BP Cherry Point traffic is reported in Section 2. The study team's method and results to forecast the volume of study area vessel traffic from 2010 to 2030 is reported in Section 3. Existing traffic (baseline including BP) and new developments (cumulative) are projected. Cumulative traffic is reported in Section 4. Section 5 describes the @RISK model and sources of uncertainty. Total traffic for the seven analysis cases is presented in Section 6. These five sections of Appendix C, the vessel traffic forecast report, are summarized as follows.

8.1 BP Cherry Point Traffic (2010)

In order to forecast the proportion of tanker and tug traffic attributable to BP Cherry Point activities within the Puget Sound, the study team had to first assess what portion of current traffic is attributable to BP Cherry Point. BP tankers accounted for 962 days, or 39% of total tanker time. BP tugs accounted for 197 days, or 3% of total tug time. Traffic days by activity type and by subarea for BP tankers and for BP tugs are shown in Tables 40a and 40b, respectively.

Table 40a BP Tanker Traffic Days by Activity Type and by Subarea, 2010 (Source: MX 2012)

Activity Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Transiting	103	64	1	3	6	37	23	237
Maneuvering	0	7	0	3	6	0	21	37
At-Anchor	0	105	0	52	184	0	1	342
At-Berth	0	0	0	0	0	0	345	345
Total	103	176	1	58	196	37	391	962

Table 40b BP Tug Traffic Days by Activity Type and by Subarea, 2010 (Source: MX 2012)

Activity Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Transiting	0	93	5	35	42	125	85	384
Maneuvering	0	0	0	0	0	0	46	46
At-Anchor	0	0	0	0	0	0	0	0
At-Berth	0	0	0	0	0	0	0	0
Total	0	93	5	35	42	125	131	430

8.2 Baseline Traffic Forecasting

The study team's baseline vessel traffic forecast includes all existing traffic, of both non-BP and BP traffic. BP traffic is included as it is forecast along with other tankers and tugs. The forecast relies heavily upon a commodity-based economic forecast generated by BST Associates, as well as historic trends and patterns of vessel behavior. The Washington Public Ports Association, in partnership with the Washington State Department of Transportation, periodically funds a marine cargo forecast and performance assessments of the state's marine port transportation system.

Table 40c Study Area Baseline Vessel Traffic Days, 2030 (Source: NEI 2013)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	296	745	30	594	278	59	480	2483
Tank Barge	175	877	21	682	206	124	685	2771
Bulker	756	464	209	35	22	2	238	1726
Cargo	556	325	112	33	165	3	106	1300
Tug	426	1713	129	1265	582	483	1674	6272

8.3 Cumulative Traffic Forecasting

At the outset of the vessel traffic study, the NEI project team conducted interviews with project stakeholders to assess regional activity that could change historic vessel traffic volumes or patterns. The study team conducted interviews with local ports, shipping companies, refineries, and small boat harbors. During these interviews, it became apparent that several potential events could significantly change the projected tanker and tug vessel traffic volumes used in our analysis. These events include:

1. New oil production from the Alaska Outer Continental Shelf (OCS) beginning in 2024.
2. Shale oil production from the Alaska North Slope with substantial volumes online by 2016.
3. Expansion of Kinder Morgan's Transmountain pipeline to export oil to Asia. Construction will begin in 2016 and increased tanker traffic is incorporated into the 2030 estimates.
4. Construction of the Gateway Pacific Terminal (GPT) will increase study area bulker vessel volumes and is incorporated into the 2030 estimates.

While not definite, OCS production, shale oil production, Kinder Morgan's expansion, and construction of GPT are considered reasonably foreseeable by the study team, and all four were factored into our cumulative traffic forecast. The potential for a reduction in crude oil transport by sea due to an increase in transport by rail was studied, as detailed in Appendix C. Pursuant to this study, it was decided that an increase in crude oil transport by rail would not be included as a cumulative traffic event. The specific assumptions regarding cumulative traffic are summarized in Table 40d.

Table 40d Cumulative Forecast Assumptions (Data Source: NEI 2013)

Year	Case
2030	• Alaska Outer Continental Shelf (OCS) production comes on line with an assumed 300,000 barrels of oil per day (BOPD), or about 1 additional tanker every 3.25 days or 112 additional tankers in 2030.
	• Other Alaska oil production declines by about 141,000 BOPD from 2012 levels, or about 1 tanker every 7 days resulting in about 52 fewer tanker calls
	• Oil shale production increases to 190,000 BOPD, or about 1 additional tanker every 5 days, or 73 additional tankers in 2030.
	• Kinder Morgan traffic increases to 348 additional tankers per year (forecasted volume is 34 tankers per month, but 5 are already calling, so there will be an increase of 29 per month).
	Net effect: Total tanker additions are 533, less reductions from Other Alaska production of 52, for a net of 481compared to 2010 levels. Washington refineries are not expected to be able to handle this entire increase; while the additional tankers from Alaska will displace all foreign tankers (11) and some Canadian crude, it is estimated that 53 of the annual tankers will be routed to California refineries rather than Washington State. The maximum number of additional tankers is 428 (533-(52+53)).

8.4 Building in Uncertainty

Forecasting is, by nature, an inexact science. While the study team forecasted vessel traffic volumes and patterns based on known data, there is inherent uncertainty in predicting the future. For example, export volumes of petroleum products from the study region could be higher or lower than forecasted by BST. Deviation from BST's economic forecast would skew resulting vessel traffic estimates.

To encompass such uncertainty, the study team built variation into the model using Palisade Corporation's @RISK software. Key areas modeled using @RISK were the commodity growth rates used for the economic forecast, trip-to-transit ratios for future traffic flows, cruise vessel trips and tug maneuvering, and at-berth time.

8.5 BP Scenario Results

For Cases 4 through 7, variability exists in both the number of vessels calling at BP Cherry Point and the non-BP traffic volumes. Total traffic days by subarea are compared for these four cases in Figure 12. Total traffic days by vessel type and by subarea are tabulated in Section 6 of Appendix C.

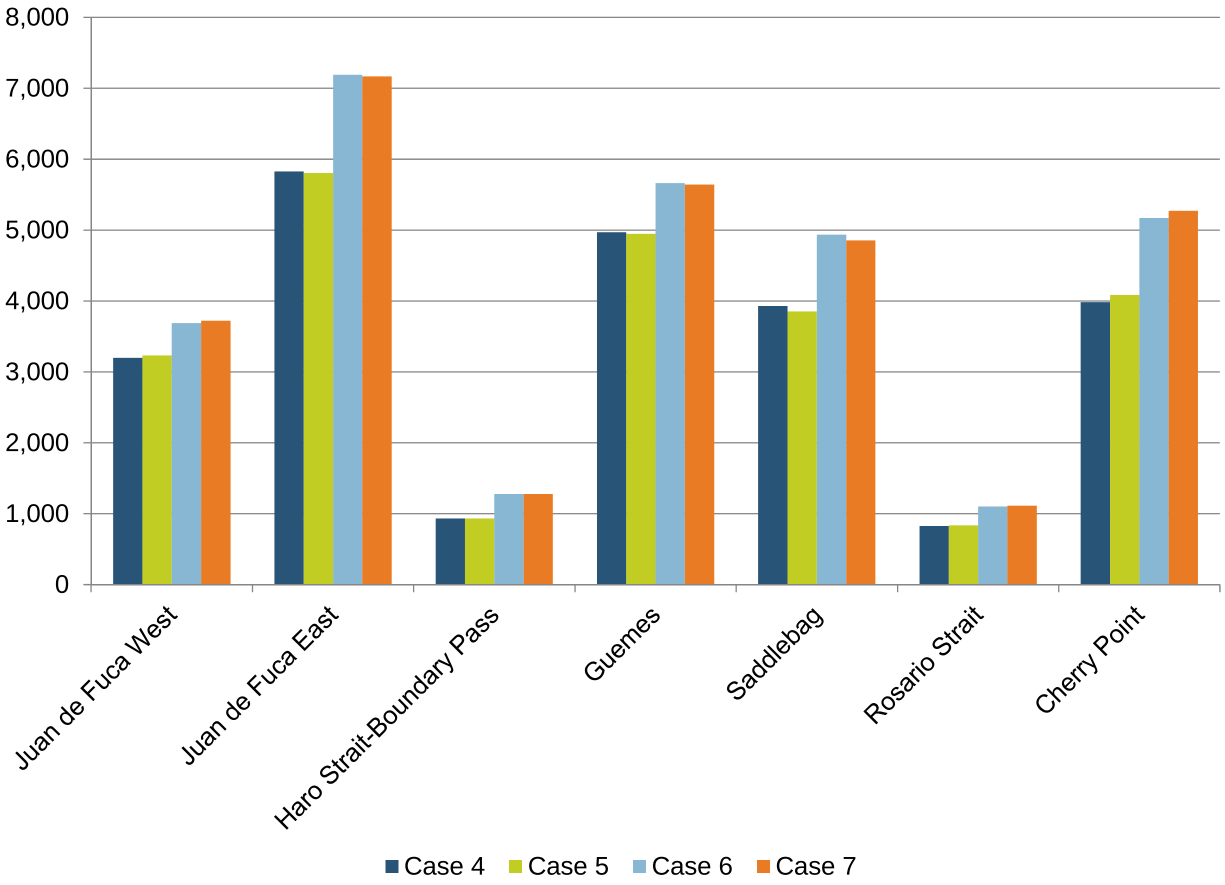

Figure 12 **Comparison of Total Vessel Traffic Days for Cases 4–7 (Source: NEI, 2013)**

Section 9 Oil Outflow

9.1 Spill Probabilities ($SP_{c,v,i}$)

When an incident occurs, it is necessary to determine whether the incident results in a spill. This is accomplished by assigning a spill probability to each forecast year, vessel type, incident type (*f,v,i*) combination for each BP-VTA case, and by sampling for a spill with a random number when an incident with that (*f,v,i*) combination occurs. ERC provides spill probabilities for the project-specific vessel types based on vessel type, incident type, and number of hulls (either single or double) in Appendix D. Spill probabilities are derived from ERC's prior research and comprehensive dataset of domestic and international spills.

ERC also provides the probabilities of having a single or double hull for each vessel type for years 2010 and 2030 in Appendix D. Tankers and tank barges have an 87% probability of double hull in 2010, and a 100% probability of double hull in 2030. For deep draft vessels (tankers, bulkers, and general cargo vessels), bunker tanks have a 5% probability of double walls in 2010, and a 91% probability of double walls in 2030. Double hulls and double-walled bunker tanks reduce spill probability. After randomly sampling the number of hulls of a vessel, the appropriate spill probability is randomly sampled for the given vessel type and incident type, thus returning the result of either spill or no spill. The method for determining if an incident results in a spill is summarized in Figure 13. Spill probability data for each (*f,v,i*) combination are presented in Appendix D.

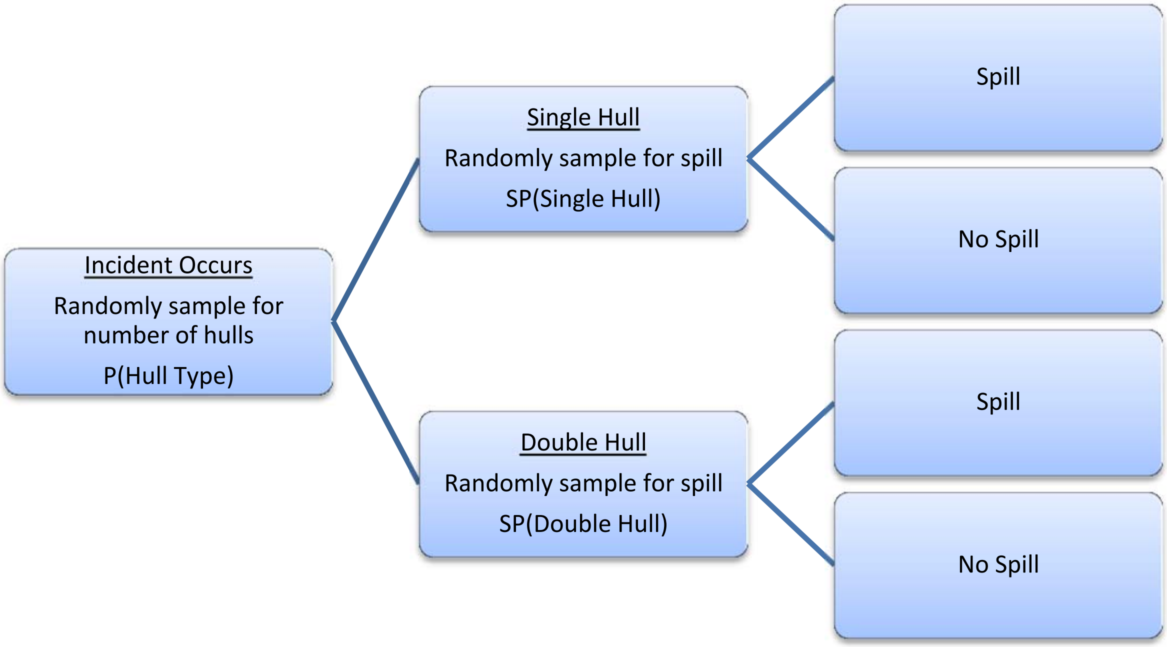

Figure 13 Flow diagram for determination of whether a spill occurs given an incident

For incidents involving tankers, there are independent probabilities of a bunker spill and a cargo spill. Each probability is randomly sampled, and if both samples result in a spill, then the total spill volume is the sum of the bunker spill and the cargo spill.

9.2 Outflow Volumes

When a spill occurs, it is necessary to determine the quantity of oil outflow. When a spill occurs for a given vessel type, incident type (*v,i*) combination, a cumulative distribution function (CDF) for the given combination is randomly sampled to return an outflow percentage (in the case of impact and other non-impact incidents), or an absolute outflow volume, in the case of transfer and bunker errors. For impact and other non-impact incidents, the capacity of the vessel type (*v*) is then randomly sampled using the appropriate method from Section 9.3. For spills due to impact and other non-impact incidents, the spill volume ($SV_{c,v,a,i,l}$) equals the product of the sampled outflow percentage and the sampled vessel capacity (Equation 4). For transfer and bunker errors, the spill volume equals the sampled absolute outflow volume.

ERC developed CDFs of bunker oil and cargo oil outflow as percentages of vessel bunker and cargo capacities for vessel type and incident type (*v,i*) combinations (Appendix D), based on their comprehensive dataset of domestic and international spills. ERC reports that outflow modeling for double hulls has demonstrated a 50% reduction in the volumes of outflows for the very largest incidents. The outflow percentage curves from Appendix D that are used in the contaminant outflow model are listed in Table 41.

Table 41 Outflow Percentage Curves from Appendix D used in Incremental Risk Assessment Model

Vessel Type(s), (*v*)	Commodity	Incident Type(s), (*i*)	Appendix D Table No.
Single Hull Tanker	Cargo Oil	Impact Incidents	9
Double Hull Tanker	Cargo Oil	Impact Incidents	8
Single Hull Tank Barge	Cargo Oil	Impact Incidents	11
Double Hull Tank Barge	Cargo Oil	Impact Incidents	12
All Vessel Types	Bunker Oil	Impact Incidents	16

Additional CDFs were developed for prediction of oil outflow for (*v,i*) combinations not listed, as described in Sections 9.2.1 through 9.2.4.

9.2.1 Cargo Oil Outflow Volume for Tanker and Tank Barge Transfer Error Spills

Cargo oil outflow percentage cumulative distribution functions for tanker and tank barge transfer error spills are provided by ERC in Appendix D, Tables 14 and 15, based on United States spill data. However, it is assumed that transfer errors are not a function of vessel capacity, and therefore alternative CDFs were developed using absolute spill volumes in place of outflow percentages. Data for transfer error spill sizes in the study area between 1995-2010, provided by ERC and BP, are used to construct transfer error cargo outflow CDFs for tankers and tank barges. The tail of each CDF is then extended to capture the maximum theoretical transfer error outflow derived by ERC in Appendix D, Tables 14 and 15. The maximum theoretical outflow in Appendix D is presented as a percentage of total capacity, so the average capacities of all tankers and all tank barges in the system in 2010 were used to calculate the volume of maximum theoretical outflow for their respective CDFs. Probabilities of these maximum theoretical outflows are equal to the probabilities provided by ERC in

Appendix D, Tables 14 and 15. The resultant CDFs of oil outflow volume for tanker and tank barge transfer error spills are presented in Figure 14 and Figure 15, respectively.

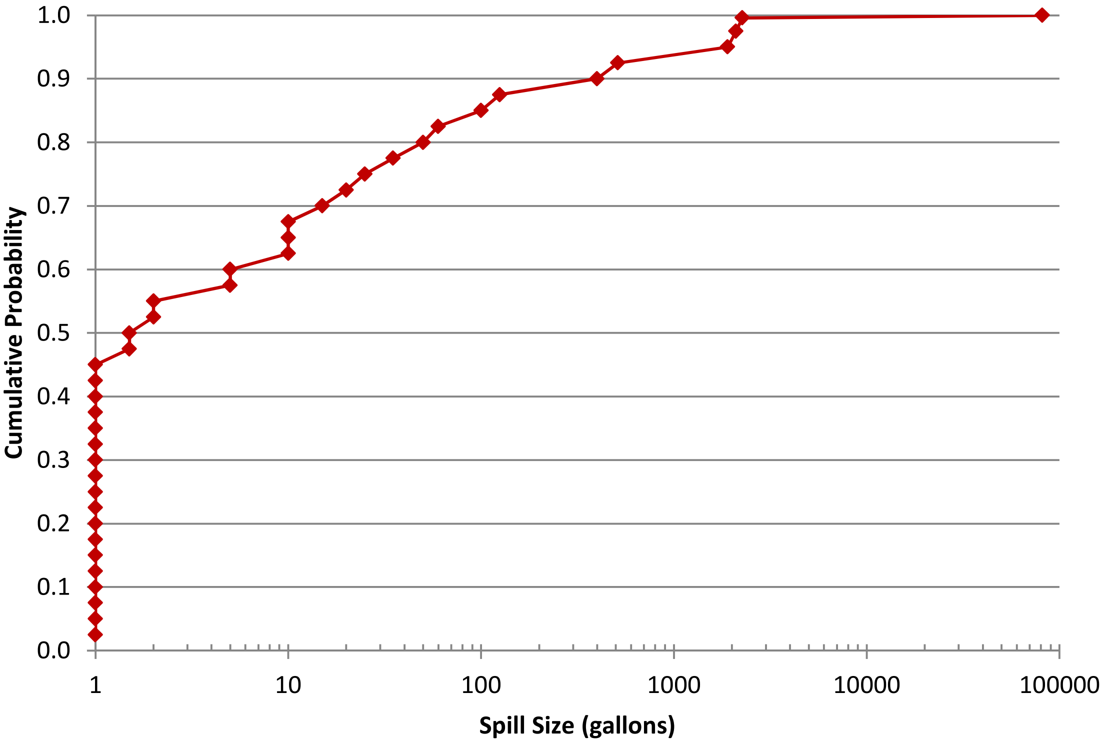

Figure 14 CDF of Cargo Oil Outflow Volume for Tanker Transfer Error Spills (Data Sources: Environmental Research Consulting, Inc. 2013, BP 2007)

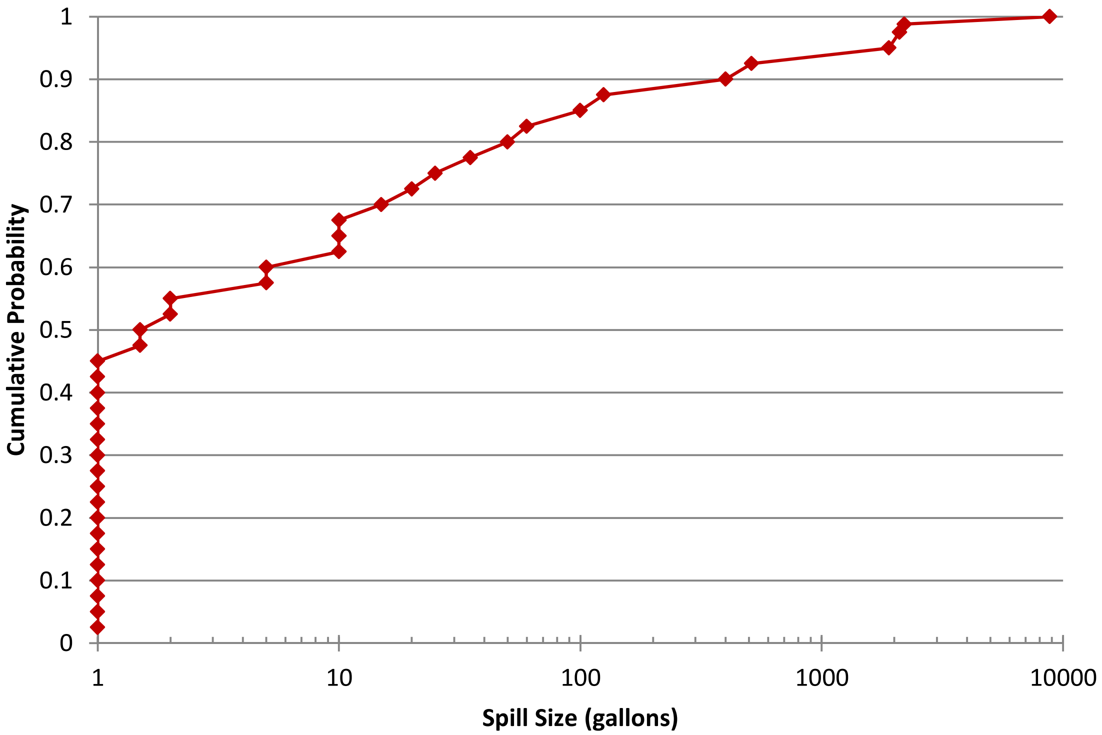

Figure 15 **CDF of Cargo Oil Outflow Volume for Tank Barge Transfer Error Spills (Data Sources: Environmental Research Consulting, Inc. 2013, BP 2007)**

9.2.2 Oil Outflow Volume for Bunker Error Spills

Bunker oil outflow percentage cumulative distribution functions are provided by ERC in Appendix D, Tables 17 and 18, based on United States spill data. However, it is assumed that bunker errors are not a function of vessel capacity, and therefore alternative CDFs were developed using absolute spill volumes in place of outflow percentages. Data provided by ERC for bunker error spill sizes in the study area between 1995-2010 are used to construct bunker error outflow CDFs for large VTA vessels (tankers, tank barges, bulkers, cargo ships, and cruise ships) and small VTA vessels (fishing vessels, passenger ferries, and tug boats). Note that tank barges can have bunker error spills when their cargo is bunker oil and a spill occurs due to an error on the tank barge. The tail of each CDF is then extended to capture the maximum theoretical bunker error outflow derived in by ERC in Appendix D, Tables 17 and 18. The maximum theoretical outflows are presented as percentages of total capacity, so the average capacities of all large VTA vessels and all small VTA vessels in the system in 2010 were used to calculate the volume of maximum theoretical outflow for their respective CDFs. Probabilities of these maximum theoretical outflows are equal to the probabilities provided by ERC in Appendix D. The resultant CDFs of oil outflow volume for large VTA vessel and small VTA vessel bunker error spills are presented in Figure 16 and Figure 17.

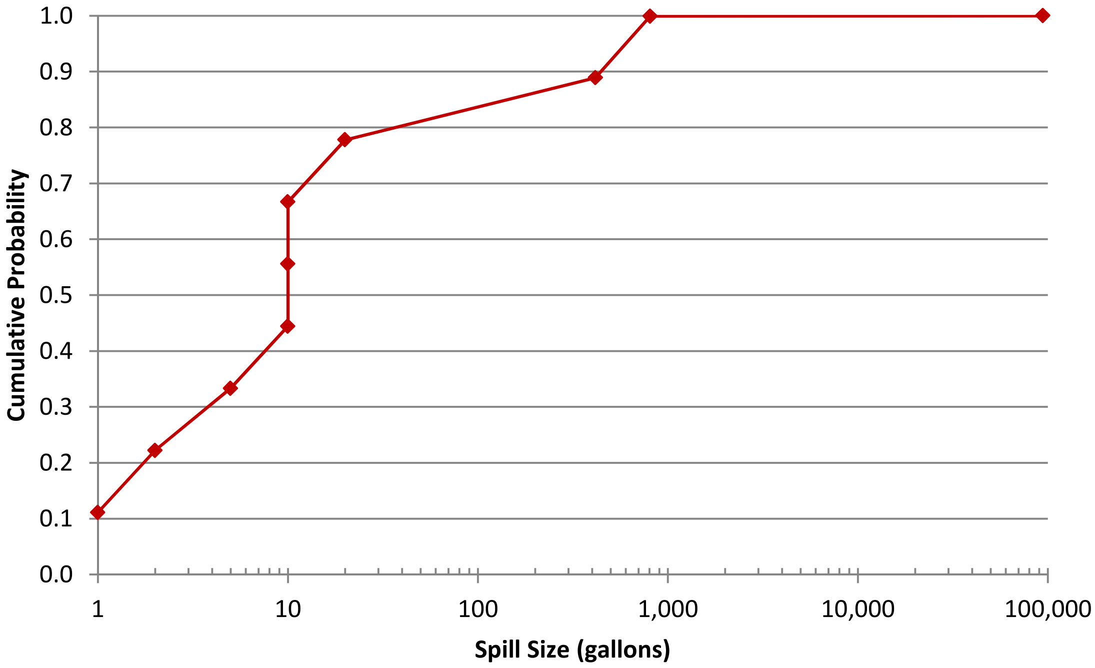

Figure 16 CDF of Bunker Outflow Volume for Tanker, Tank Barge, Bulker, and Cargo Vessel Bunker Error Spills (Data Source: Environmental Research Consulting, Inc. 2013)

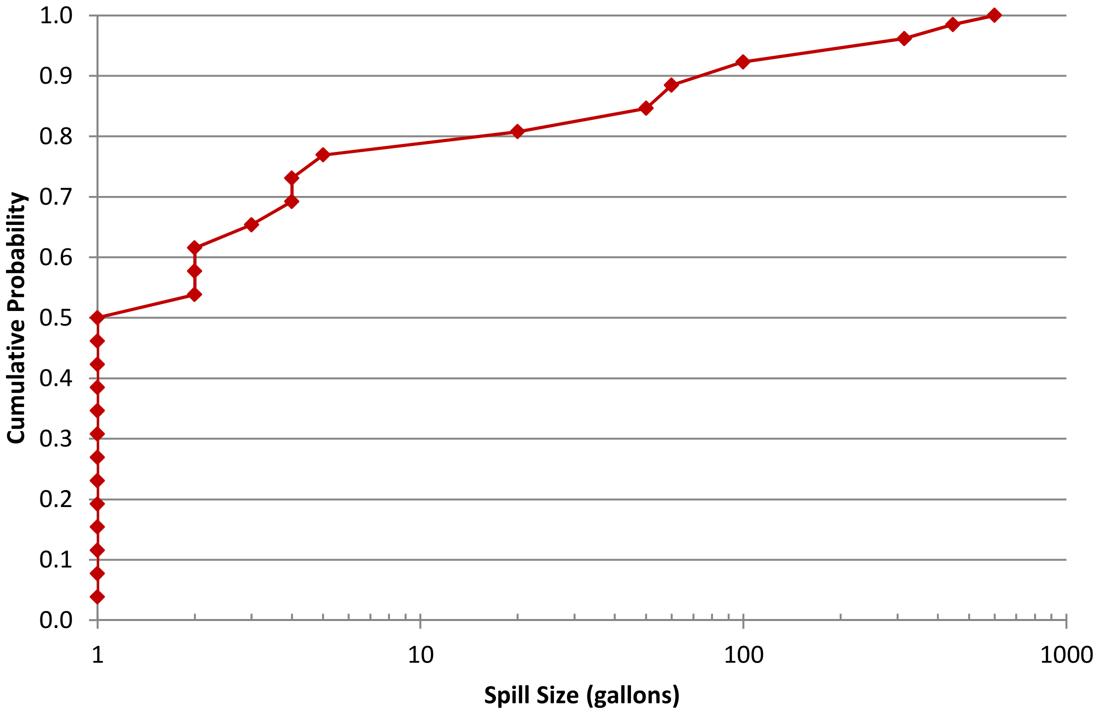

Figure 17 CDF of Bunker Outflow Volume for Fishing Vessel, Passenger Ferry, and Tugboat Bunker Error Spills (Data Source: Environmental Research Consulting, Inc. 2013)

9.2.3 Bunker Outflow Percentage for All Vessel Other Non-Impact Spills

A CDF was developed for bunker oil outflow for other non-impact spills for all vessel types using historical incident data from the study area, as provided by ERC to develop incident rates (as presented in Section 7). Bunker spill volumes of other non-impact incidents from this database that resulted in spills were used to construct a bunker outflow percentage cumulative distribution function.

For tankers, it was unknown whether the amount spilled was from bunkers, cargo, or both. It was therefore assumed that both were spilled, with the amount of bunkers and cargo oil spilled being proportional to the bunker and cargo oil capacity of the vessel.

The historical database of 429 incidents in the study area contains no incidents of 100% bunker oil outflow (total loss). It is assumed that total loss could occur, in the event that a catastrophic event, such as hull girder collapse, results in the ship sinking. To capture the possibility of a total loss, it is assumed that the next incident will be a total loss. This results in a probability of 1 / (429 + 1) = 0.0023 that the spill volume will be less than a total loss but greater than the next largest spill. Above the cumulative probability of 1 – 0.0023 = 0.9977, cumulative probability approaches unity as outflow percentage approaches 100%. This CDF is illustrated in Figure 18.

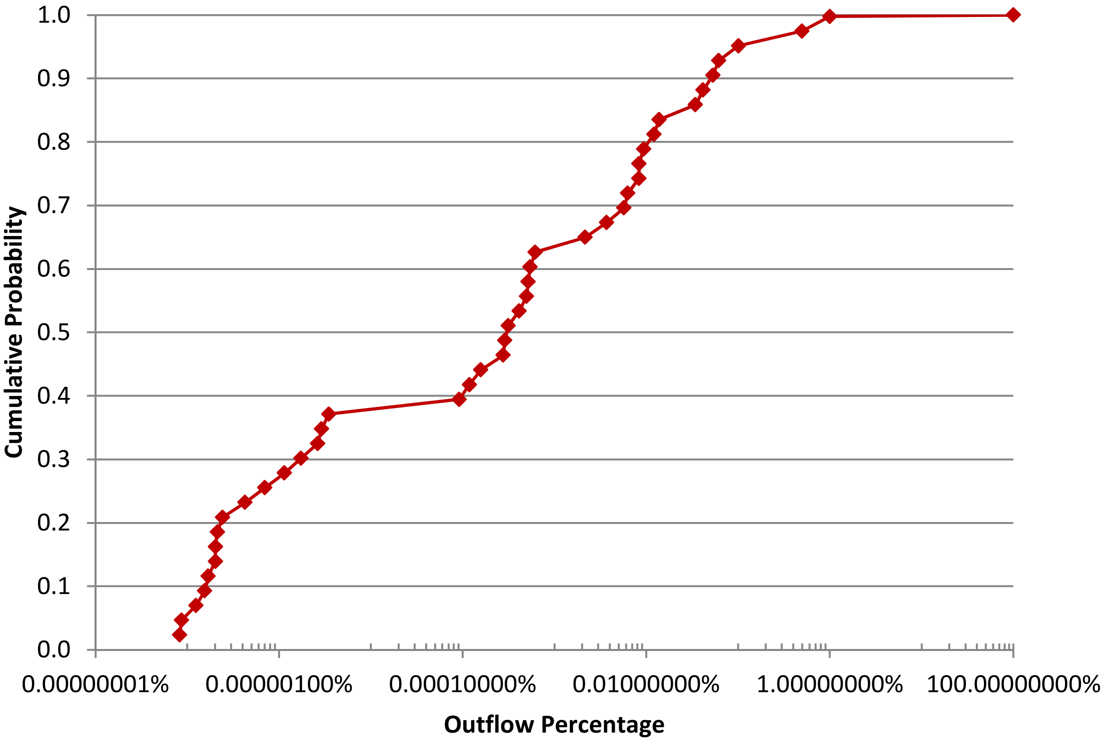

Figure 18 CDF of Bunker Outflow Percentage for All Vessel Other Non-Impact Spills (Data Source: Environmental Research Consulting, Inc. 2013)

9.2.4 Cargo Oil Outflow Percentage for Tankers and Tank Barges for Other Non-Impact Spills

Cargo oil outflow percentage cumulative distribution functions for tanker and tank barge other non-impact spills are provided by ERC in Appendix D, Tables 10 and 13, based on worldwide spill data. However, it was found that outflow percentages in these curves drastically exceed historical spill percentages in the study area. An alternative CDF was therefore developed using historical incident data from the study area, as provided by ERC to develop incident rates (as presented in Section 7). Tanker and tank barge cargo spill volumes of other non-impact incidents from this database that resulted in spills were used to construct cargo oil outflow percentage cumulative distribution functions.

For tankers, it was unknown whether the amount spilled was from bunkers, cargo, or both. It was therefore assumed that both were spilled, with the amount of bunkers and cargo oil spilled being proportional to the bunker and cargo oil capacity of the vessel.

Worldwide historical spill data shows that the theoretical worst-case outflow percentage has been 12.8% for a tanker and 30% for a tank barge for spills due to other non-impact incidents (Appendix D, Tables 10 and 13). Tanker and tank barge spill data were aggregated to create an outflow percentage curve, but to account for different theoretical worst-case outflow percentages, the CDFs for tankers and tank barges diverge at their maximum possible outflow percentage, using the aforementioned maximum values.

The historical database of 429 incidents in the study area contains no incidents of maximum theoretical cargo oil outflow for tankers or tank barges. To capture the theoretical probability of maximum outflow, it is assumed that the next incident that will enter the database will be a maximum outflow event. This results in a probability of 1 / (429 + 1) = 0.0023 that the spill volume will be less than the maximum theoretical outflow but greater than the next largest spill. Above the cumulative probability of 1 – 0.0023 = 0.9977, cumulative probability approaches unity as outflow percentage approaches the maximum theoretical outflow. The CDFs for tanker and tank barge cargo oil other non-impact spill outflow percentages are shown in Figure 19 and Figure 20, respectively.

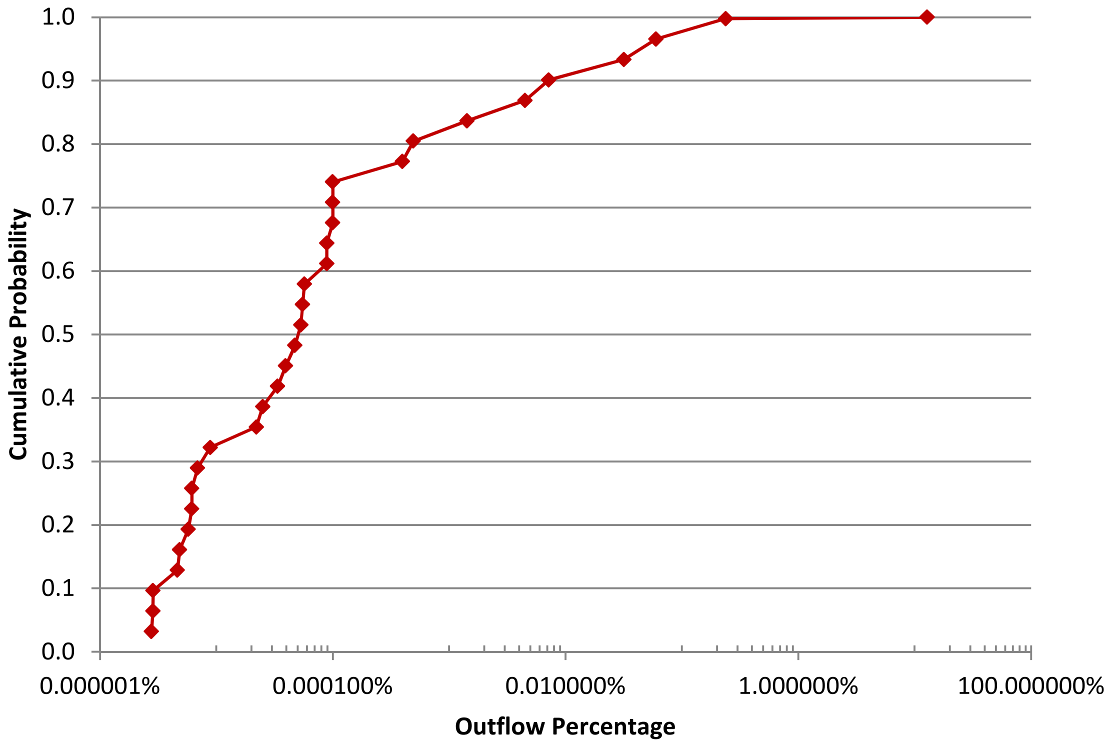

Figure 19 CDF of Cargo Oil Outflow Percentage for Tanker Other Non-Impact Spills (Data Source: Environmental Research Consulting, Inc. 2013)

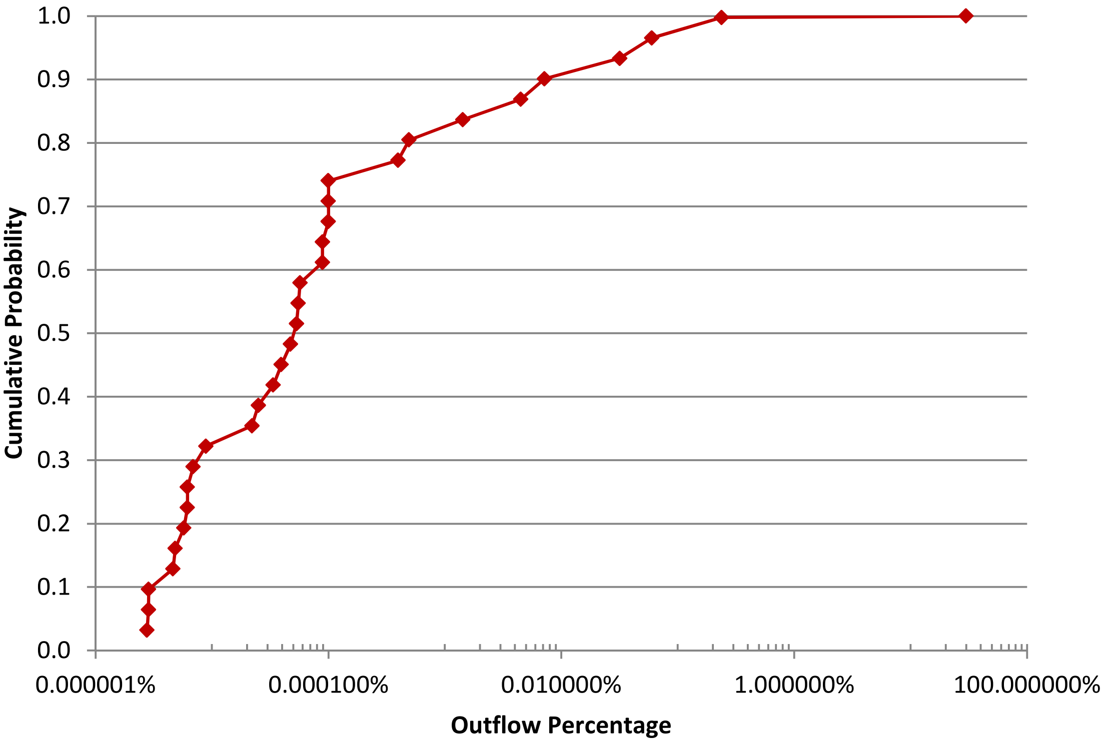

Figure 20 **CDF of Cargo Oil Outflow Percentage for Tank Barge Other Non-Impact Spills (Data Source: Environmental Research Consulting, Inc. 2013)**

9.3 Vessel Capacities ($VC_{c,v}$)

Vessel capacities are the maximum amounts of bunker (fuel) oil and cargo oil that each vessel in the system can carry. Tens of thousands of VTA vessels transit within the system each year, and it is impossible to know the exact distribution of vessels in forecast year 2030. Thus, vessel capacities for each vessel type are random variables with the capacity of each vessel type being described by a probability distribution function.

Changes in the capacity distributions of certain vessel types are also anticipated for future years. Various techniques are employed to account for trends and discrete anticipated changes in the capacity distributions of vessels in the system.

The methods used to determine vessel capacities for each vessel type are detailed below.

9.3.1 Tankers

9.3.1.1 Non-BP Tankers

Marine Exchange of Puget Sound (MX) data was used to determine every non-BP tanker that transited through the system in 2010. Non-BP Tankers are split into two sub-categories (product and crude) due to significant differences in size and transit frequency. Federal regulation (33 CFR 165.1303) limits capacity of tankers in the study area to a capacity of 125,000 DWT. However, tankers larger than this are able to operate in the study area by having a separate, 125,00 DWT load line. Tankers larger than 125,000 DWT are therefore considered to have a capacity of 125,000 DWT for the purposes of cargo and bunker capacity calculations in this study. Figure 21 shows the DWT distribution of non-BP-calling tankers prior to this adjustment.

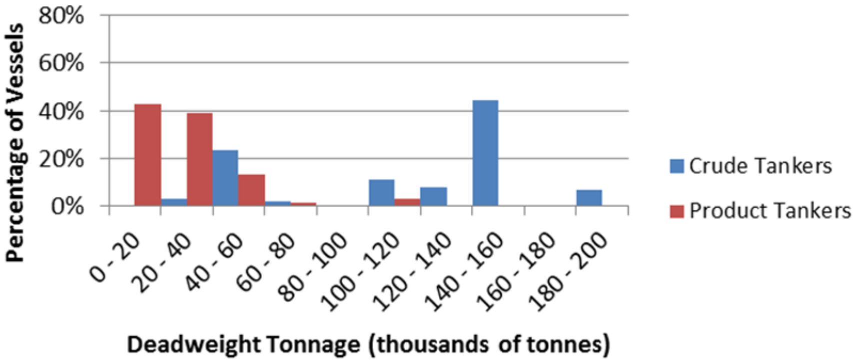

Figure 21 Non-BP Tanker DWT Distribution, 2010 (Data source: MX, 2013)

NEI provided formulae for the average deadweight tonnage of non-BP product tankers (Equation 14) and non-BP crude tankers (Equation 15), and numbers of non-BP product and crude tanker vessel traffic days in the system, hindcast for 2010 and forecast for 2030.

$$\textit{Average DWT Product} = -6{,}482 \times \ln(\textit{Year} - 1998) + 49{,}895 \qquad 14$$

$R^2 = 0.488$

$$\textit{Average DWT Crude} = 5{,}685.4 \times \ln(\textit{Year} - 1998) + 105{,}505 \qquad 15$$

$R^2 = 0.294$

The average DWT for crude carriers and product tankers from MX and the crude and product volumes from BST were used to determine the crude to product ratio for non-BP tankers. BST provided historical crude and product volumes back to 1995 and forecast commodity volumes through 2030. Numbers of trips by crude carriers and product tankers were estimated by dividing the average vessel capacity into the commodity volumes. This approach was used to find a ratio of crude to product trips in 2010 and 2030 for the non-BP calling tankers.

The BST tanker data was used to determine trends and ratios. In 2010, the number of tanker trips derived from BST data is 273 crude + 350 product = 623 trips (44% / 56%). In 2030, the number of trips derived from the BST forecast is 227 crude + 348 product = 575 trips (39% / 61%). The Marine Exchange records show the opposite ratio (61% crude and 39% product) in 2010, but the total unique trips are within 5% (594 MX versus 623 BST) of the BST derived estimate. The BST report only provides overall industry data; whereas the MX provides both overall data and data on calls specifically to BP. The inconsistency between the 2010 MX and the BST data was recognized and addressed by choosing to use the BST data for Non-BP Tankers, reflective of the overall industry, and to use the MX data for BP-tankers.

Numbers of tankers by subtype are converted to percentages, as shown in Table 42. It is assumed that the breakdown of product versus crude tankers is consistent across all subareas, as the MX data shows a strong correlation between percentage of routes by tanker vessel type and percentage of routes by both tanker vessel types.

Table 42 Non-Tanker Traffic Breakdown by Subtype

	2010	2030
Product	56%	61%
Crude	44%	39%

Finally, Environmental Research Consulting (ERC) provided a regression equation for estimating tanker bunker capacity (Equation 16)[7] and a geometric tanker cargo capacity (Equation 17)[8] in gallons, based on DWT (Appendix D).

$$\textit{Tanker Bunker Capacity} = 5.086 \text{ x } \textit{DWT} + 106{,}924 \quad \text{(gallons)} \qquad 16$$

$$R^2 = 0.958$$

$$\textit{Tanker Cargo Capacity} = 285.4 \text{ x } \textit{DWT} \text{ (gallons)} \qquad 17$$

To sample a non-BP tanker capacity, a random number is generated to determine the tanker subtype (product or crude), with probabilities of returning a product or crude tanker in a given year shown in Table 42. Another random number is generated to randomly select a deadweight tonnage of that tanker subtype from the database of non-BP tankers in the system in 2010. For forecast year 2030, the DWT is then extrapolated by multiplying the sampled DWT by the ratio of average 2010 DWT to average 2030 DWT using Equation 9 or 10, depending on the tanker subtype. Finally, the bunker and cargo capacities are estimated from Equations 16 and 17.

9.3.1.2 BP-Calling Tankers

MX data was used to determine deadweight tonnage (DWT) for every tanker that called at the BP Cherry Point facility in 2010. Figure 22 shows the DWT distributions for BP-calling tanker subtypes in the system in 2010. As with Non-BP tankers, as described in 9.3.1.1, BP-calling tankers larger than 125,000 DWT are considered to have a capacity of 125,000 DWT for the purposes of cargo and bunker capacity calculations herein. Figure 22 shows the DWT distribution of tankers prior to this adjustment.

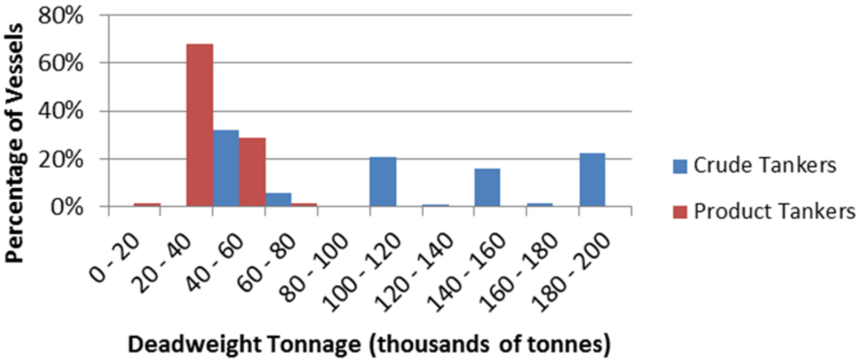

Figure 22 BP-Calling Tanker DWT Distribution, 2010 (Data source: MX, 2013)

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[7] Based on adjustment for 70% bunker capacity, as noted in Appendix D.

[8] Based on adjustment for 98% cargo oil capacity, as noted in Appendix D.

NEI provided percentages of BP-calling product and crude tankers using MX data, and a forecast number of BP-calling product and crude tankers for 2030, as presented in Table 43.

The 2010 MX shows 228 crude carrier and 101 product tanker calls to the BP dock. This is a 69% / 31% ratio and a total of 329 calls. BP provided data was within 1% (332 calls) for total number of calls, but was −/+ 17% for the crude to product ratio. BP-provided 2010 data showed 52% / 48%. The inconsistency between the MX data and the BP-provided data was recognized and addressed by choosing to use the MX data. The MX database was the primary data source for the vessel traffic analysis and forecast. Using the MX database for total number of calls is consistent with rest of the analysis.

The ratio of crude carriers to product tankers calling at BP in 2030 was derived from the historical MX data (2006-2010) and underlying economic forecast by BST. Recent history (2006-2010) was considered a better indicator of future crude to product ratios than the average from the 13 years of available BP or MX data. The underlying economic forecast showed a drop in the volume of crude. Coupled with a forecasted increase in crude carrier size (though still remaining well below the 125,000 DWT limit), 190 crude calls are forecast for 2030 (down from 228 in 2010). The BST economic forecast for product volumes was flat over the study period, so there were 101 product calls forecast to 2030 (same as in 2010). Forecasting existing traffic forward resulted in 190+101= 291 calls at BP in 2030. This is a 65% / 35% ratio. This ratio was then applied to the prescribed number of calls at BP in the 2030 forecast cases.

Table 43 BP Tanker Traffic Breakdown by Subtype

	2010	2030
Product	31%	35%
Crude	69%	65%

To sample a BP tanker capacity, a random number is generated to determine the tanker subtype (product or crude), with probabilities of returning a product or crude tanker in a given year shown in Table 43. Another random number is generated to randomly select a deadweight tonnage of that tanker subtype from the database of BP tankers in the system in 2010. For forecast year 2030, the DWT is then extrapolated by multiplying the sampled DWT by the ratio of average 2010 DWT to average 2030 DWT using Equation 18 or 15, depending on the tanker subtype. Finally, the bunker and cargo capacities are estimated from Equations 16 and 17.

9.3.1.3 Impact of Crude to Product Ratios

The crude to product ratio has an insignificant impact on the analysis outcome. It affects only the spill volumes due to variation in vessel cargo spill probability (Appendix D Table 2) and deadweight (distribution in Figure 22), which is input to estimating bunker and cargo capacity (Equations 16 and 17). More crude carriers and less product tankers would probabilistically result in greater outflow volumes. However, in this comparative analysis, relative differences between cases will not be affected.

9.3.2 Cargo Ships

MX data was used to determine deadweight tonnage (DWT) for every cargo ship that transited through the system in 2010. Cargo ships were split into two sub-categories, container and general cargo, due to significant differences in size and transit frequency. Figure 23 shows the DWT distributions for cargo ship subtypes in the system in 2010.

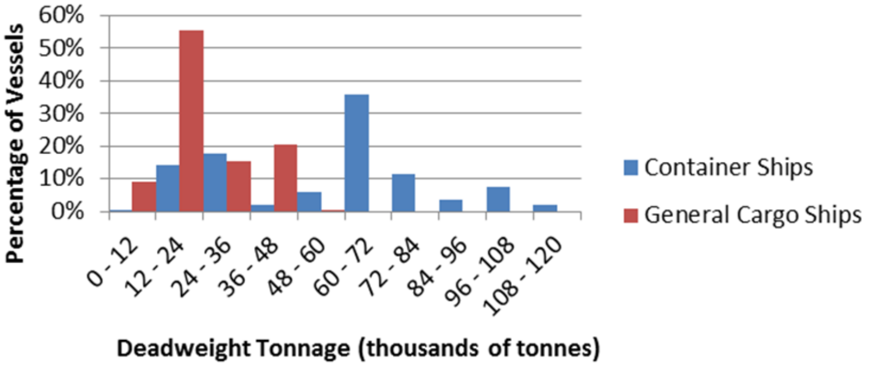

Figure 23 Cargo Ship DWT Distribution, 2010 (Data source: MX, 2013)

NEI provided formulae for the weighted average DWT of container ships (Equation 18) and general cargo ships (Equation 19), and numbers of container and general cargo ships in the system, hindcast for 2010 and forecast for 2030. Numbers of cargo ships by subtype were converted to percentages, as shown in Table 44.

$$\textit{Average DWT Container} = 6{,}534.9 \times \ln(\textit{Year} - 1998) + 39{,}156 \tag{18}$$

$R^2 = 0.893$

$$\textit{Average DWT General Cargo} = 740.35 \times \ln(\textit{Year} - 1998) + 21{,}503 \tag{19}$$

$R^2 = 0.199$

Table 44 Cargo Ship Traffic Breakdown by Subtype

	2010	2030
Container	87%	79%
General Cargo	13%	21%

Finally, ERC provided a regression equation for estimating cargo ship bunker capacity in gallons, based on DWT, Equation 11[9] (Appendix D, Equation 16).

$$\textit{Bunker Capacity Cargo Ship} = 27.545 \times \textit{DWT} - 64{,}922 \text{ (gallons)} \tag{20}$$

$R^2 = 0.930$

To sample a cargo ship bunker capacity, a random number is generated to determine the ship subtype, with probabilities of returning a container ship or general cargo vessel in a given year shown in Table 44. Another random number is generated to randomly select a DWT of that cargo ship subtype from the database of cargo ships in the system in 2010. For forecast year

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[9] Based on adjustment for 70% capacity, as noted in Appendix D.

2030, the DWT is then extrapolated to 2030 by multiplying the sampled DWT by the ratio of average 2010 deadweight to average forecast 2030 DWT, using Equation 18 or 19, depending on the cargo ship subtype. Finally, the bunker capacity is derived from Equation 20.

9.3.3 Bulk Carriers

MX data was used to determine deadweight tonnage (DWT) for every bulk carrier (bulker) that transited through the system in 2010. Bulkers were split into two sub-categories, grain and non-grain, due to significant differences in size and transit frequency. Figure 24 shows the DWT distributions for bulker subtypes in the system in 2010.

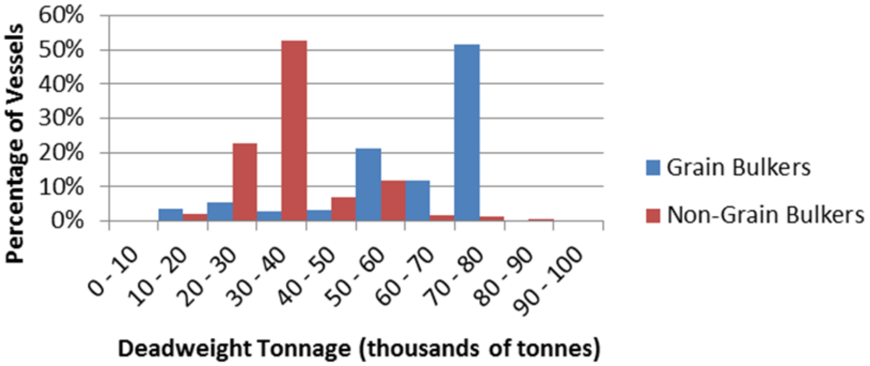

Figure 24 Bulk Carrier DWT Distribution, 2010 (Data source: MX, 2013)

NEI provided formulae for the weighted average DWT of grain bulkers (Equation 21) and non-grain bulkers (Equation 22), and numbers of grain and non-grain bulkers in the system, hindcast for 2010 and forecast for 2030. Numbers of cargo ships by subtype were converted to percentages, as shown in Table 45.

$$\textit{Average DWT Grain} = -541.4 \times \ln(\textit{Year} - 1998) + 62{,}087 \qquad 21$$

$R^2 = 0.021$

$$\textit{Average DWT Non-Grain} = 1597.8 \times \ln(\textit{Year} - 1998) + 32246 \qquad 22$$

$R^2 = 0.165$

Table 45 Bulker Traffic Breakdown by Subtype

	2010	2030
Grain	43%	24%
Non-Grain	57%	76%

A regression equation for estimating bulk carrier bunker capacity based on DWT was formulated using information from 21 bulkers of various sizes, including Capesize and Panamax vessels, as shown in Figure 25. The data points circled in green are vessels that actually transited through the system in 2010. The Capesize vessels are those in the upper right-hand corner of the figure. The gap that exists between approximately 80,000 and 180,000 DWT in the data set used to create Figure 25 is because very few tankers are built in this size range, for economic reasons. The least-squared regression line shown in Figure 25 is used to estimate bulker bunker capacity in gallons. Like tankers and cargo ships, bunker tanks of bulk carriers are rarely filled to more than 70%, as described in Appendix A, so an adjustment factor of 70% is applied to the equation describing the least-squared regression line. The regression equation is shown as Equation 23.

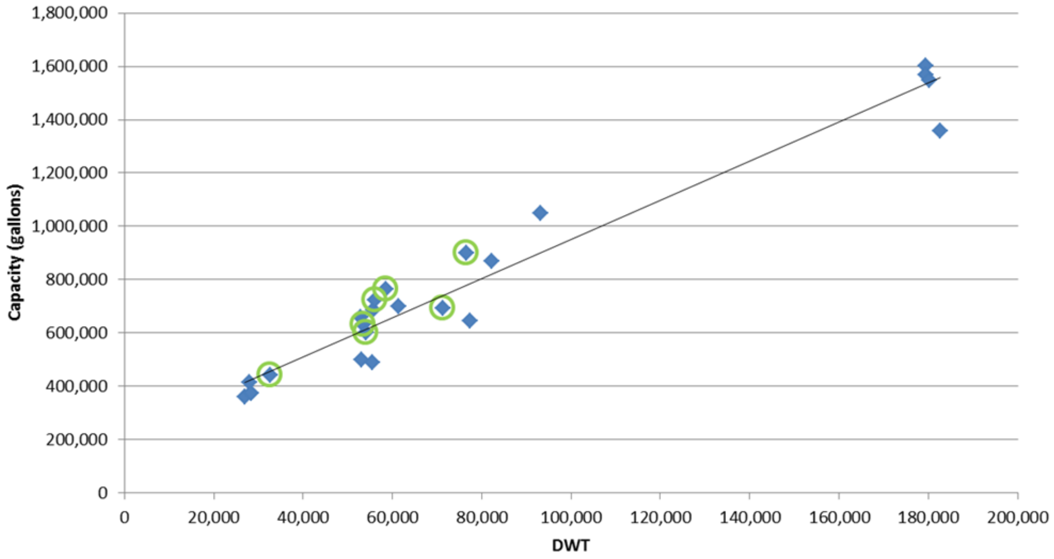

Figure 25 Bulker Bunker Capacity versus DWT

$$\textit{Bunker Capacity Bulker} = 5.125 \times \textit{DWT} + 152{,}964 \quad \text{(gallons)} \qquad 23$$

$R^2 = 0.948$

To sample a bulker bunker capacity, a random number is generated to determine the bulker subtype, with probabilities of returning a grain or non-grain bulker in a given year shown in Table 45. Another random number is generated to randomly select a DWT of that bulker subtype from the database of bulkers in the system in 2010. For 2030, the DWT is then extrapolated to the forecast year by multiplying the sampled DWT by the ratio of average 2010 deadweight to the average forecast 2030 DWT, using Equation 21 or 26, depending on the bulker subtype. Finally, the bunker capacity is derived from Equation 23.

9.3.4 Tank Barges

A comprehensive study of tank barges operating in the study area in 2012 was conducted, and a database of characteristics of those 26 vessels was compiled. Length times beam times depth and capacity for 18 tank barges with available capacity data were plotted against each other. The equation of a least-squared regression line fit to the data was used to estimate the capacities of the remaining eight tank barges. An adjustment factor of 98% was applied to the tank barge capacities to match the convention in Appendix D. Based on expert judgment and interviews with tank barge owners, it was estimated when each tank barge would reach the end of its service life, to account for a changing capacity distribution over time. Since the total forecasted capacity of the fleet in 2026 was assumed to meet the demands of additional forecasted traffic, including the bunkering demands of GPT-calling bulk carriers, it was assumed that no new barges will begin operating in the system prior to 2026. A summary of tank barge sizes is shown in Figure 26.

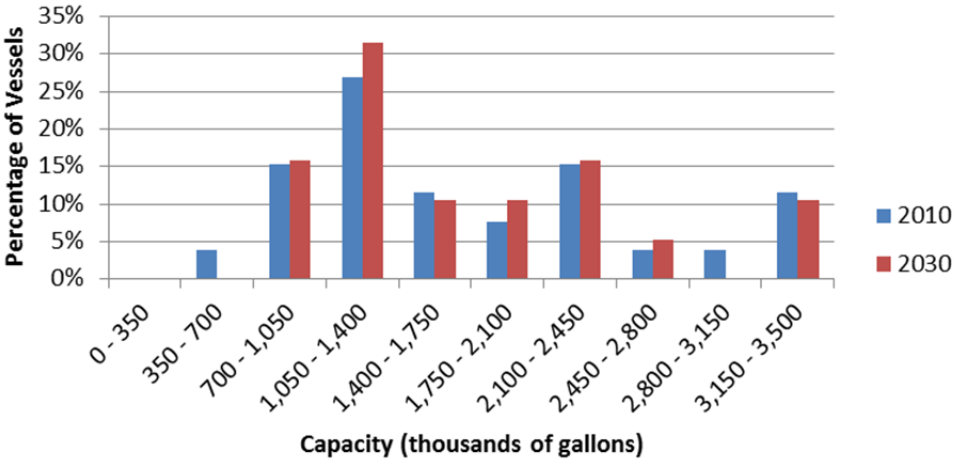

Figure 26 Tank Barge Cargo Capacity Distribution (Data source: Little River Marine Consultants, Inc. 2013)

It is important to note that tank barges are towed by tugboats, which are also at risk for oil outflow. Oil outflow from tugboats is accounted for separately.

9.3.5 Tugboats

As part of their vessel traffic study (Appendix C), NEI provided a comprehensive database of tugboats that transited the system from 2007-2010. In total, there were 668 tugs accounting for 76,929 transits through the system. It would be impractical to obtain capacity information on all 668 tugs, so a representative distribution of tugboat bunker capacities was developed based on the tugs in the system. This was accomplished by sorting the tugs by number of transits from 2007-2010 and obtaining capacity information for tugs accounting for a significant percentage of total tug traffic in the system. In all, 24 tug bunker capacities were obtained for tugs that accounted for 18,246 transits (24%) of the 2007-2010 tugboat traffic. The tugboat bunker capacity distribution of this representative database is summarized in Figure 27.

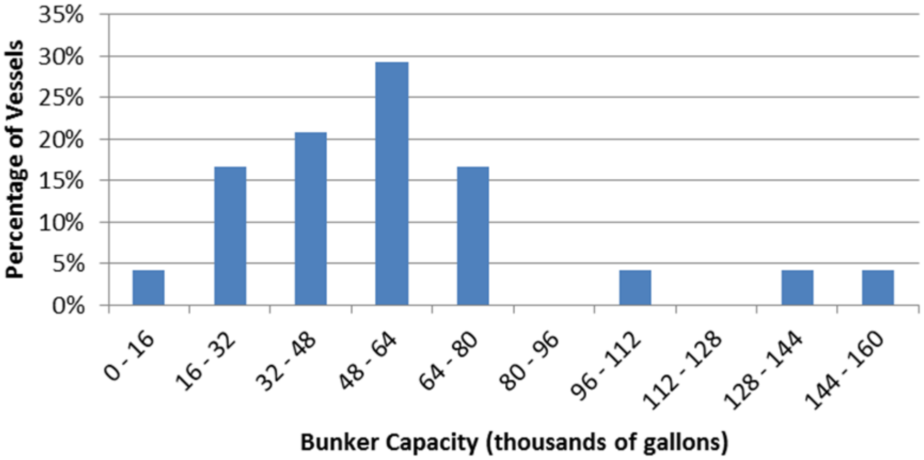

Figure 27 Tugboat Bunker Capacity Distribution (Data sources: NEI, 2013; Little River Marine Consultants, Inc. 2013)

The capacity of one of the tugs in the representative database is randomly selected to obtain a tugboat bunker capacity within the scenario simulation. Expert judgment revealed that the current fleet of tugboats in the study area has sufficient size and operational capability to handle the demand of forecasted traffic through 2030, including cumulative traffic. It is therefore assumed that there will be no change in the capacity distribution of tugs between 2010 and 2030.

9.3.5.1 BP-Calling Tugboats

Tugboats are defined as BP-calling tugboats during the time they are escorting and docking BP-calling vessels. It is assumed that the bunker capacities of BP-calling tugboats follow the same distribution of all tugboats in the system, as described in Section 9.3.5. To test the validity of this assumption, Frosty Leonard, of Little River Consultants, a former Crowley employee, and subject matter expert, verified that there is no appreciable difference in tugboat size between general tugs and oil tanker escort tugs. Additionally, it was found that of the tugs in the database used to create the capacity distribution illustrated in Figure 27, those that are currently dedicated to tanker escort service are only 14% larger than those that are not[10].

9.3.6 Passenger and Fishing Vessels

Passenger and Fishing Vessels are composed of three vessel subtypes: cruise ships, passenger ferries, and fishing vessels greater than 60 feet in length overall (LOA). Due to significant differences in size and transit frequency, bunker capacity distributions were developed for each of these subtypes. To sample a Passenger and Fishing Vessel bunker capacity, a random number is generated to determine the Passenger and Fishing Vessel subtype (cruise, ferry, or fishing vessel), with probabilities of returning a given subtype in a given year shown in Table 46, as provided by NEI as part of their vessel traffic study (Appendix C).

Table 46 Passenger and Fishing Vessel Traffic Breakdown by Subtype (Data source: NEI, 2013)

	2010	2030
Cruise Ship	29%	40%
Passenger Ferry	38%	39%
Fishing Vessel	33%	21%

Depending on which Passenger and Fishing Vessel subtype is randomly selected, one of the methods in the following sections is used to return a bunker capacity for that subtype.

9.3.6.1 Cruise Ships

MX data was used to determine deadweight tonnage (DWT) for every cruise ship that transited through the system in 2010. Figure 28 shows the DWT distribution for cruise ships in the system in 2010.

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[10] It was assumed a 14% difference in average size of general tugboats and tanker escorting tugboats was not significant enough to warrant the addition of a new vessel type. If this new vessel type was modeled with a unique size distribution, it would have a negligible impact on oil outflow results.

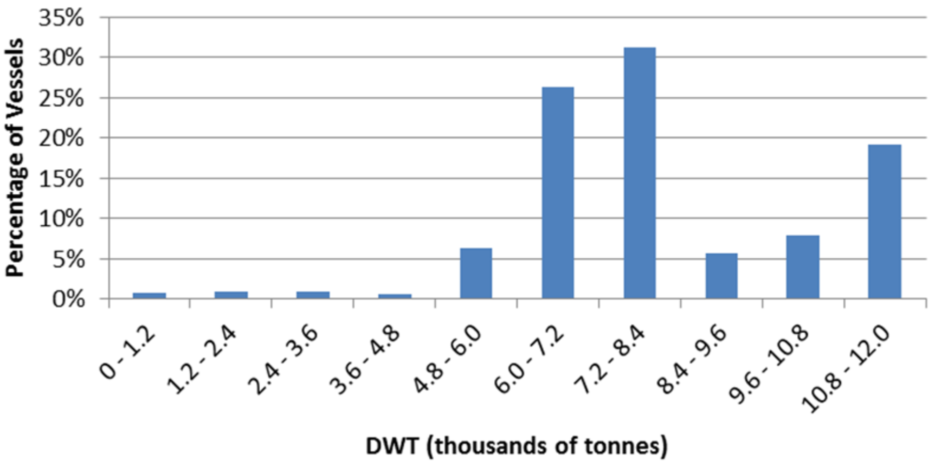

Figure 28 Cruise Ship DWT Distribution, 2010 (Data source: MX, 2013)

The yearly periodical *Significant Ships* (Reference 23) was used to build a database of cruise ship characteristics. DWT and bunker capacity for 23 cruise ships were plotted against each other, and a least-squared regression line was fit to the data, as shown in Figure 29. The data points circled in green are vessels that actually transited through the system in 2010. The regression equation is shown as Equation 24.

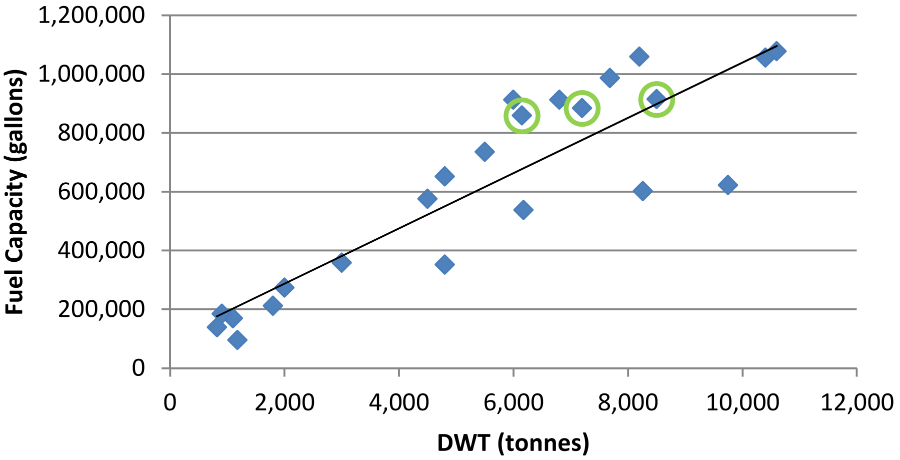

Figure 29 Cruise Ship Bunker Capacity versus DWT (Data source: The Glosten Associates 2013)

$$\textit{Cruise Ship Bunker Capacity} = 93.976 \times \textit{DWT} + 99{,}871 \quad \text{(gallons)} \qquad 24$$

$R^2 = 0.782$

To obtain a cruise ship bunker capacity, the DWT of one of the cruise ships in the NEI database of 2010 cruise ship transits is randomly selected. The bunker capacity is then derived using Equation 24. It is assumed that there will be negligible changes in the DWT distribution and relationship between DWT and bunker capacity of cruise ships between 2010 and 2030.

9.3.6.2 Passenger Ferries

Washington State Ferry is the largest passenger and automobile ferry fleet in the US, and its vessels account for a significant portion of the ferry traffic in the study area. Therefore, the bunker capacity distribution of its current fleet was assumed to represent the bunker capacity distribution of all passenger ferries in the study area. Vessel capacities were obtained from a phone interview with Washington State Ferry Chief Naval Architect Cotty Fay. The passenger ferry bunker capacity distribution of this representative database is summarized in Figure 30.

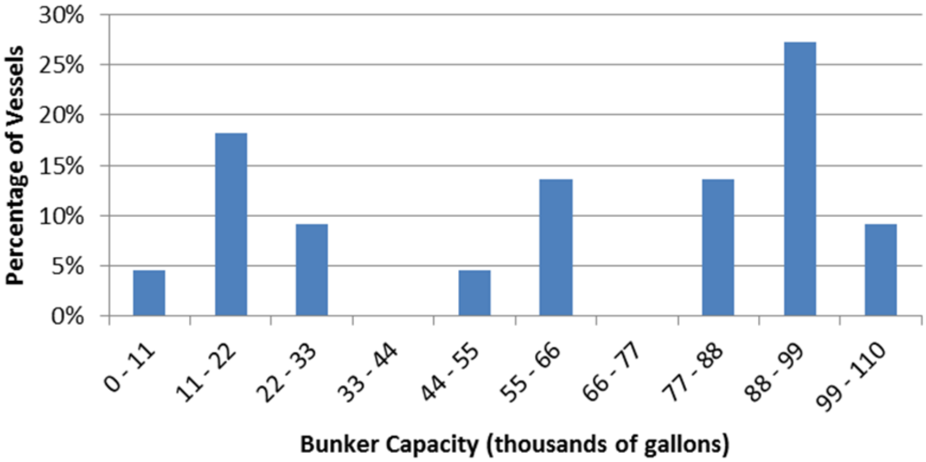

Figure 30 Passenger Ferry Bunker Capacity Distribution

The capacity of one of the ferries in the representative database is randomly selected to obtain a passenger ferry bunker capacity. It is assumed that there will be negligible change in the capacity distribution of passenger ferries between 2010 and 2030.

9.3.6.3 Fishing Vessels greater than 60 feet

MX data was used to compile a database of 3,376 recorded fishing vessel transits of vessels greater than 60 feet Length Overall (LOA) between 2008 and 2010. This database of fishing vessels was assumed to represent the entire distribution of fishing vessel LOA for the system. The fishing vessel LOA distribution of this representative database is summarized in Figure 31.

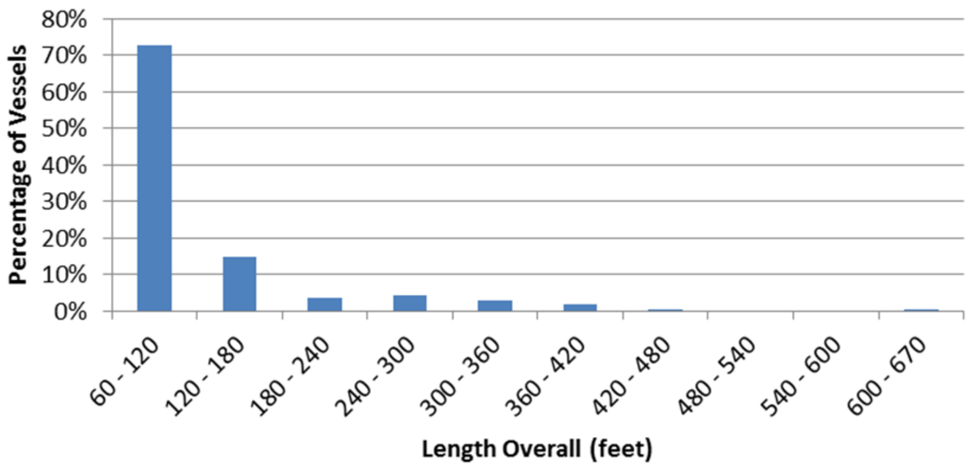

Figure 31 Fishing Vessel greater than 60 feet Length Overall Distribution (Data source: MX, 2013)

Various sources were used to compile a database of fishing vessel characteristics. LOA and bunker capacity for 16 fishing vessels of various sizes were plotted against each other, and a least-squared regression curve was fit to the data, as shown in Figure 32. The data points circled in green are vessels that actually transited through the system between 2008 and 2010. The regression equation is shown as Equation 25.

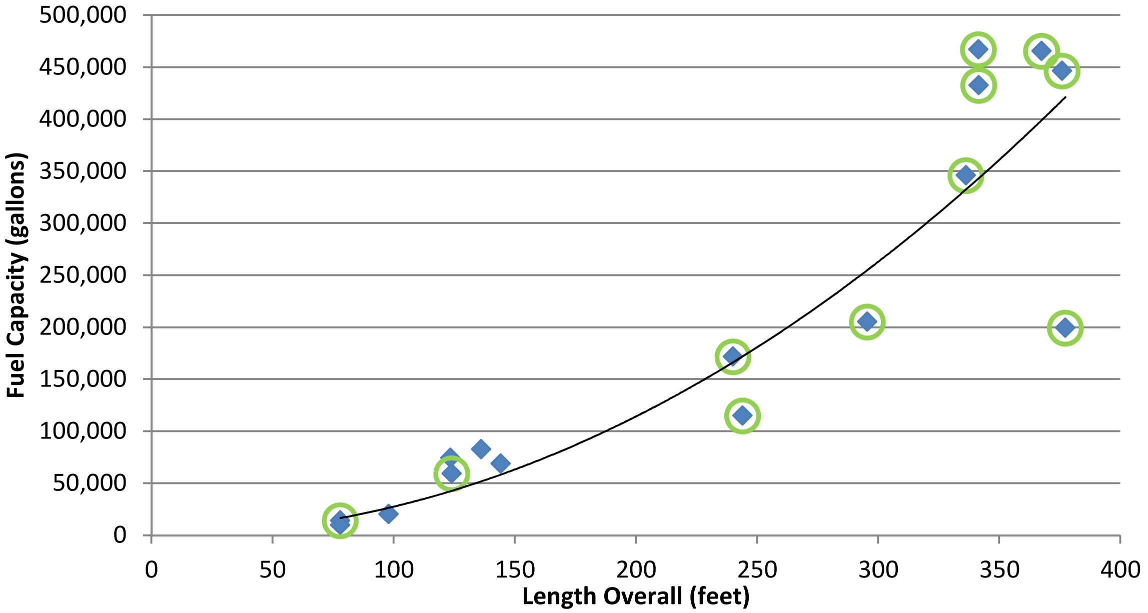

Figure 32 Fishing Vessel Bunker Capacity versus LOA

$$\textit{Bunker Capacity Fishing Vessel} = 2.109 \times LOA^{2.057} \quad \text{(gallons)} \qquad 25$$

$R^2 = 0.918$

The LOA of one of the fishing vessels in the NEI database of 2008-2010 fishing vessel transits is randomly selected to obtain a fishing vessel bunker capacity. The bunker capacity is then derived using Equation 25. It is assumed that there will be negligible changes in the LOA distribution and relationship between LOA and bunker capacity of fishing vessels between 2010 and 2030.

Section 10 Incremental Risk Results

10.1 Representative Risk Statistics

Prediction results are plotted as cumulative probability distributions and statistics of the distributions are tabulated for 1) annual number of potential incidents; 2) annual number of potential spills; and 3) annual potential oil outflow. The selected statistics to characterize incremental risk are the average, 50th and 95th percentiles. It is appropriate to compare the average prediction for the number of incidents and or for the number of spills. With respect to volume of oil outflow, it is appropriate to compare the median (50th percentile) of the 10,000 predictions or some other percentile value (e.g., 95th), rather than the average.

The choice of using either the average prediction or a percentile of the prediction is a result of the mathematical detail of the Monte Carlo simulation. As described in Section 4, the methodology for sampling oil outflows includes several binary processes. For example, in the Monte Carlo simulations, the question is asked "*if a collision occurs was there a spill*?" The answer is binary, either *Yes* or *No*. The number of incidents and number of spills are integer numbers; i.e., there cannot be a fraction of an incident or a fractional number of spills. A Poisson sampling method predicts the integer number of incidents, including the possibility of zero incidents, in each of the 10,000 predictions for the forecast year.

The average of 10,000 integers may not be an integer. A percentile value of a distribution of 10,000 integers, many of which are zeros, does not produce a meaningful number; e.g., many of the 10,000 predictions resulted in zero incidents in several of the subareas. For example, consider the case of 2,500 predictions with 3 incidents and 7,500 predictions with no incidents. The median of these 10,000 predictions is zero. The average of these 10,000 predictions, however, is 0.0003 incidents. Of the 10,000 predictions in the example case, half of the predictions are for zero incidents, and half of the 10,000 predictions are for zero or more number of incidents; thus, the median value is zero. By reporting the average for annual number of potential incidents and spills, predictions and differences between predictions of less than one are captured in the incremental risk analysis.

The appropriate measure to compare oil outflow is not the average of the 10,000 predictions, but rather the median (50th percentile) or 95th percentile. The reason is that, unlike predictions of the number of incidents, which because of the Poisson method resemble a normal distribution, oil spill volume predictions have possibilities of very large values. This skews the oil outflow distribution to have a shape that does not resemble a normal distribution. Some of the 10,000 predictions for oil outflow for the year 2030 contain values that are the result of the combination of very rare events. When calculating the average of the 10,000 predictions, the predictions with very large outflow volumes have a significant impact on the average, but do not distort the median. Consequently, comparisons between the averages of two sets of 10,000 predictions, one of which might contain a very large oil outflow and the other of which might not (purely because the random sampling of very rare events), are not meaningful. In place of the average, the median is reported. The median is not distorted by rare, large volume predictions.

Rare events, such as collisions, contribute significantly to the 95th statistic of the oil outflow distribution. When producing 10,000 predictions of what will happen in 2030, these rare events may or may not have been included in the prediction. For example, in a set of 10 predictions where the first set is {1,2,3,4,5,6,7,8,9,100} and the second set is {1,2,3,4,5,6,7,8,9,1000000}, the second set produces a rare very high number, but the first does not. The two averages are 14.5 and 100,004.5, respectively. The median (50th percentile) of the first set is 5.5 and the median of the second set is 5.5, which indicates that the two sets of predictions are similar. In a set of 10 predictions, the 95th percentile is the average of the 9th and 10th predictions, in order of increasing size. The 95th percentile of the first example set is 54.5, and the 95th percentile of the second is 500,004.5, which indicates that a rare combination showed up in the second set, but not in the first. As a consequence, the 95th percentile is an unstable measure to use for comparison with another set of 10,000 predictions. When looking at the 95th percentile results, conclusions should be made from differences in order of magnitude, rather than percentage differences. To emphasize this appropriate interpretation of results, spill volume outflow distributions are plotted on a logarithmic scale.

10.2 Statistical Accuracy, Uncertainty, and Comparisons

The reported distribution statistics are to be interpreted as a measure of risk. The average values do not mean that this will be the average number of incidents or spills in 2030; rather, it means that the statistic is the average of 10,000 attempts to predict the number of incidents and spills in 2030. Likewise, the median and 95th percentile reported spill volumes are the median and 95th percentile of 10,000 attempts to predict the spill volumes in 2030.

The statistics of the probability distributions are a measure of the accuracy of the predicted values. They are not a prediction of the statistics of the distribution of incidents, spills, and volumes that will occur in the forecast year.

If there are no uncertainties in the predictions, then the average, median, 95th percentile, and all other statistical measures will be identical, because all 10,000 predictions will result in the same number; e.g., if there are no uncertainties in the forecast of vessel traffic movement, no uncertainties in the volumes of oil they will be carrying, no uncertainties in the forecast of incident rates, no uncertainties in the rate at which a spill occurs as a result of an incident, and no uncertainties in any of the other underlying parameters, then there will be no uncertainty in the prediction of the number of incidents, number of spills, and the volume of oil outflow that will occur in 2030. The prediction will be that there are a particular number of incidents, a particular number of spills, and a particular volume of oil spilled. This prediction accuracy, however, is clearly impossible.

Since it is clearly impossible to predict the actual number of incidents and spills, or the volume of oil spilled in 2030, with and without the North Wing at the BP Terminal, it is only appropriate to compare common statistical measures of the prediction sets.

Comparison between all seven cases is presented in the figures of cumulative distribution functions (CDFs) and in the summary tables of the representative statistics on the distributions. In Figure 33, for instance, all seven cases are shown. The predicted increase in total annual number of incidents from 2010 to 2030, with BP North Wing, maximum single wing calls, and general traffic at any given probability level is the difference between the curves for Case 1 and Case 4. The graph shows that the 95th percentile annual number of incidents under these conditions is predicted to increase from 37 in 2010 (Case 1) to 45 in 2030 (Case 4). Similarly, the cumulative probability range for 30 incidents is 0.64 to 0.71 for Case 1. This means that

7% [(0.71 - 0.64)*100] of the model predictions, or 700 of 10,000, predicted 30 incidents. Some CDFs show that the model predicts the 50th and 95th percentile number of incidents or spills to be zero, but the average number of spills is nonzero. This means that the number of spills in the highest 5% of samples is nonzero. The four representative risk statistics are given for all seven cases in the CDF figure legends.

10.3 Summary Results

Table 47 through Table 60 are summarized results of the incremental risk assessment model, showing average number of incidents, average number of spills, 50th percentile spill volume, and 95th percentile spill volume. Table 47 presents summary results across all subareas and incident types. Table 48 through Table 53 present summary results broken down by subarea. Table 54 through Table 60 present summary results broken down by incident type.

Table 47 Summary Results for All Subareas and Incident Types

	Cases						
	1	2	3	4	5	6	7
Year	2010	2010	2010	2030	2030	2030	2030
North Wing	No	No	Yes	No	Yes	No	Yes
South Wing	Max. Cap.	Actual Calls	Actual Calls	Max. Cap.	N+S = 420 calls	Max. Cap.	N+S = 420 calls
Traffic	2010	2010	2010	2030 General	2030 General	Gen. + Cum.	Gen. + Cum.
Avg. # Incidents	27.78	27.62	27.62	34.35	34.85	46.14	46.66
Avg. # Spills	9.99	9.89	9.88	12.39	12.68	16.58	16.97
50th Spill Vol.	985	975	961	1,109	1,193	2,141	2,396
95th Spill Vol.	90,900	86,172	81,620	62,644	69,617	95,490	114,977

Table 48 Summary Results for Collisions across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	0.76	0.73	0.76	0.87	0.88	1.43	1.42
Avg. # Spills	0.11	0.10	0.11	0.07	0.08	0.10	0.10
50th Spill Vol.	0	0	0	0	0	0	0
95th Spill Vol.	555	673	601	79	120	475	477

Table 49 Summary Results for Allisions across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	1.80	1.79	1.80	1.98	2.00	3.54	3.56
Avg. # Spills	0.15	0.14	0.15	0.13	0.13	0.21	0.22
50th Spill Vol.	0	0	0	0	0	0	0
95th Spill Vol.	4,102	2,704	3,142	1,115	1,083	6,287	8,081

Table 50 Summary Results for Groundings across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	1.37	1.35	1.34	1.41	1.44	2.02	2.03
Avg. # Spills	0.14	0.14	0.13	0.11	0.11	0.14	0.14
50th Spill Vol.	0	0	0	0	0	0	0
95th Spill Vol.	2,228	3,883	2,385	552	624	2,798	4,269

Table 51 Summary Results for Transfer Errors across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	2.36	2.35	2.32	2.32	2.44	2.97	3.13
Avg. # Spills	2.18	2.16	2.14	2.13	2.25	2.73	2.89
50th Spill Vol.	15	15	15	13	16	32	37
95th Spill Vol.	2,195	2,179	2,166	2,171	2,187	2,257	2,269

Table 52 Summary Results for Bunker Errors across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	2.26	2.27	2.27	4.19	4.20	5.71	5.71
Avg. # Spills	2.09	2.09	2.09	3.87	3.87	5.24	5.25
50th Spill Vol.	9	8	10	53	52	104	100
95th Spill Vol.	572	582	597	809	810	1,002	975

Table 53 Summary Results for Other Non-Impact Errors across all subareas

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	19.23	19.12	19.13	23.57	23.90	30.47	30.80
Avg. # Spills	5.34	5.25	5.25	6.08	6.25	8.16	8.36
50th Spill Vol.	148	146	142	217	233	465	498
95th Spill Vol.	16,287	18,212	17,408	16,535	17,585	24,947	23,752

Table 54 Summary Results for Strait of Juan de Fuca West across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	3.48	3.47	3.48	4.09	4.18	4.69	4.79
Avg. # Spills	0.86	0.87	0.84	0.94	0.98	1.19	1.24
50th Spill Vol.	< 1	< 1	< 1	< 1	< 1	2	2
95th Spill Vol.	4,368	5,609	4,269	2,669	3,372	5,692	7,002

Table 55 Summary Results for Strait of Juan de Fuca East across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	6.53	6.41	6.41	7.32	7.36	10.05	10.18
Avg. # Spills	2.28	2.22	2.20	2.39	2.38	3.51	3.55
50th Spill Vol.	18	18	16	18	19	68	73
95th Spill Vol.	9,310	11,316	8,164	6,926	8,109	16,407	16,170

Table 56 Summary Results for Haro Strait and Boundary Pass across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	0.73	0.73	0.74	0.92	0.91	1.91	1.87
Avg. # Spills	0.15	0.15	0.16	0.19	0.19	0.36	0.36
50th Spill Vol.	0	0	0	0	0	0	0
95th Spill Vol.	5	5	4	13	10	93	108

Table 57 Summary Results for Guemes Channel and Fidalgo Bay across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	5.53	5.54	5.51	6.84	6.82	8.21	8.17
Avg. # Spills	2.36	2.32	2.36	2.97	2.95	3.54	3.53
50th Spill Vol.	12	12	13	23	22	40	41
95th Spill Vol.	3,066	2,869	3,259	2,515	2,534	3,361	3,305

Table 58 Summary Results for Saddlebag across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	3.92	3.89	3.85	6.15	6.15	8.24	8.21
Avg. # Spills	1.31	1.29	1.26	2.29	2.29	2.93	2.93
50th Spill Vol.	2	1	1	13	12	22	23
95th Spill Vol.	795	641	669	1,267	1,291	1,830	1,948

Table 59 Summary Results for Rosario Strait across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	0.82	0.80	0.84	0.90	0.91	1.23	1.25
Avg. # Spills	0.12	0.11	0.12	0.12	0.13	0.16	0.16
50th Spill Vol.	0	0	0	0	0	0	0
95th Spill Vol.	3	3	4	3	4	11	8

Table 60 Summary Results for Cherry Point across all incident types

	Cases						
	1	2	3	4	5	6	7
Avg. # Incidents	6.77	6.78	6.79	8.13	8.51	11.81	12.20
Avg. # Spills	2.93	2.93	2.93	3.48	3.76	4.88	5.19
50th Spill Vol.	40	40	41	57	72	153	193
95th Spill Vol.	11,751	10,344	10,427	8,053	10,475	16,170	16,866

10.4 Total Number of Incidents

Figure 33 shows the cumulative distribution function of total yearly incidents for the entire study area for each case. Because the Poisson distribution is used to sample for the number of incidents in each scenario, the number of annual incidents is always returned as an integer value. A comparison between predicted and actual incidents for 2010 is given in Section 11.2.

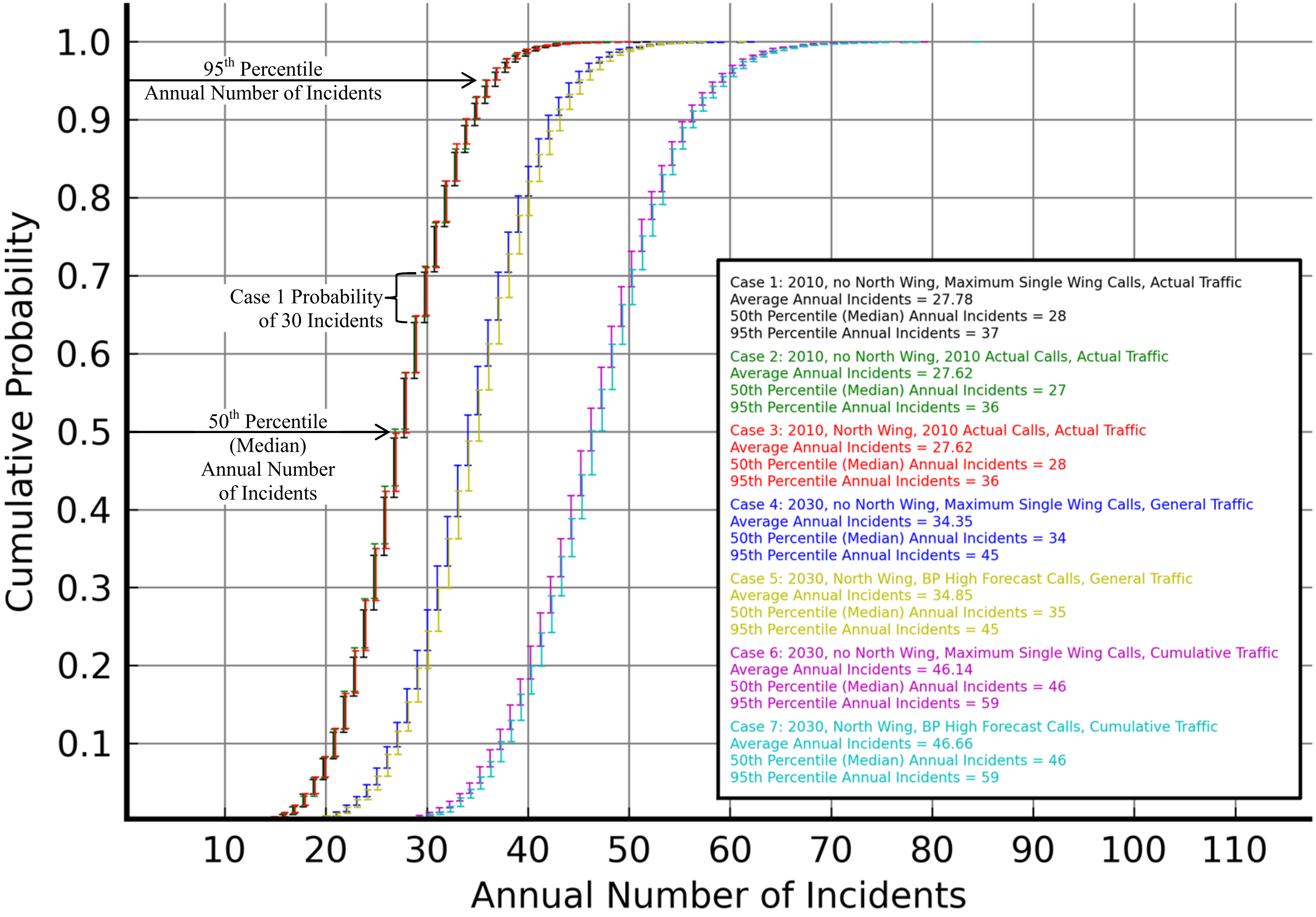

Figure 33 CDF of Total Annual Number of Incidents (All Subareas)

10.5 Total Number of Spills

Figure 34 shows the cumulative distribution function of total yearly spills throughout the system for the seven Cases. Because the Poisson distribution is used to sample for the number of incidents in each scenario and a spill can only occur as a result of an incident, the number of annual spills is always returned as an integer value. A comparison between predicted and actual spills for 2010 is given in Section 11.2.

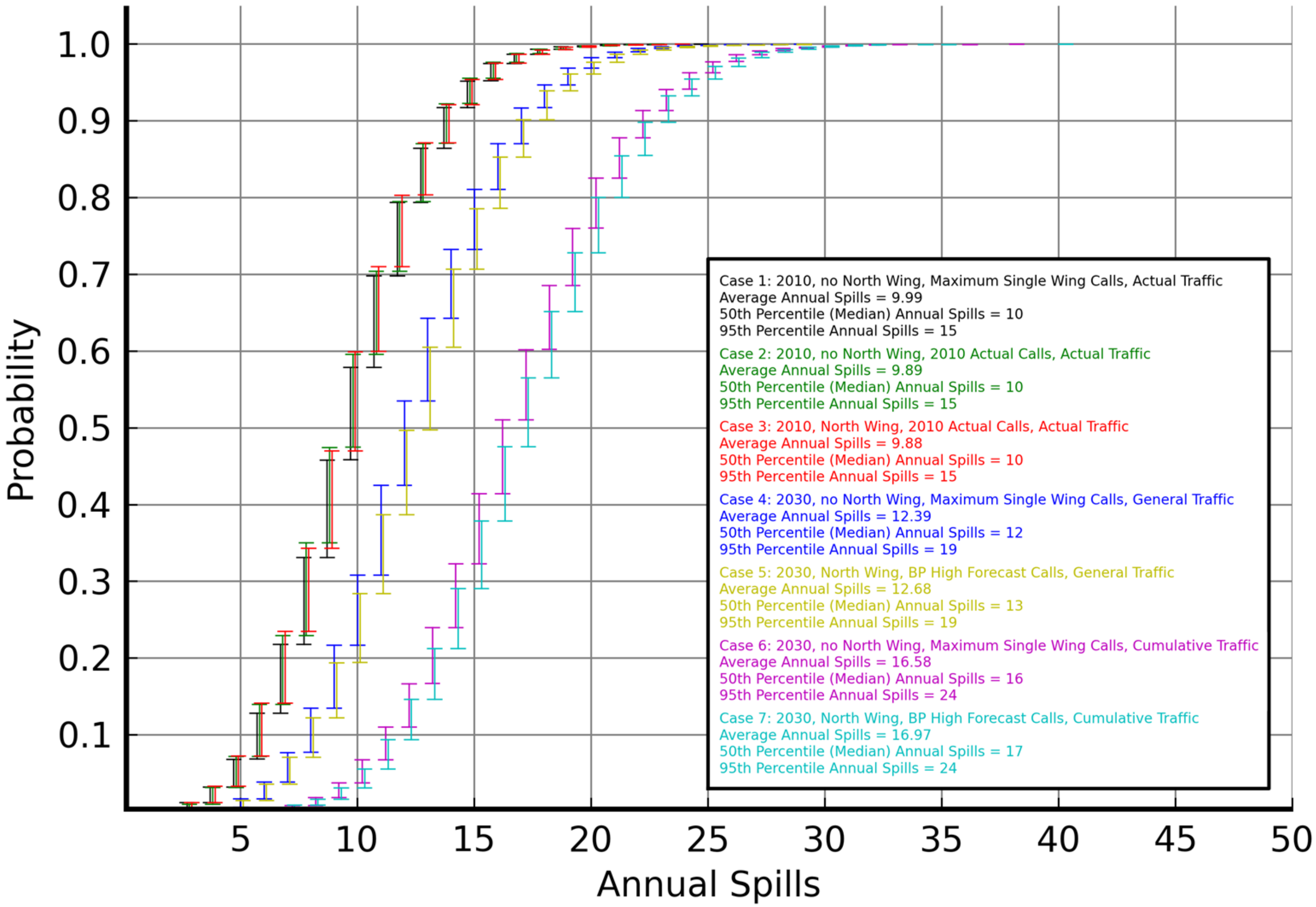

Figure 34 CDF of Total Annual Number of Spills (All Subareas)

10.5.1 Number of Spills by Geographic Subarea

Tables 1 through 3 of Appendix E show the average, median, and 95th percentile number of spills predicted by the oil outflow model for each subarea for the seven cases. Cumulative distribution functions of predicted spills per subarea for the seven cases are presented in Appendix E, Figures 1 through 7.

10.5.2 Number of Spills by Incident Type

Tables 4 through 6 of Appendix E show the average, median, and 95th percentile number of spills predicted by the oil outflow model by incident type for the seven cases. Cumulative distribution functions of predicted spills by incident type are presented in Appendix E, Figures 8 through 13.

10.5.3 Number of Spills by Geographic Subarea and Incident Type

Tables 7 through 13 of Appendix E show the average, median, and 95th percentile number of spills by subarea and incident type for the seven cases.

10.6 Total Annual Oil Outflow

Figure 35 shows the cumulative distribution function of total annual volume of oil outflow throughout the system for the seven cases.

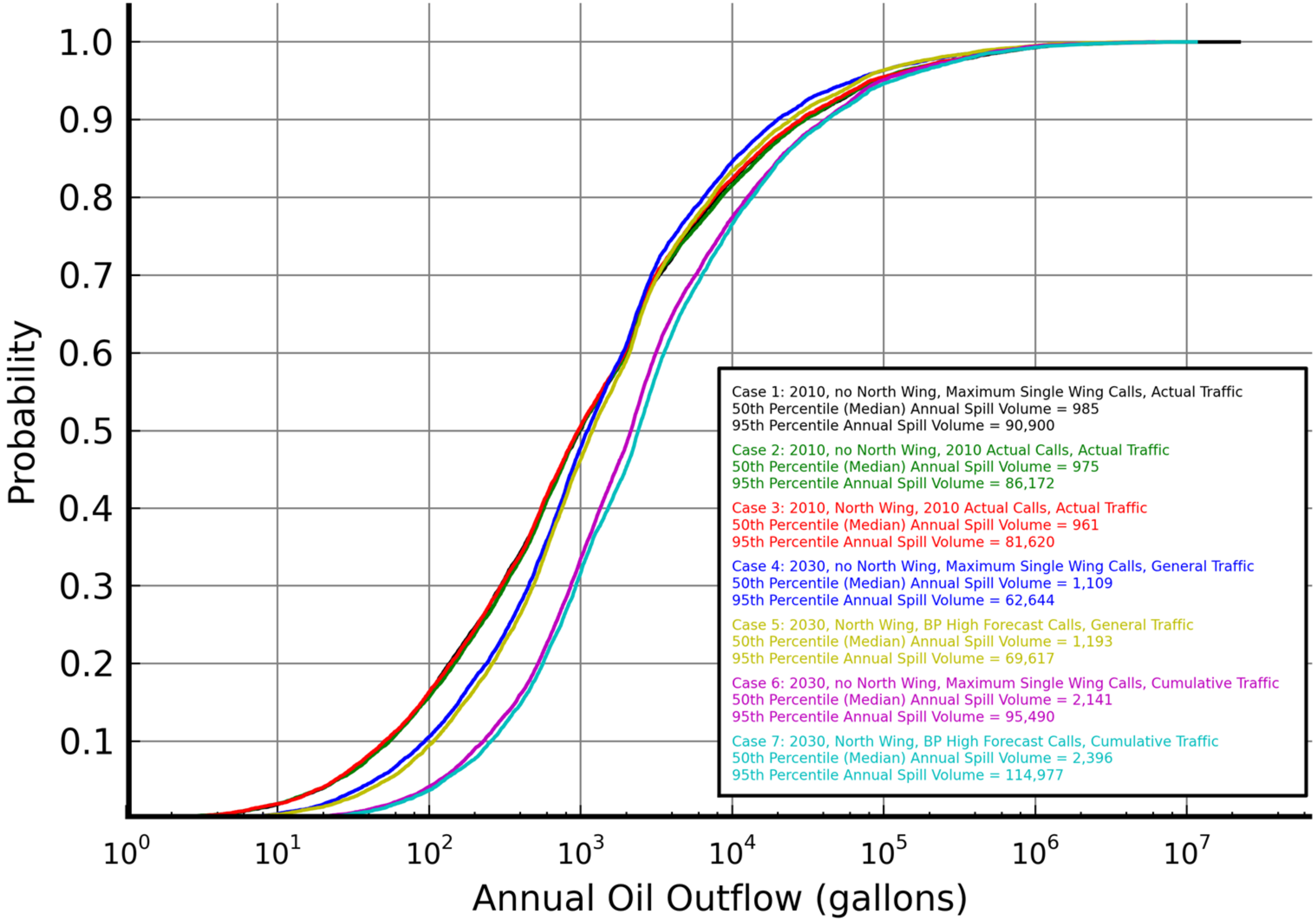

Figure 35 CDF of Predicted Total Annual Volume of Oil Outflow (All Subareas)

10.6.1 Annual Oil Outflow by Subarea

Table 14 of Appendix E shows the 50th percentile (median) annual oil outflow predicted by the model for each subarea for the seven cases. Table 15 of Appendix E shows the 95th percentile annual oil outflow predicted by the model for each subarea for the seven cases. Figures 14 through 20 of Appendix E show the cumulative distribution functions of oil outflow per subarea for the seven cases.

10.6.2 Annual Oil Outflow by Incident Type and Subarea

Tables 16 through 22 of Appendix E show the 50th percentile (median), 95th percentile, and 99th percentile annual oil outflow predicted by the model for each subarea and incident type for the seven cases.

Section 11 Conclusions

11.1 Incremental Risk Comparisons

The seven analysis cases only vary by number of wings at the BP Terminal and by traffic volume. Traffic volumes vary by number of calls at the BP Terminal, by forecast changes in existing general traffic from 2010 to 2030, and by the addition of cumulative traffic in 2030.

Table 61 shows the estimated total annual average number of incidents, average number of spills, 50th percentile (median) spill volume in gallons, and 95th percentile spill volume in gallons for the seven Cases.

Table 61 Summary of Total Annual Results

	Cases						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Year	2010	2010	2010	2030	2030	2030	2030
North Wing	No	No	Yes	No	Yes	No	Yes
South Wing	Max. Cap.	Actual Calls	Actual Calls	Max. Cap.	N+S = 420 calls	Max. Cap.	N+S = 420 calls
Traffic	2010	2010	2010	2030 General	2030 General	Gen. + Cum.	Gen. + Cum.
Avg. # Incidents	27.78	27.62	27.62	34.35	34.85	46.14	46.66
Avg. # Spills	9.99	9.89	9.88	12.39	12.68	16.58	16.97
50th Spill Vol.	985	975	961	1,109	1,193	2,141	2,396
95th Spill Vol.	90,900	86,172	81,620	62,644	69,617	95,490	114,977

Conclusions are drawn from pairwise comparisons of risk results. Comparisons are presented for each incident type across all subareas, and for each subarea across all incident types. These comparisons are made across all activity types and all vessel types. Comparisons are made for Case 7 versus Case 5, Case 3 versus Case 2, and Case 5 versus Case 4, Case 2 versus Case 1, Case 7 versus Case 6, and Case 4 versus Case 1. Comparison results are presented as change in predicted average number of incidents, average number of spills, 50th percentile (median) spill volume, and 95th percentile spill volume for each pairwise comparison. Both the absolute and percentage change between comparison cases are presented. The absolute change is calculated by subtracting the prediction of the case with the smaller case number from the prediction of the case with the larger case number, for example, Case 3 – Case 2. The percentage change is calculated by dividing the absolute change by the prediction of the case with the smaller case number, for example, (Case 3 – Case 2) / Case 2. Table 62 lists the pairwise comparison tables below.

Table 62 Pairwise Comparison Summary Result Tables

Subarea(s)	Incident Type(s)	Activity Type	Vessel Type	Table Number
All	All	All	All	Table 63
All	Collision	All	All	Table 64
All	Allision	All	All	Table 65
All	Grounding	All	All	Table 66
All	Transfer Error	All	All	Table 67
All	Bunker Error	All	All	Table 68
All	Other Non-Impact Error	All	All	Table 69
Strait of Juan de Fuca West	All	All	All	Table 70
Strait of Juan de Fuca East	All	All	All	Table 71
Haro Strait and Boundary Pass	All	All	All	Table 72
Guemes Channel and Fidalgo Bay	All	All	All	Table 73
Saddlebag	All	All	All	Table 74
Rosario Strait	All	All	All	Table 74
Cherry Point	All	All	All	Table 76

Table 62 summarizes the pairwise comparison tables below across all subareas, and for each subarea across all incident types. The effect of adding the BP North Wing on system risk in 2010 is isolated by comparing Cases 2 and 3, for which the number of BP calls and General traffic remain the same. The change in number of spills, and thus the change in annual spill volume, is negligible due to the addition of the second wing, as shown in Table 63. The added tanker wait time without the North Wing is a small percentage of the total vessel exposure in the system.

The effect of adding six calls to the BP Terminal with a single wing is isolated by comparing Case 1 and Case 2. Table 63 shows that the model predicts a very small increase in risk due to the addition of these six BP tankers and their associated tug traffic.

The effect of adding the BP North Wing on system risk in 2030 without cumulative traffic is isolated by comparing Cases 4 and 5. There is a reduction in BP tanker time at anchor per call and over all calls with the North Wing. The reduction in anchor time from Cases 4 to 5 is greater than in the increase in vessel traffic days in the other three activity types. Over all four activity types, BP-Calling vessel traffic days go down from Case 4 to 5. Yet, the at anchor activity type has relatively low incident rates. The reduction in anchoring time with an increase in underway, maneuvering, and at berth time leads to a small increase in risk, due to the increase in number of BP calls.

The effect of adding the BP North Wing on system risk in 2030 with cumulative traffic is isolated by comparing Cases 6 and 7. Small increases in incidents, spills, and total annual outflow are again predicted. These increases are again a result of the additional BP-calling tankers and associated tugs. The incremental risk between Cases 4 and 5 and between Cases 6 and 7 is effectively the same, as expected, as they isolate the same change in BP-calling traffic.

The effect of forecasting non-BP traffic from 2010 to 2030 is isolated by comparing Cases 1 and 4. The reduction in spill volumes is due to double hulls in 2030 compared to 2010. While double hulls do not affect incident rates, they do reduce spill probability and outflow in the event of a spill. A moderate increase in the number of incidents and spills is predicted with the growth of general traffic to 2030.

The effect of adding cumulative traffic to the general traffic is isolated by comparing Cases 4 and 6 and Cases 5 and 7. A significant increase in incidents, spills, and total annual outflow in 2030 is predicted if the cumulative projects come online as anticipated, versus if they do not come online. This is a result of the significant anticipated increase in vessel traffic due to the cumulative projects.

Table 63 Pairwise Comparisons of Incremental Risk for All Subareas and All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
All Subareas and All Incident Types	Change	% Change	Change	% Change	Change	% Change
Avg. # Incidents	11.81	34%	0.00	0%	0.50	1%
Avg. # Spills	4.29	34%	-0.01	0%	0.29	2%
50th Spill Volume	1,204	101%	-14	-1%	84	8%
95th Spill Volume	45,360	65%	-4,552	-5%	6,973	11%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
All Subareas and All Incident Types	Change	% Change	Change	% Change	Change	% Change
Avg. # Incidents	-0.16	-1%	0.52	1%	6.57	24%
Avg. # Spills	-0.10	-1%	0.39	2%	2.40	24%
50th Spill Volume	-10	-1%	255	12%	123	13%
95th Spill Volume	-4,728	-5%	19,486	20%	-28,256	-31%

Table 64 Pairwise Comparisons of Incremental Risk for Collisions in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Collision	Change	% Change	Change	% Change	Change	% Change
Avg. # Incidents	0.54	61%	0.03	4%	0.01	1%
Avg. # Spills	0.02	25%	0.01	10%	0.01	14%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	357	299%	-72	-11%	40	50%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Collision	Change	% Change	Change	% Change	Change	% Change
Avg. # Incidents	-0.03	-4%	-0.01	-1%	0.11	14%
Avg. # Spills	-0.01	-9%	0.00	0%	-0.04	-36%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	118	21%	2	0%	-475	-86%

Table 65 Pairwise Comparisons of Incremental Risk for Allisions in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Allision	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	1.56	78%	0.01	1%	0.02	1%
Avg. # Spills	0.09	69%	0.01	7%	0.00	0%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	6,998	646%	437	16%	-33	-3%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Allision	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.01	-1%	0.02	1%	0.18	10%
Avg. # Spills	-0.01	-7%	0.01	5%	-0.02	-13%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	-1,398	-34%	1,794	29%	-2,987	-73%

Table 66 Pairwise Comparisons of Incremental Risk for Groundings in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Grounding	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.59	41%	-0.01	-1%	0.03	2%
Avg. # Spills	0.03	27%	-0.01	-7%	0.00	0%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	3,645	584%	-1,498	-39%	73	13%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Grounding	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.02	-1%	0.01	0%	0.04	3%
Avg. # Spills	0.00	0%	0.00	0%	-0.03	-21%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	1,655	74%	1,471	53%	-1,677	-75%

Table 67 Pairwise Comparisons of Incremental Risk for Transfer Errors in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Transfer Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.69	28%	-0.03	-1%	0.12	5%
Avg. # Spills	0.64	28%	-0.02	-1%	0.12	6%
50th Spill Volume	20	125%	0	-1%	3	23%
95th Spill Volume	82	4%	-12	-1%	17	1%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Transfer Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.01	0%	0.16	5%	-0.04	-2%
Avg. # Spills	-0.02	-1%	0.16	6%	-0.05	-2%
50th Spill Volume (gallons)	0	-2%	5	16%	-2	-13%
95th Spill Volume (gallons)	-16	-1%	12	1%	-24	-1%

Table 68 Pairwise Comparisons of Incremental Risk for Bunker Errors in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Bunker Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	1.51	36%	0.00	0%	0.01	0%
Avg. # Spills	1.38	36%	0.00	0%	0.00	0%
50th Spill Volume	48	91%	1	16%	-1	-1%
95th Spill Volume	165	20%	15	3%	2	0%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Bunker Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.01	0%	0.00	0%	1.93	85%
Avg. # Spills	0.00	0%	0.01	0%	1.78	85%
50th Spill Volume	-1	-10%	-4	-4%	44	464%
95th Spill Volume	11	2%	-27	-3%	237	42%

Table 69 Pairwise Comparisons of Incremental Risk for Other Non-Impact Errors in All Subareas

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Other Non-Impact Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	6.90	29%	0.01	0%	0.33	1%
Avg. # Spills	2.11	34%	0.00	0%	0.17	3%
50th Spill Volume	265	114%	-5	-3%	16	7%
95th Spill Volume	6,167	35%	-804	-4%	1,050	6%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Other Non-Impact Error	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.11	-1%	0.33	1%	4.34	23%
Avg. # Spills	-0.09	-2%	0.20	2%	0.74	14%
50th Spill Volume	-2	-1%	33	7%	68	46%
95th Spill Volume	1,925	12%	-1,195	-5%	248	2%

Table 70 Pairwise Comparisons of Incremental Risk for Strait of Juan de Fuca West Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Strait of Juan de Fuca West	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.61	15%	0.01	0%	0.09	2%
Avg. # Spills	0.26	27%	-0.03	-3%	0.04	4%
50th Spill Volume	2	1314%	0	-57%	0	186%
95th Spill Volume	3,630	108%	-1,339	-24%	703	26%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Strait of Juan de Fuca West	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.01	0%	0.10	2%	0.61	18%
Avg. # Spills	0.01	1%	0.05	4%	0.08	9%
50th Spill Volume	0	52%	1	35%	0	329%
95th Spill Volume	1,240	28%	1,310	23%	-1,699	-39%

Table 71 Pairwise Comparisons of Incremental Risk for Strait of Juan de Fuca East Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Strait of Juan de Fuca East	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	2.82	38%	0.00	0%	0.04	1%
Avg. # Spills	1.17	49%	-0.02	-1%	-0.01	0%
50th Spill Volume	54	290%	-2	-10%	0	3%
95th Spill Volume	8,062	99%	-3,152	-28%	1,183	17%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Strait of Juan de Fuca East	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.12	-2%	0.13	1%	0.79	12%
Avg. # Spills	-0.06	-3%	0.04	1%	0.11	5%
50th Spill Volume	0	1%	5	7%	1	3%
95th Spill Volume	2,006	22%	-236	-1%	-2,384	-26%

Table 72 Pairwise Comparisons of Incremental Risk for Haro Strait and Boundary Pass Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Haro Strait and Boundary Pass	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.96	105%	0.01	1%	-0.01	-1%
Avg. # Spills	0.17	89%	0.01	7%	0.00	0%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	98	973%	0	-9%	-3	-25%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Haro Strait and Boundary Pass	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.00	0%	-0.04	-2%	0.19	26%
Avg. # Spills	0.00	0%	0.00	0%	0.04	27%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	0	5%	14	15%	9	185%

Table 73 Pairwise Comparisons of Incremental Risk for Guemes Channel and Fidalgo Bay Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Guemes Channel and Fidalgo Bay	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	1.35	20%	-0.03	-1%	-0.02	0%
Avg. # Spills	0.58	20%	0.04	2%	-0.02	-1%
50th Spill Volume	19	90%	1	7%	-1	-6%
95th Spill Volume	770	30%	390	14%	20	1%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Guemes Channel and Fidalgo Bay	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.01	0%	-0.04	0%	1.31	24%
Avg. # Spills	-0.04	-2%	-0.01	0%	0.61	26%
50th Spill Volume	0	0%	1	2%	11	92%
95th Spill Volume	-197	-6%	-56	-2%	-552	-18%

Table 74 Pairwise Comparisons of Incremental Risk for Saddlebag Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Saddlebag	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	2.06	33%	-0.04	-1%	0.00	0%
Avg. # Spills	0.64	28%	-0.03	-2%	0.00	0%
50th Spill Volume	11	87%	0	-13%	0	-2%
95th Spill Volume	657	51%	28	4%	24	2%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Saddlebag	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.03	-1%	-0.03	0%	2.23	57%
Avg. # Spills	-0.02	-2%	0.00	0%	0.98	75%
50th Spill Volume	0	-14%	1	6%	11	717%
95th Spill Volume	-155	-19%	118	6%	472	59%

Table 75 Pairwise Comparisons of Incremental Risk for Rosario Strait Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Rosario Strait	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.34	37%	0.04	5%	0.01	1%
Avg. # Spills	0.03	23%	0.01	9%	0.01	8%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	4	90%	1	51%	1	28%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Rosario Strait	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	-0.02	-2%	0.02	2%	0.08	10%
Avg. # Spills	-0.01	-8%	0.00	0%	0.00	0%
50th Spill Volume	0	n/a	0	n/a	0	n/a
95th Spill Volume	0	-2%	-2	-22%	1	21%

Table 76 Pairwise Comparisons of Incremental Risk for Cherry Point Across All Incident Types

	Case 7 v. 5		Case 3 v. 2		Case 5 v. 4	
Cherry Point	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	3.69	43%	0.01	0%	0.38	5%
Avg. # Spills	1.43	38%	0.00	0%	0.28	8%
50th Spill Volume	121	167%	1	3%	16	28%
95th Spill Volume	6,391	61%	83	1%	2,423	30%

	Case 2 v. 1		Case 7 v. 6		Case 4 v. 1	
Cherry Point	**Change**	**% Change**	**Change**	**% Change**	**Change**	**% Change**
Avg. # Incidents	0.01	0%	0.39	3%	1.36	20%
Avg. # Spills	0.00	0%	0.31	6%	0.55	19%
50th Spill Volume	0	-1%	40	26%	17	43%
95th Spill Volume	-1,407	-12%	696	4%	-3,699	-31%

11.2 Incremental Risk Model Validation

Annual historical incidents and total oil outflow were used to validate the oil outflow model 2010 hindcast and 2030 forecast. Incidents in the study area between the years 1995 and 2010 were used to derive incident rates for the outflow model. Total numbers of incidents, numbers of spills, and annual outflow volumes in the study area by year are shown in Table 77.

Table 77 **Historical Numbers of Incidents, Numbers of Spills, and Oil Outflow by VTA Vessels in the Study Area**

Year	Number of Incidents (*NI*)	Number of Spills (*NS*)	Oil Outflow (gallons)
1995	14	11	362
1996	16	12	14342
1997	19	15	1976
1998	20	15	493
1999	15	11	326
2000	13	12	167
2001	22	17	4113
2002	40	22	3462
2003	39	11	103
2004	32	11	112
2005	28	13	578
2006	26	10	45
2007	33	9	47
2008	35	9	112
2009	31	4	10017
2010	46	7	46
Median	**27**	**11**	**344**

Case 3 serves as a baseline for model validation, as the model is predicting the number of incidents and total annual oil outflow for a year and traffic combination that actually occurred (2010 actual traffic, with the BP North Wing in operation). Table 78 shows that for 2010, the number of incidents predicted has a median value of 28, and the total oil outflow predicted has a median value of 961. Comparing these predicted values with the actual median values from 1995-2010 (Table 77), shows that the model is in close agreement with number of incidents and number spills and is conservative with regard to oil outflow.

Table 78 **Case 3 Median Number of Incidents and Median Total Annual Oil Outflow**

	Number of Incidents (*NI*)	Number of Spills (*NS*)	Oil Outflow (gallons)
Median	**28**	**10**	**961**

The conservatism in the total annual oil outflow is primarily attributed to the fact that, over the years investigated in Table 77 (1995-2010), study area spill volumes tended to be less than those of United States and international data used to develop outflow percentage and outflow volume cumulative distribution functions.

11.3 Risk Mitigation

The reduction and management of traffic volumes is an appropriate focus for reducing incremental risk. Risk mitigation measures available for study include existing and alternative:

- Traffic Routing.
- Traffic Management.
- Anchoring.
- Pilotage.
- Maneuvering for Mooring, Approach, and Departure.

Probabilistic risk statistics as modeled in the Monte Carlo Incremental Risk Assessment Model are sensitive to vessel exposure time and to spill rates per time in the system. To the extent that risk mitigation measures can be modeled by time and by rates, the incremental effectiveness of proposed measures can be assessed.

Appendix A Vessel Traffic Database

The Task 2 Vessel Traffic Study is an input to the Task 4 Vessel Traffic Forecast and to the Task 3 Incident Rates (IRs). The Forecast is based on the final data presented herein. The Incident Rates are based on the data presented in the draft report, delivered 15 May 2013. Summary traffic data presented in the body of the main report is also based on the earlier hindcast. The differences between the two versions are small.

The main differences are in the tug vessel traffic days and in the maneuvering vessel traffic days. There are more tug days in the final hindcast. Tug homeports were revised when new data became available. Assumptions on required maneuvering time were revised to be longer. An increase in historical traffic would lower the IRs. Higher IRs are conservative for predicting risk. The incremental risk between cases is not affected.

Task 2: Analysis Format and Vessel Traffic Data

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Abbreviations

AIS	Automatic Identification System
AMHS	Alaska Marine Highway System
ATB	Articulated Tank Barge
B.C.	British Columbia
CCG	Canadian Coast Guard
DWT	Deadweight Tons
ITB	Integrated Tank Barge
MX	Marine Exchange of Puget Sound
nm	nautical miles
NRT	Near-Real Time
USCG	United States Coast Guard
VEAT	Washington Department of Ecology’s Vessel Entries and Transits
VTS Puget Sound	Vessel Traffic Service Puget Sound
WADEC	Washington Department of Ecology

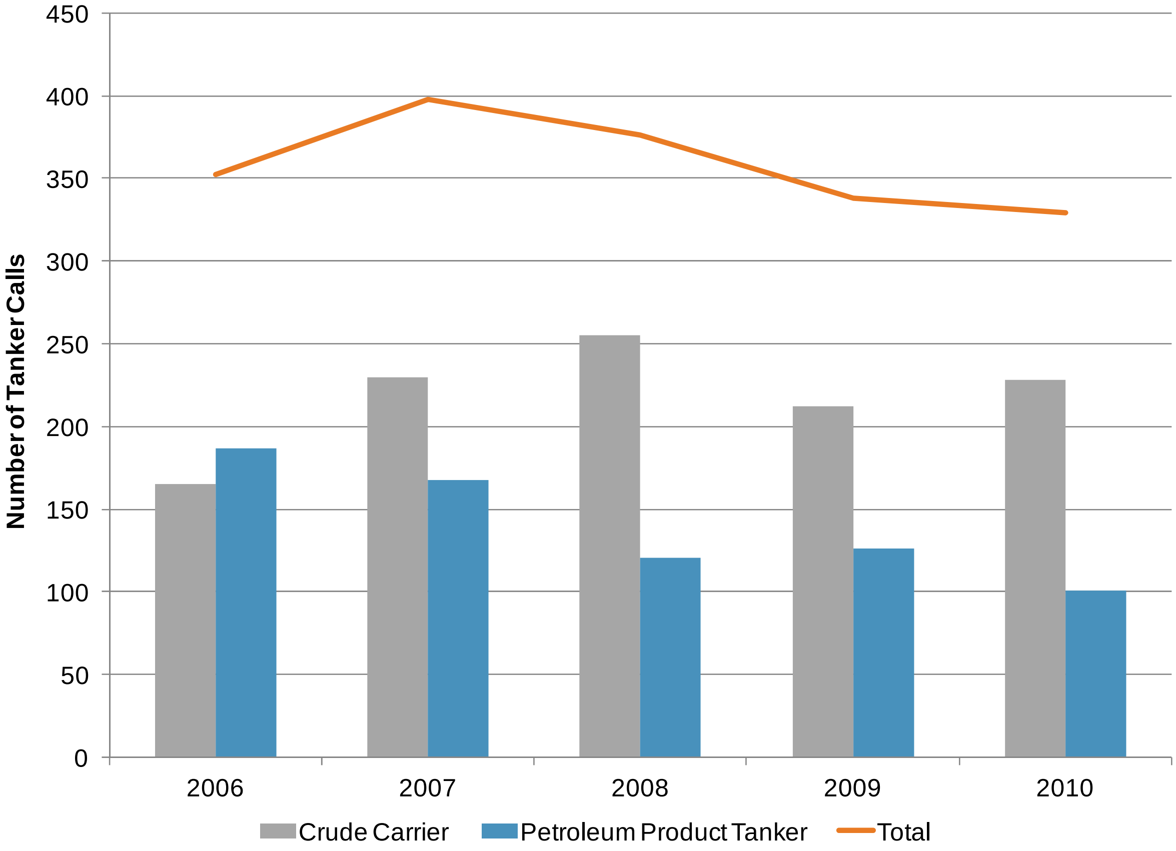
Executive Summary

A Vessel Traffic and Risk Assessment Study is being conducted by The Glosten Associates for the BP Cherry Point facility. The purpose of the study is to assess how changes in the number of vessel calls to the two Cherry Point BP docks alter the regional risk profile for vessel collision and resulting contaminant outflows. Northern Economics Inc. is contributing to the risk assessment by summarizing historic and existing vessel traffic volumes. This memo summarizes Northern Economics, Inc.'s vessel traffic database and analysis format designed for the BP Cherry Point risk assessment study.

The area studied includes the designated Puget Sound vessel transit lanes, the maneuvering area near the BP terminal at Cherry Point, the local anchorage areas, and the transit routes for tugs assisting BP traffic. BP's Cherry Point facility is located in Northwest Washington, approximately seven miles south of Blaine and eight miles northwest of Ferndale, WA (Washington State Department of Ecology [WADEC] 2013a). Incoming crude not transported via pipeline is moved via tankers calling at the South Wing of the BP Terminal. BP ships refined products in both tank vessels and tank barges from both wings of the BP Terminal, though barges typically only call at the South Wing.

The South Wing at the BP Cherry Point Terminal is equipped to handle a maximum of 335 vessels per year. According to Marine Exchange of Puget Sound (MX) data, in recent years calls for both docks combined ranged from 320 to 400 per year (Figure ES-1). In 2010, MX data shows total crude and product tanker calls to BP Cherry Point at 329. According to figures BP provided to the study team, total tanker calls in 2010 were 3332. The one percent discrepancy between the data sets is acknowledged by the study team and considered reasonable. This analysis was conducted using MX data for 2010.

Figure ES-1. Vessel Calls to BP Cherry Point, 2006–2010

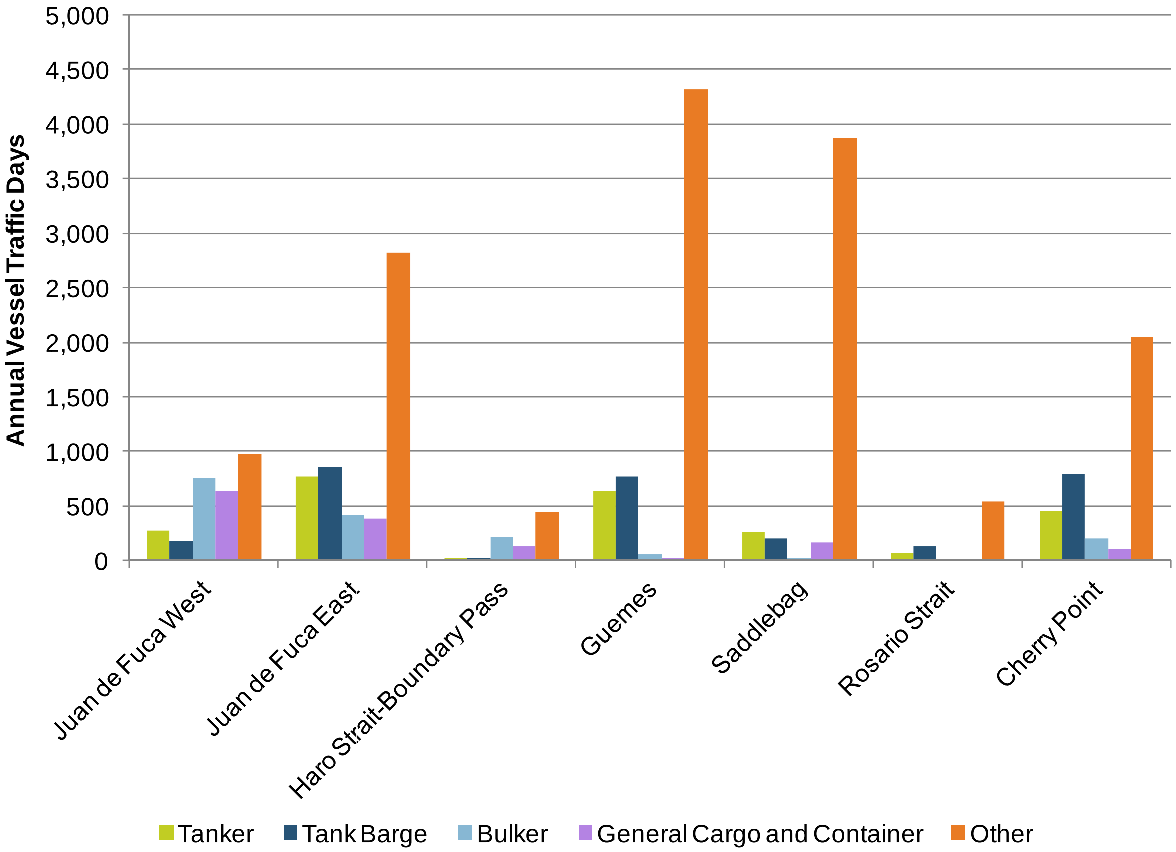


Source: Northern Economics, Inc. using MX 2012

The study team generated estimates of vessel traffic days by vessel type, activity type and subarea. Figure ES-2 summarizes our results, showing average annual vessel traffic days by subarea. Other vessels, comprised of tugs, passenger and large fishing vessels, account for the vast majority of traffic days spent in each subarea. Other vessels spend the most traffic days in Saddlebag, Guemes Channel and Juan de Fuca East subareas; the least amount of time is spent in Haro and Rosario Strait. These activity patterns are the result of:

- High volumes of ferry traffic transiting and docking in Juan de Fuca East and Guemes Channel
- High volumes of tug traffic transiting Juan de Fuca East and Cherry Point
- High volumes of fishing vessels transiting Juan de Fuca East and docking for extended periods in Guemes Channel and Saddlebag

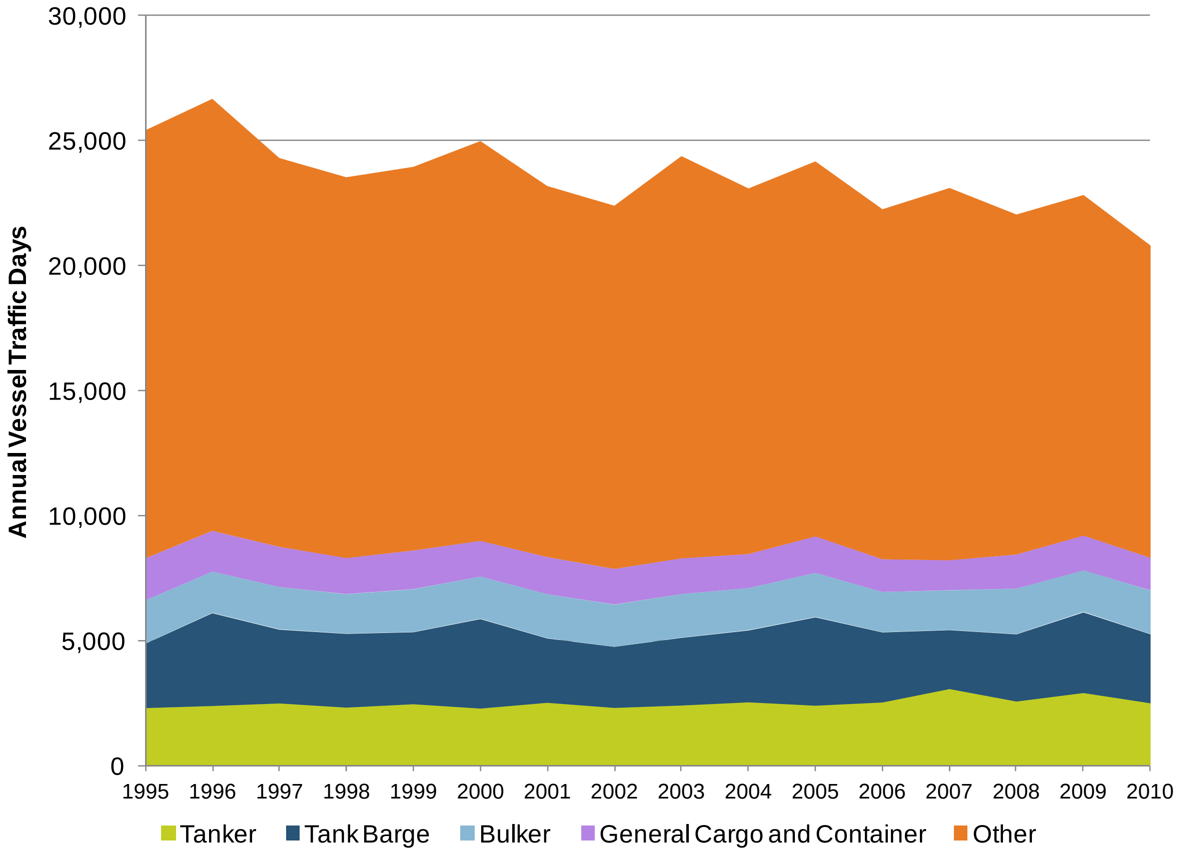
Figure ES-2. Vessel Traffic Days by Subarea and Vessel Type, Average (1995–2010)



Source: Northern Economics, 2013

Between 1995 and 2010, the traffic days spent in each subarea by vessel type remained somewhat consistent. The sole exception was time spent by Other vessels, for which there is an estimated decrease from 17,000 traffic days a year to less than 13,000 (Figure ES-3). The decrease is due primarily to a drop in the number of large fishing vessels transiting the study area. Large fishing vessel transits in 2011 are only 42 percent of the estimated transits in 1995. The decline in the number of transits is a result of changes in fishery management regimes and changes in the profitability of the fisheries.

Figure ES-3. Vessel Traffic Days by Vessel Category, Average (1995–2010)



Source: Northern Economics, 2013

1 Introduction

The Glosten Associates was retained by Cardno-Entrix to examine the impact of the second dock at the BP Cherry Point facility, as measured by the change in the risk profile of collisions and spills in North Puget Sound. As part of this effort, Northern Economics, Inc. was asked to examine the historic and current patterns of traffic in the study area. This report summarizes Northern Economics' analysis format and the vessel traffic data base designed for the BP Cherry Point Vessel Traffic Analysis.

1.1 BP Cherry Point

BP's Cherry Point facility is located in Northwest Washington, approximately seven miles south of Blaine and eight miles northwest of Ferndale, WA (Washington State Department of Ecology [WADEC] 2013a). BP Cherry Point is the largest refinery in Washington, and specializes in the refinement of Alaska North Slope crude. Currently the refinery produces 2.5 million gallons of jet fuel, 3.5 million gallons of gasoline, 2.2 million gallons of diesel, 360,000 gallons of butane and 140,000 gallons of propane each day (BP 2013a).

The products produced by BP are distributed to market via land and water. BP operates the Olympic pipeline, which is the largest petroleum products pipeline in the Pacific Northwest, connecting four of the Puget Sound area refineries to 23 gasoline, diesel and jet fuel terminals in Washington and Oregon. The Olympic Pipeline provides 300,000 barrels per day of product to major cities such as Seattle, Tacoma, Olympia and Portland (BP 2013b).

Incoming crude not transported via pipeline is moved via tankers calling at the South Wing of the BP Terminal. BP ships refined products in both tank vessels and tank barges from both wings of the BP Terminal (Figure 1), though barges typically only call at the South Wing.

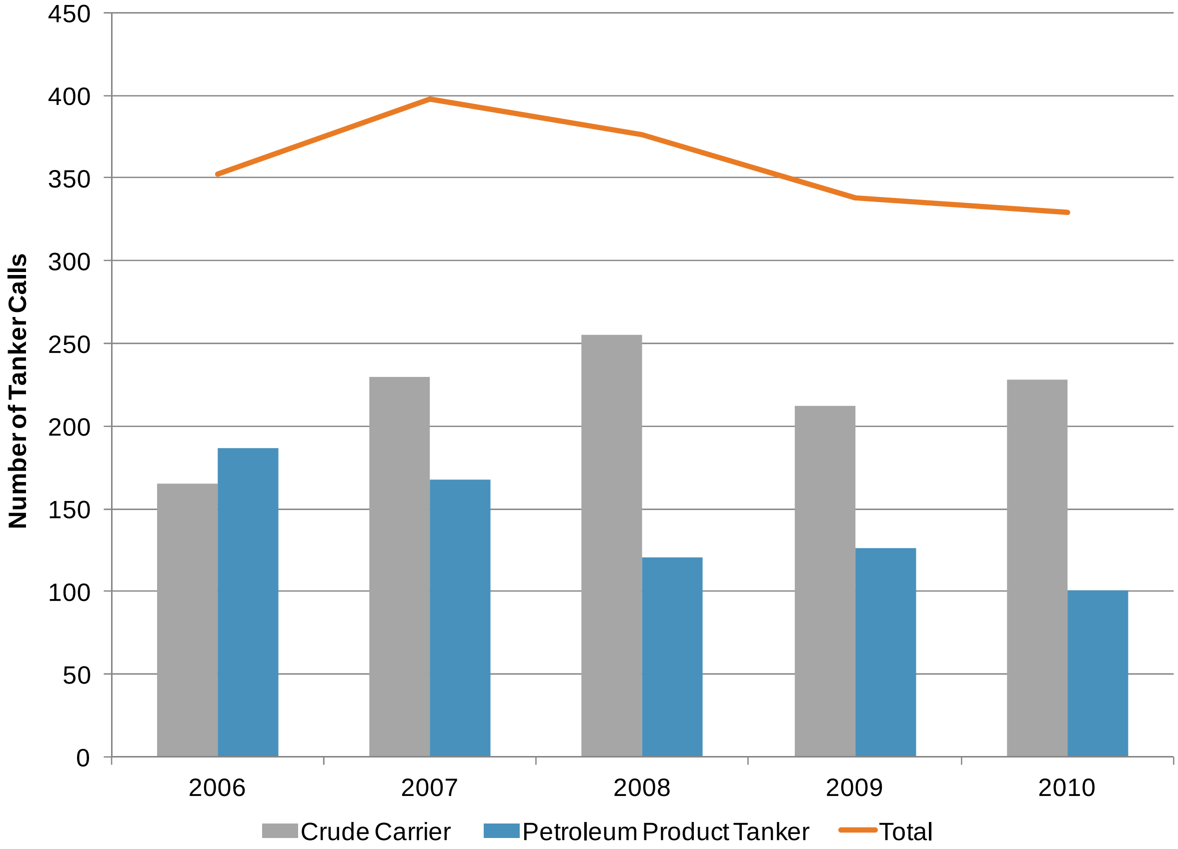
Figure 1. BP Cherry Point Facility Docks

Source: NOAA 2013

The BP Cherry Point docks are referred to as the North dock and the South dock and are located at general position Latitude 480 51.7′N Longitude 1220 44.8′W. There is a deep water anchorage used by calling vessels, located southwest of the BP facility and 1.5 nautical miles due west of Neptune Beach, WA. The South Wing at the BP Cherry Point Terminal is equipped to handle a maximum of 335 vessels per year. According to Marine Exchange of Puget Sound (MX) data, in recent years calls for both docks combined ranged from 320 to 400 per year (Figure 2).

In 2010, MX data shows total crude and product tanker calls to BP Cherry Point at 329. According to figures BP provided to the study team, total tanker calls in 2010 were 3332. The one percent discrepancy between the data sets is acknowledged by the study team and considered reasonable. This analysis was conducted using MX data for 2010.

Figure 2. Vessel Calls to BP Cherry Point, 2006–2010



Source: Northern Economics, Inc. using MX 2012

1.2 Report Organization

In the following sections we discuss how the crude and product tankers travelling to and from the BP Cherry Point facility compare to other vessel traffic in the study area. More specifically:

- **Section 2: Transits and Calls** describes the various types of vessel traffic included in our analysis, and the basic movements of each.

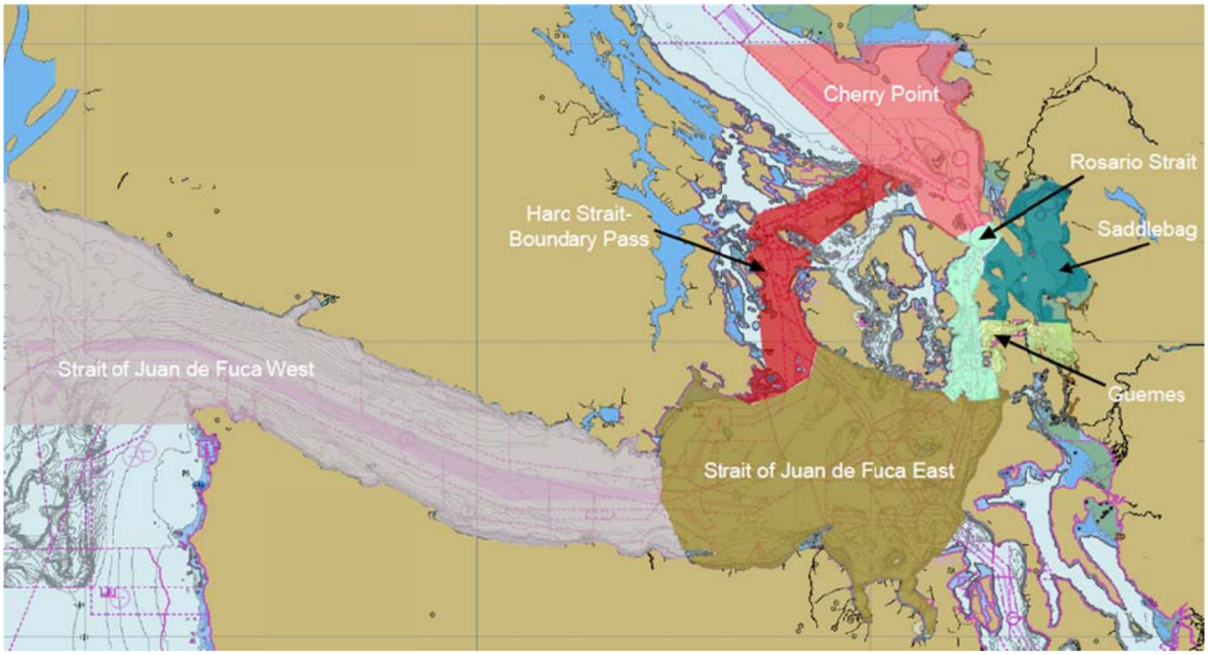
- **Section 3: Vessel Traffic Data** summarizes the results of our modeling. Vessel traffic days by area and activity type are presented. This section includes a description of the information and processes that the study team used in producing our results.
- **Section 4: Anchorages** summarizes anchorage use within the study area.

2 Transits and Calls

In this section we describe the various vessel types operating in the traffic analysis study area; a brief description of the activities and transit patterns of each vessel type is presented to form a baseline understanding of vessel traffic in the North Puget Sound.

The traffic analysis study area, shown in Figure 3, extends west to the end of the Strait of Juan de Fuca, North to the Canadian border, and south to the beginning of Admiralty Inlet. While most Canadian and South Puget Sound destinations are not included in our analysis, vessels which transit the study area en route to these destinations have been incorporated.

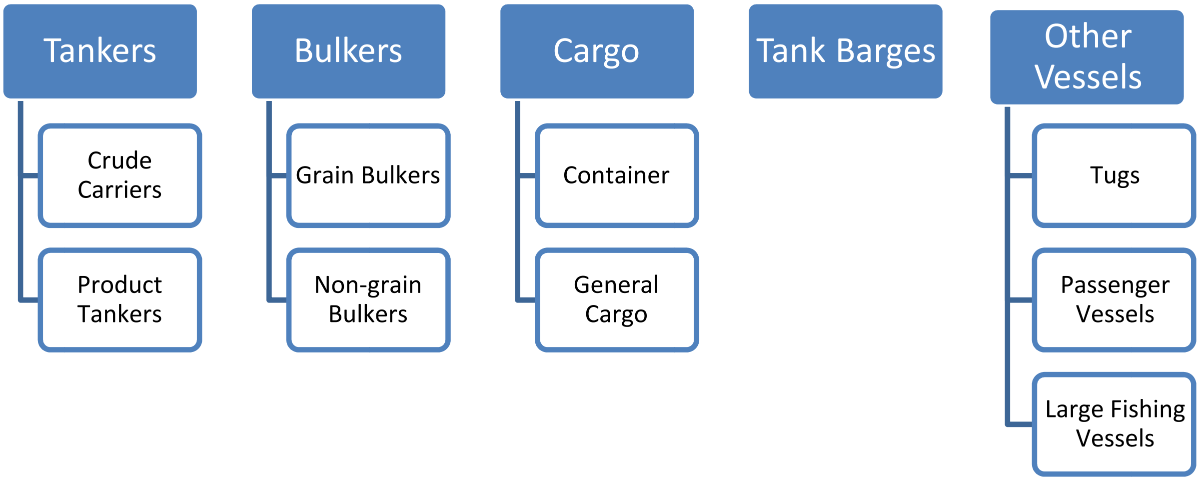
Figure 3. Map of BP Study Subareas



Source: The Glosten Associates 2012

For the purpose of this analysis, vessel traffic includes tankers, bulkers, cargo ships, tank barges, and other vessels. The hierarchy of vessels is illustrated in Figure 4.

Figure 4. Vessel Traffic Types



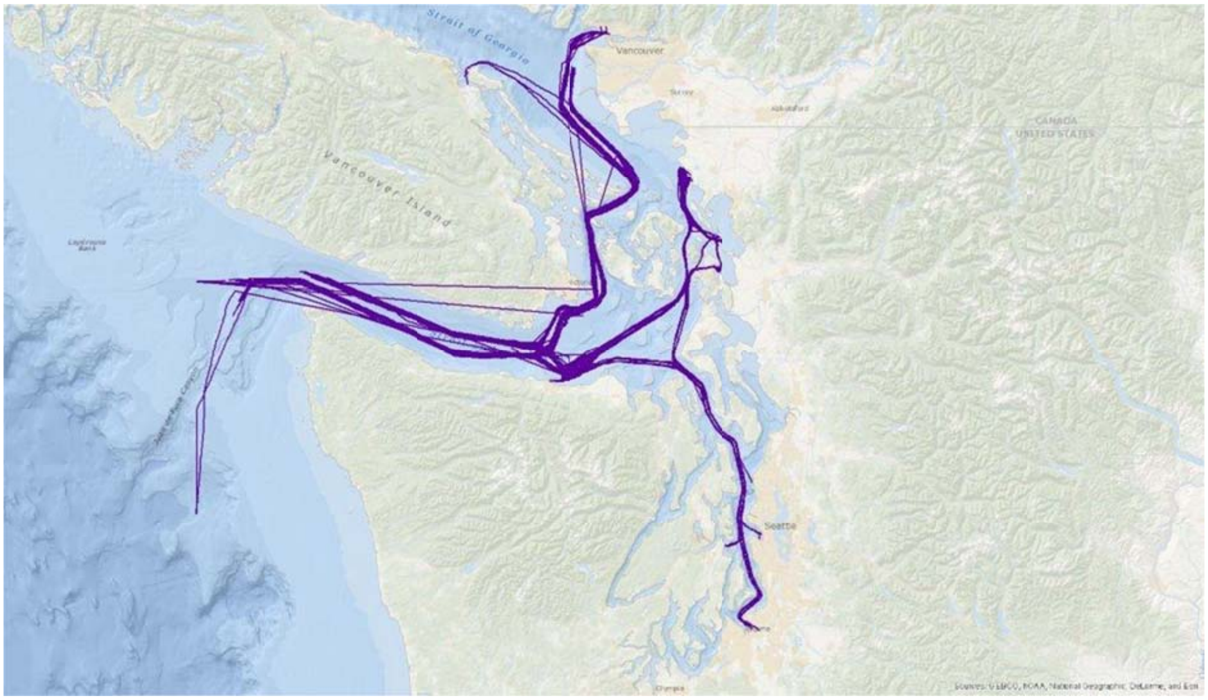
Source: Northern Economics, Inc. 2013

Small fishing, charter, and recreational watercraft are omitted from the quantitative portion of our analysis because their movements and behavior could not be accurately tracked with the data sources available.

2.1 Tankers

Tankers, as defined within our study, include crude tankers and petroleum product tankers (including ATBs and ITBs) as well as chemical tankers. Activity among these vessels is in large part generated by refinery activity. U.S. Oil in Tacoma, Tesoro and Shell near March Point, Phillips 66 in Ferndale, BP at Cherry Point, and Chevron in Burnaby, B.C. all contribute to study area tanker activity. In addition, the Westridge marine terminal located in Burnaby, British Columbia exports crude oil, which also moves via tankers. Figure 5 illustrates one month of 2010 transit data for tankers to illustrate their unique traffic pattern.

Figure 5. Tanker Vessel Pattern (July 2010)



Note: Lines appearing to cross land may be the result of errors in the near real-time (NRT) data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT data (U.S. Coast Guard [USCG] and Canadian Coast Guard [CCG]) 2010.

Crude tankers calling at Puget Sound refineries have carrying capacities which are restricted by law:

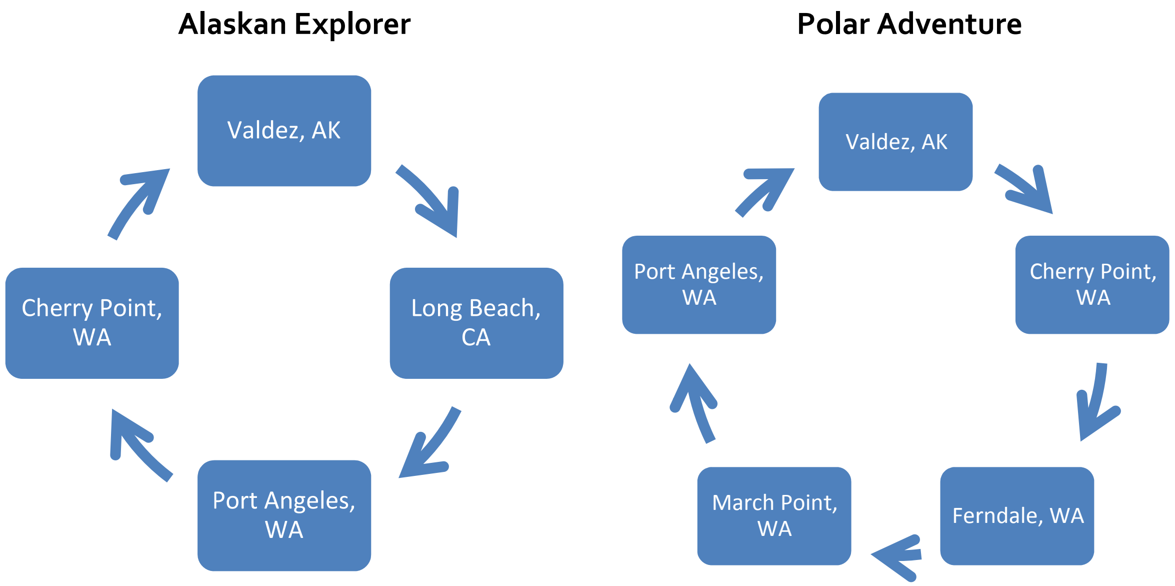
> "Per 33 CFR § 165.1303, all tank vessels, U.S. or foreign flag, larger than 125,000 deadweight tons (DWT) bound for a port or place in the United States may not operate east of a line extending from Discovery Island Light to New Dungeness Light and all points in the Puget Sound area north and south of these lights…. Because current U.S. regulations limit the size of tankers in Puget Sound to 125,000 DWT, larger capacity tankers would have to alter their load line to restrict loading in recognition of that limitation. To facilitate compliance for domestic tankers with a designed capacity larger than 125,000 DWT, the Coast Guard has authorized ABS to add a special Puget Sound load line mark ("PS") to the

> domestic U.S. load line "ladder" for certain TAPS tankers. This mark corresponds to the 125,000 DWT draft, taking into consideration each tanker's light ship displacement, bunker capacity, etc. This policy does not apply to other than U.S. flag tankers." Puget Sound Harbor Safety Plan, April 2012

As indicated above, many of the vessels calling Puget Sound destinations are designed to carry a volume of crude much larger than 125,000 DWT (or approximately 796,000 barrels). At the Valdez Marine Terminal, where tankers load Alaska North Slope crude for delivery to Lower-48 refineries, the largest tankers can carry up to two million barrels of oil (Alyeska Pipeline 2013).

Some crude tankers calling at Washington refineries load with a volume of oil that exceeds the 125,000 DWT limit while in Valdez. Before arriving in Puget Sound these tankers call at a non-Washington refinery to perform a partial offload. For example, the Alaskan Explorer, a double-hulled tanker which operates between Alaska and Lower-48 refineries, has made the voyage shown below in Figure 6. Similarly, tankers which load at the 125,000 DWT restriction may proceed directly to Puget Sound, but may still carry a volume of crude sufficient for more than one refinery. Crude tankers calling directly at Washington refineries frequently conduct multiple offloads, via itineraries like that shown for the Polar Adventure.

Figure 6. Sample Tanker Itineraries, 2010



Note: The Port Angeles calls are likely for bunkering, not offloading crude
Source: Northern Economics, Inc. using MX 2012

As shown above, vessels calling at BP Cherry Point may be making one or multiple offloads at Puget Sound refineries. It should be noted, however, that BP Cherry Point and Phillips 66 are the refineries with the deepest dockside depths. Consequently, many tankers first offload crude at BP or Phillips 66, then continue on to a shallower draft facility such as Shell or Tesoro at March Point, to discharge the remaining crude.

In contrast to crude carriers, product tankers typically fully load then discharge; multiple offloads are less common. Product tankers tend to be smaller than crude carriers, and include vessels such as ATBs and ITBs. Refinery products transported through the study area include gas oil, diesel, gasoline, and jet fuels.

2.1.1 BP Cherry Point Tankers

The Marine Exchange of Puget Sound database records piloted, deep draft vessel calls to ports in Washington. Using these data, the study team is able to isolate the vessel calls to BP Cherry Point. According to the MX data, the BP Cherry Point facility received between 320 and 400 calls by tankers each year.

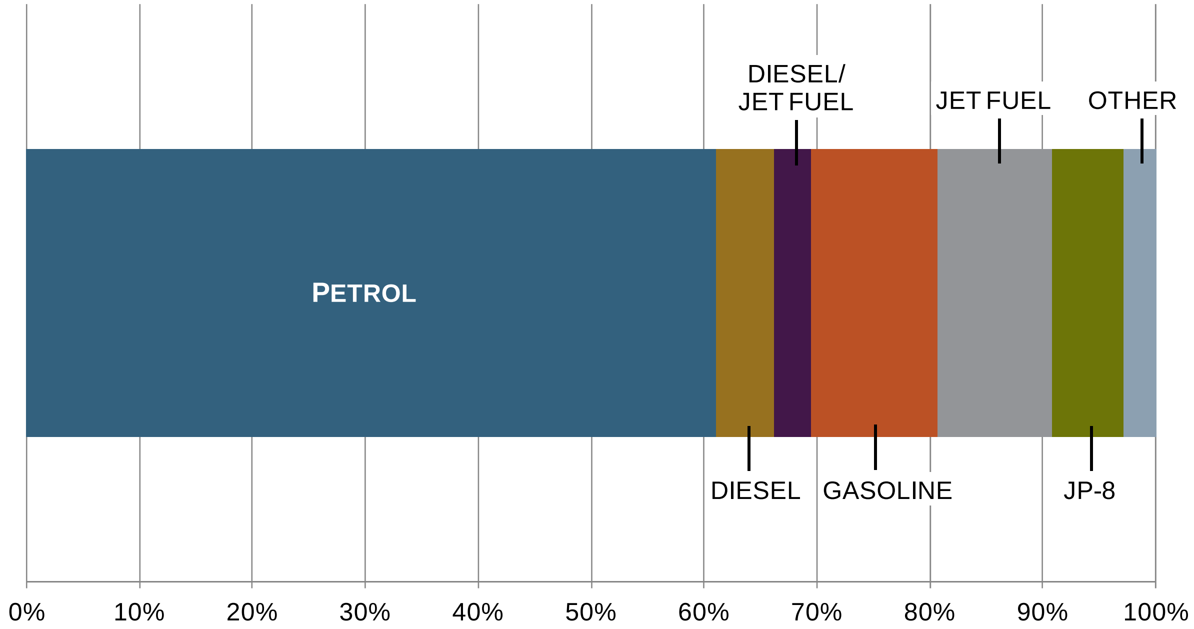
Table 1. Tanker Calls to BP Cherry Point, 2006–2010

Row Labels	2006	2007	2008	2009	2010	% of Total
Crude Carriers	165	230	255	212	228	61
Petroleum Product Tankers	187	168	121	126	101	39
Grand Total	352	398	376	338	329	100

Note: Please note that these figures do not include calls by tank barges, which are omitted from the MX data.
Source: Northern Economics using MX 2012.

Crude carriers calling at BP Cherry Point are delivering crude oil for processing (most of which comes from Alaska's North Slope). Product tankers shuttle product between the BP Cherry Point facility and destinations such as Portland, OR and Vancouver, B.C. (MX 2012). BP Cherry Point supplies approximately 20 percent of Washington's gasoline needs, as well as the majority of jet fuel for the Northwest's international airports. The breakout of commodities loaded at BP Cherry Point is shown below in Figure 7.

Figure 7. Product Tanker Cargo Loaded at Cherry Point (2006–2010)

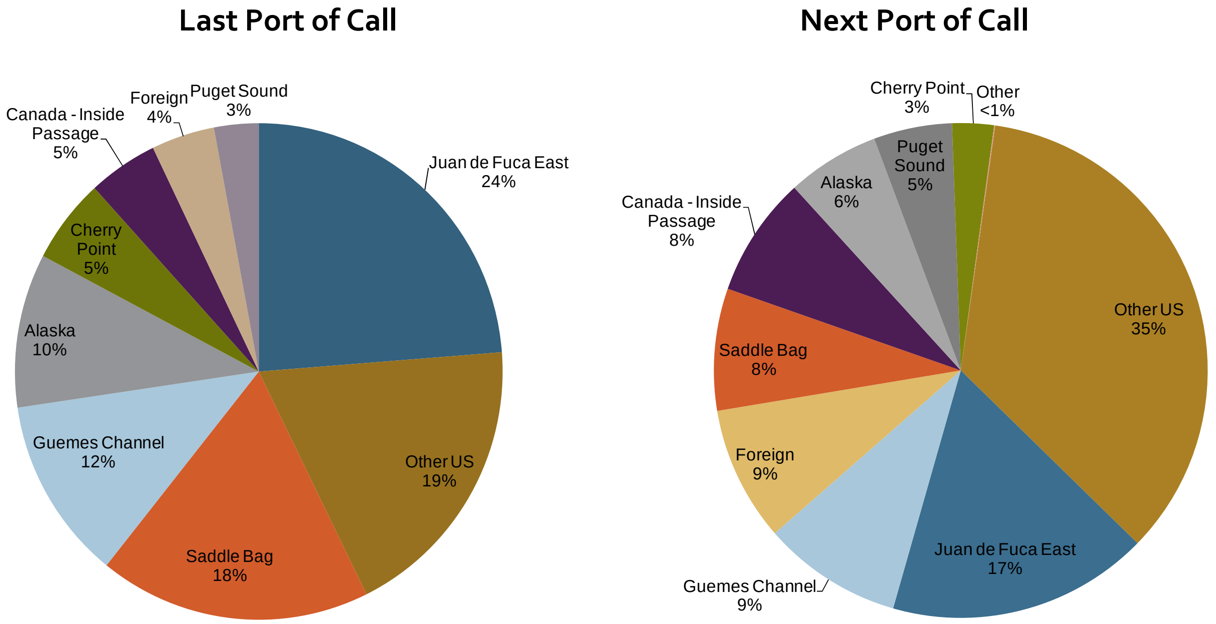


Note: BP Cherry Point does not produce a product it refers to as ‘petrol’, however, the product movements recorded by the MX data list ‘petrol’ as a commodity type. While the study team is not certain what refined product each recorded ‘petrol’ movement may represent, it is worth noting that petrol is a term commonly used in Europe to refer to gasoline.

Source: Northern Economics, Inc. using MX 2012

Using the MX traffic data, the study team was able to isolate both the last and next ports of call surrounding a vessel's BP Cherry Point call (Figure 8). Of the tankers calling at Cherry Point, most report coming directly from Port Angeles in Juan de Fuca East, where they likely stopped to anchor and/or bunker. A large percentage also report coming from and going to Other U.S. ports (not including Alaska). Other U.S. ports are primarily California refinery ports of call such as Long Beach, Richmond, San Francisco and Los Angeles.

Figure 8. Ports of Call Reported by BP Cherry Point Tankers (2006–2010)

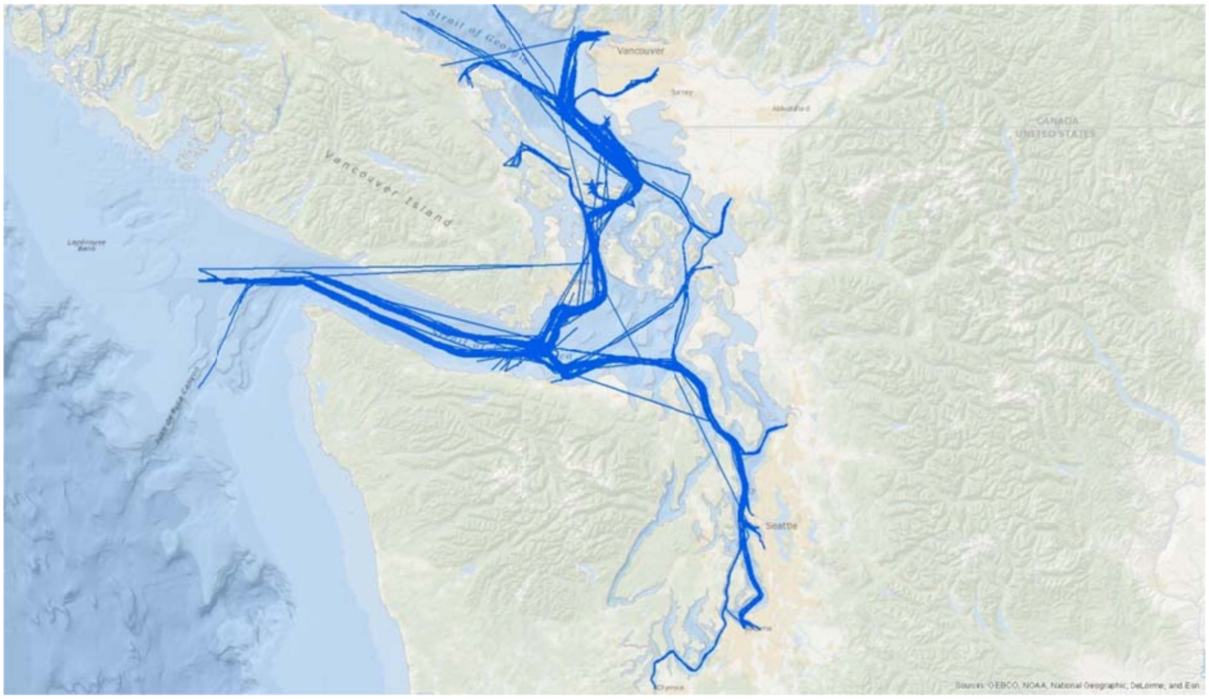


Source: Northern Economics, Inc. using MX 2012

2.2 Bulkers

The majority of bulker vessels transiting the study area are headed to Seattle or Tacoma in south Puget Sound or north to Port Metro Vancouver. Seattle-bound bulkers are typically either on-loading grain or discharging cement and gypsum. Similarly, Tacoma-bound bulkers typically on-load grain, logs and scrap metal or discharge gypsum. While some bulk vessels load petroleum coke at the Port of Bellingham, the vast majority of bulkers going north through the study area are destined for Westshore terminals at Roberts Bank (part of Port Metro Vancouver). The facility is often the busiest single coal export terminal in North America (Westshore 2012). Figure 9 illustrates the July 2010 traffic pattern for bulkers.

Figure 9. Bulker Vessel Pattern (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

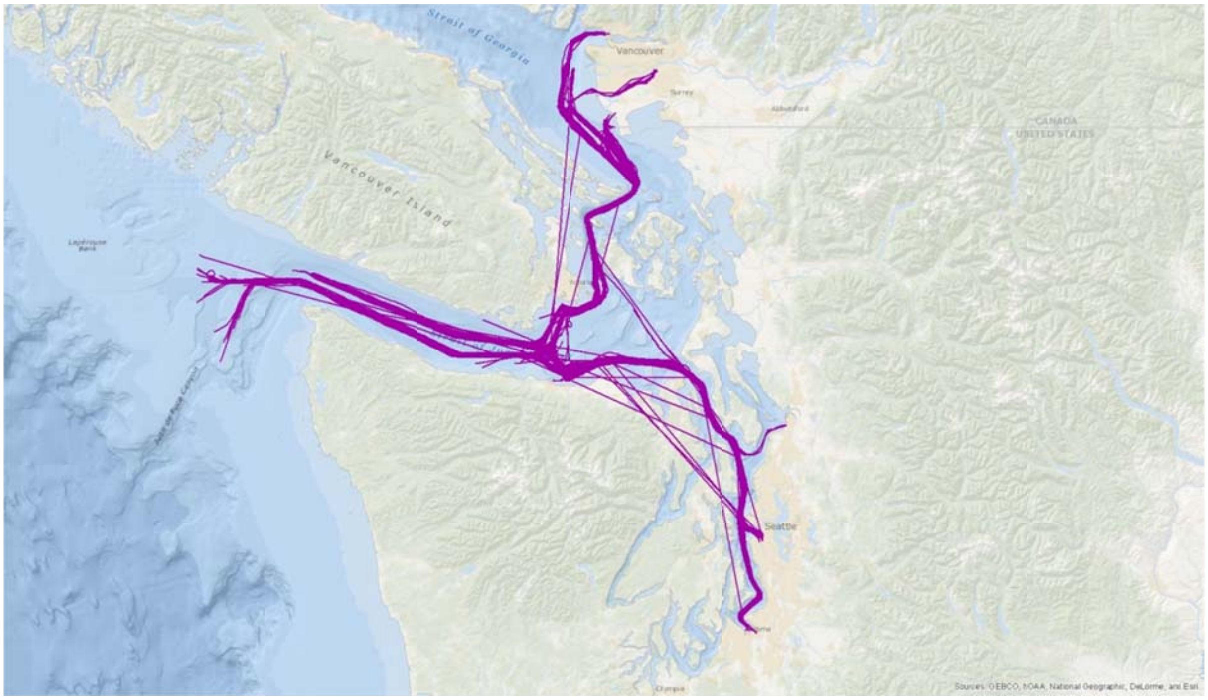
2.3 Cargo Ships

For the purpose of our analysis, cargo ships are comprised of both container vessels and general cargo vessels. Container vessels (also referred to as liner vessels) transport cargo in inter-modal containers which are individually transferred from ship to truck or rail. In contrast, general cargo vessels often carry a combination of cargo types. Those in our data set most often carry autos, other roll-on roll-off (ro-ro) cargo, small volumes of containers, and military cargo.

2.3.1 Container Vessels

Container vessels within the study area operate on a set schedule; they typically transit from berth to berth, though they must sometimes anchor to await berth at major ports. Container vessels operating in the Puget Sound stop almost exclusively in Everett, Seattle, Tacoma, and Vancouver, B.C.—which means there are no scheduled calls within the study area (Figure 10).

Figure 10. Container Vessel Pattern (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

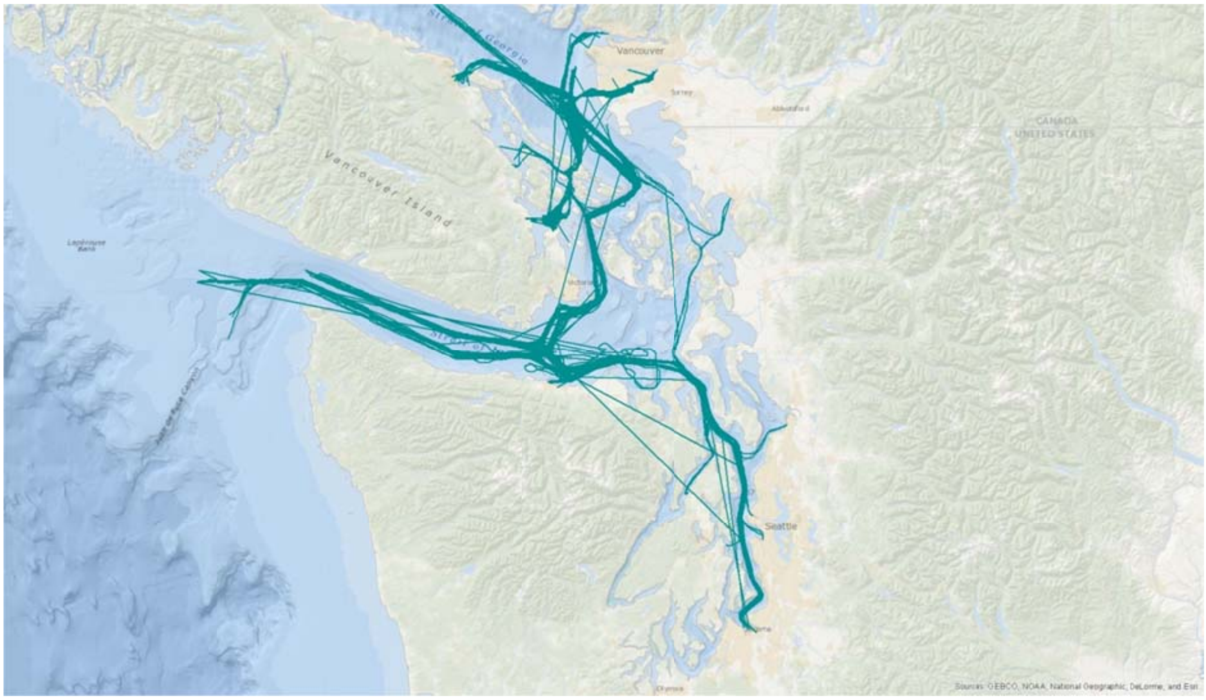
Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

Many of the container vessels calling at Vancouver also call at Puget Sound. The study team backed out the appropriate portion of these trips from container vessel calls provided by Port Metro Vancouver to avoid double-counting traffic.

2.3.1 General Cargo Vessels

General cargo vessels are similar to container vessels; however, they also call at smaller ports such as Bellingham and Sidney, B.C. In addition, there are many cargo vessels which transit the Inside Passage moving between Canadian destinations (Figure 11). While Canadian flag vessels may transit to and from Vancouver using a northern route, for the purpose of our analysis we assume that all foreign flag cargo and container vessels calling at Port Metro Vancouver transit the study area.

Figure 11. General Cargo Vessel Pattern (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT (Near-Real Time) data (USCG and CCG) 2010.

2.4 Tank Barges

Tank barges are defined as petroleum product or crude barges;[1] they are most often used to deliver petroleum products to customers or to fuel vessels. Historic tank barge transits were obtained through the Washington Department of Ecology's Vessel Entries and Transits (VEAT) data. VEAT defines a tank barge transit as any significant move between two locations, via Washington State waters, while transporting oil or chemicals. The VEAT transits were adjusted to reflect the needs of the study team; the numbers were doubled to account for empty moves, then reduced to omit moves in Washington waters which take place outside of the study area. Please note that though a tug is necessary to move a tank barge, the risk for tug collisions has been incorporated into the 'other' vessel type and is discussed further in section 2.5.1.

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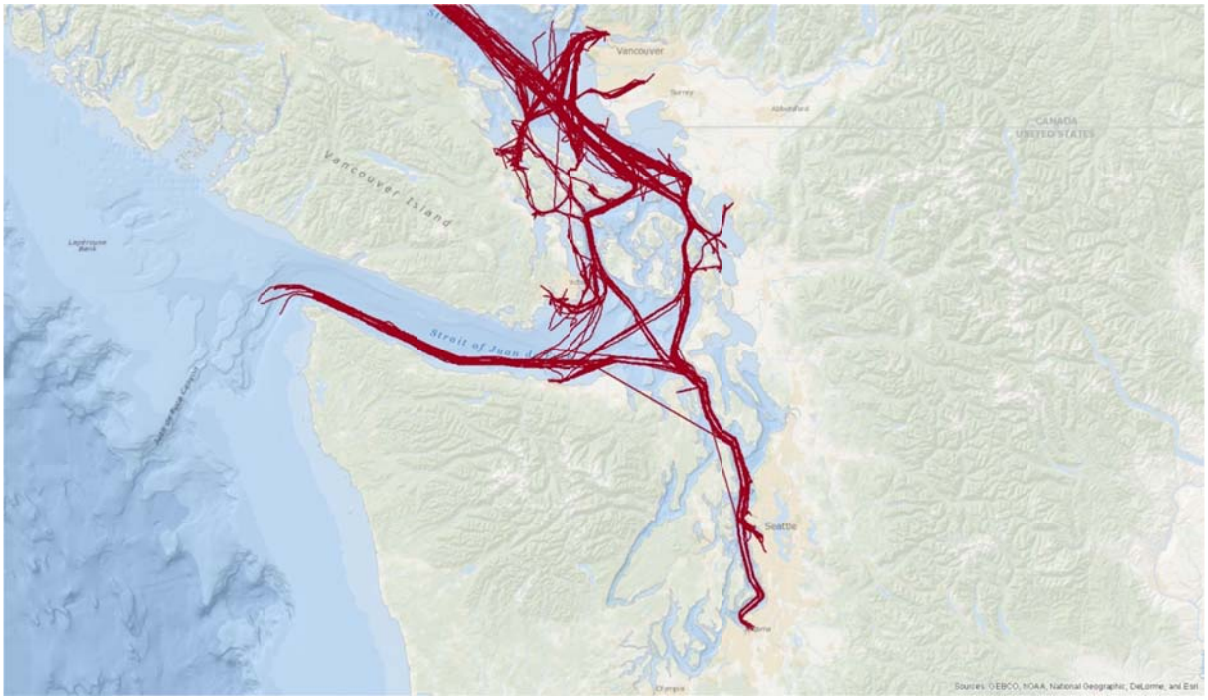
[1] ATBs and ITBs are considered tankers, not tank barges

The data show that tank barges are moved more frequently than product tankers, and are moved to a wider variety of locations, including small harbors. While more frequent, tank barge transit and load patterns are similar to those of product tankers. Tank barges are either loaded or empty—rarely are they partially loaded. Figure 12 illustrates a single month worth of tug and tank barge transits.

Figure 12. Tank Barge Transits (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

2.5 Other Vessels

The other vessel category is comprised of three major vessel types: tugs, passenger vessels, and large fishing vessels. These three vessel types are unique in transit frequencies and patterns. This section describes each of the three 'other' vessel types independently.

2.5.1 Tugs

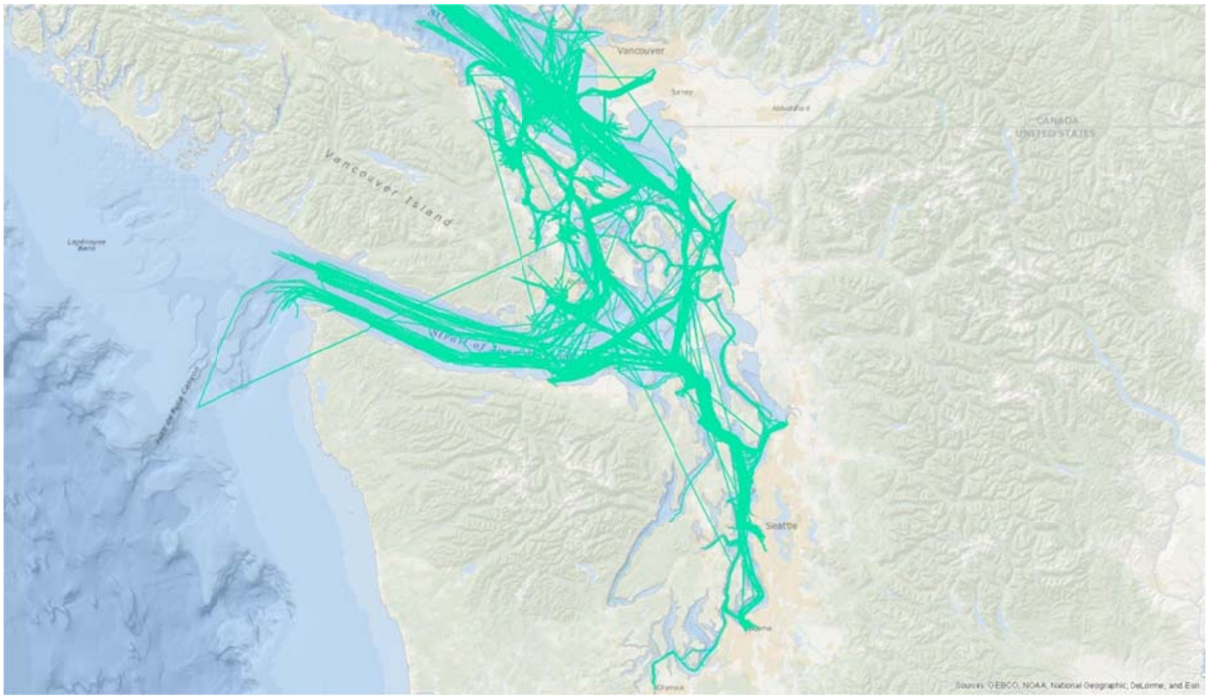
Tugs moving within the study area may move with a loaded barge, an empty barge, or without a barge. Tugs within the study area can be organized into three categories:

- Escort tugs—accompany larger vessels within the study area, such as crude and product tankers. These tugs assist with maneuvering and berthing and do not typically tow barges of any kind.
- Oil-tugs—typically move chemical or petroleum product tank barges
- Non-oil tugs—typically move gravel, equipment, wood chip and other barges

Tugs that move tank barges tend to be oil tugs; that is to say, they will most often be found moving a tank barge if anything. Similarly, barges that move other types of barges (such as chip or rail barges) are less likely to move tank barges, and most often report dry cargo tows. These are non-oil tugs.

The movements of oil tugs mimic those of tank barges, and are shown in Figure 12. Figure 13 illustrates movements of escort and non-oil tugs.

Figure 13. Escort and Non-Oil Tug Transits (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.
Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

Escort and non-oil tug movements are the most frequent of any vessel type included in the traffic analysis. These tugs can travel inside or outside of major shipping lanes, report non-traditional origins and destinations (such as navigational buoys and natural features such as inlets), and frequent small harbors.

2.5.2 Passenger Vessels

The passenger vessel component of the other category includes:

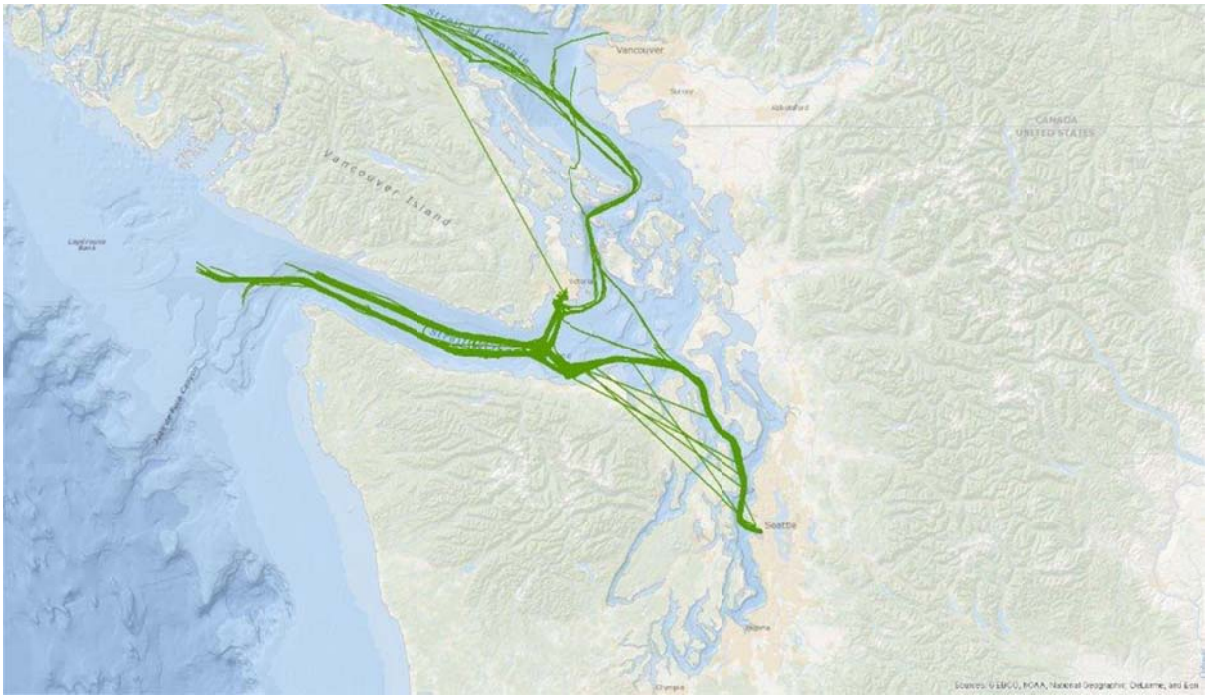
- Cruise vessels which are 300 gross tons or larger, deep draft, and require a Puget Sound pilot
- Regularly scheduled ferry services in the study area

While many small charter and recreational boats also operate in the area, they are significantly different in size and behavior, and are not included in the passenger vessel category.

2.5.2.1 Cruise Vessels

Cruise vessels operating within the study area frequently travel between Washington State, British Columbia, and Alaska. Figure 14 summarizes the transit patterns of large passenger vessels and ships operating within the study area.[2]

Figure 14. Cruise Ship Transits (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

Cruise vessels tend to make a one-way transit through the study area. Like most other large vessels, cruise vessels enter the study area through the Strait of Juan de Fuca. However, rather than calling at a berth and then exiting through the Strait of Juan de Fuca, cruise ships bound for Alaska or Canada's-Inside Passage travel north through Haro Strait and exit the study area via the Cherry Point subarea. Only those cruise ships exiting the study area destined for other U.S. or foreign ports travel back through the Strait of Juan de Fuca. In addition:

- Cruise ships southbound from Alaska travel to the West of Vancouver Island, and enter the study area through the Strait of Juan de Fuca.

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[2] The NRT data do not identify cruise vessels specifically. Instead, cruise vessels are categorized as passenger vessels or passenger ships, along with boats of a much smaller size. This illustration was generated by filtering out all passenger vessels and passenger ships less than 100 meters in length. After analyzing the data the study team believes that vessels remaining (those over 100 meters in length) are almost exclusively cruise vessels.

- Cruise ships are assumed to use Haro Strait-Boundary Pass exclusively when traveling north and south within the study area unless origins or destinations, such as destinations in Saddlebag or Guemes Channel, require the use of Rosario Strait; cruise ship calls to these destinations are few.
- Both ferries and cruise ships make berth-to-berth transits. Neither vessel type regularly anchors in the study area. Along these lines, all destinations in the Saddlebag subarea are assumed to be Bellingham, as neither ferries nor cruise ships anchor at Vendovi Island.

2.5.2.2 Ferries

Three major public ferry systems operate within the study area, as well as several smaller, privately owned ferries. The traffic analysis takes into account the transit times of these ferries, as well as at-dock time for ferries which are homeported in the study area. As previously mentioned, ferries do not have at-anchor time as they travel from berth to berth.

- The Alaska Marine Highway System (AMHS) is the northernmost ferry route to operate in the study area. AMHS operates a year-round ferry route between points in Alaska and Bellingham, WA. This ferry traffic will only impact Cherry Point, Rosario and Saddlebag subareas.
- British Columbia Ferry Services (B.C. Ferries) operates an extensive network of ferries on the west coast and the islands of British Columbia. The B.C. Ferry route between Tsawwassen and Swartz Bay passes through the Cherry Point subarea (Figure 15).

Figure 15. B.C. Ferry Service Routes

Source: B.C. Ferries 2012

- The Washington State Ferry System operates several ferries in Puget Sound; however, most of these are in the south portion of the sound, near Seattle. Within the study area the only Washington State Ferry to operate travels among Anacortes, the San Juan Islands, and Sidney, B.C. Figure 16 illustrates this route.

Figure 16. Washington State Ferry System

Source: Washington State Department of Transportation 2012.

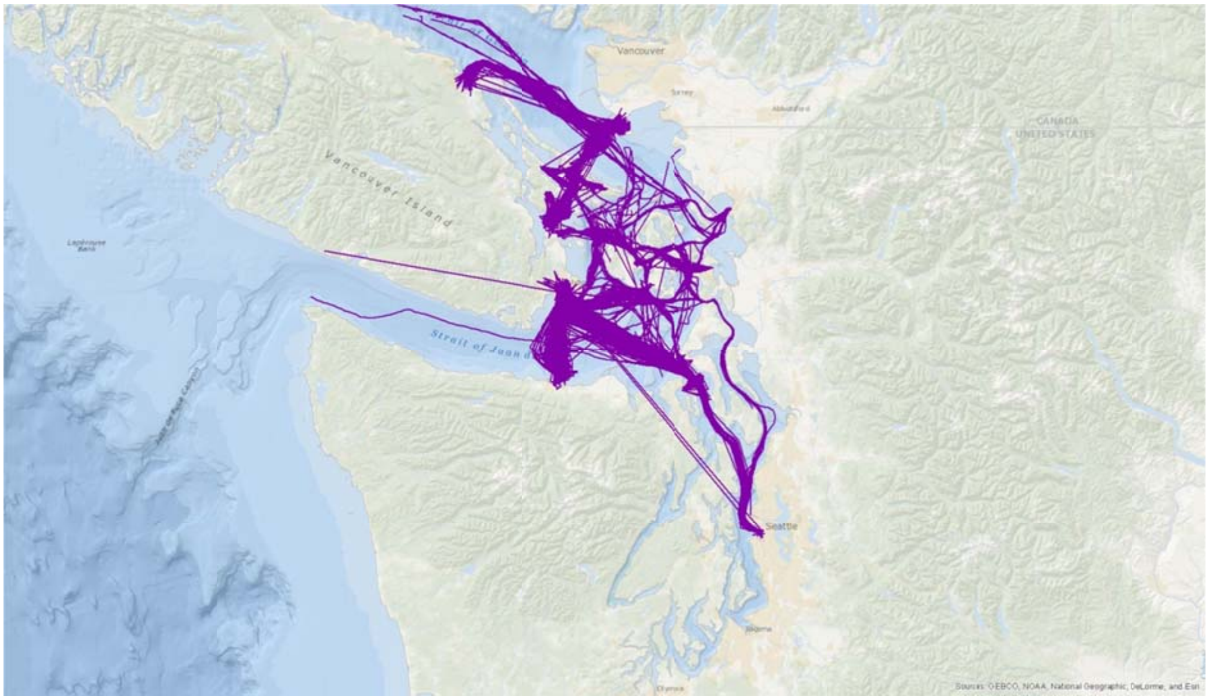
- Whatcom County owns and operates the Lummi Island Ferry, which makes frequent trips across Hale Pass between Gooseberry Point and Lummi Island in the Saddlebag subarea.

Private ferries operating within the study area include:

- Black Ball Transit, which runs between Port Angeles and Victoria, B.C.
- The Victoria Clipper, which runs between Seattle, Victoria, B.C., and the San Juan Islands
- Guemes Island Ferry, from Anacortes to Guemes Island
- San Juan Island Commuter: Bellingham, Friday Harbor, San Juan Islands
- San Juan Island Shuttle Express, Bellingham to San Juan Islands

Figure 17 illustrates the July 2010 transit pattern for ferries operating within the study area.

Figure 17. Ferry Vessel Pattern (July 2010)



Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

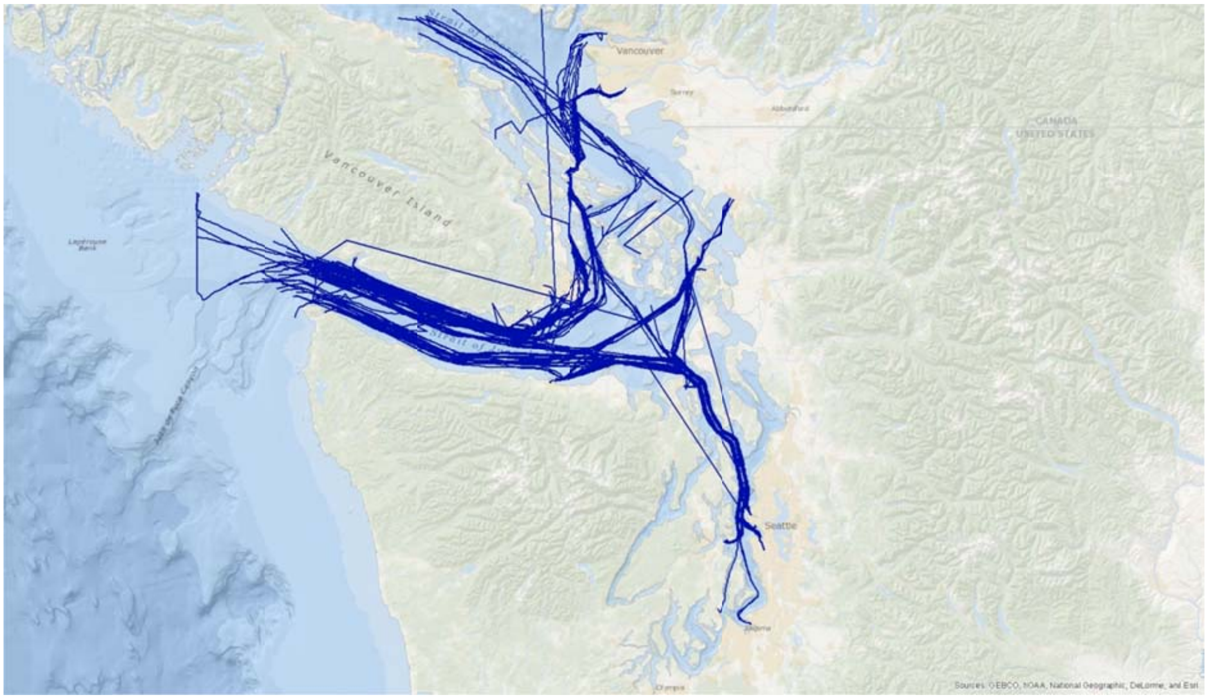
Source: Northern Economics, Inc. using NRT (Near-Real Time) data (USCG and CCG) 2010.

2.5.3 Large Fishing Vessels

For purposes of this memo, "large fishing vessels" are defined as vessels greater than 60′ length overall that are involved in commercial fishing or processing. It is assumed that in general, large fishing and processing vessels are not actively harvesting or processing fish during their transits—they are moving through the study area to fishing grounds in either Alaska or on the west coast. In general, large fishing vessels do not deliver harvests within the study area unless it is at the end an extended trip.

Figure 18 illustrates the July 2010 transit patterns for large fishing vessels operating within the study area.

Figure 18. Large Fishing Vessels (July 2010)



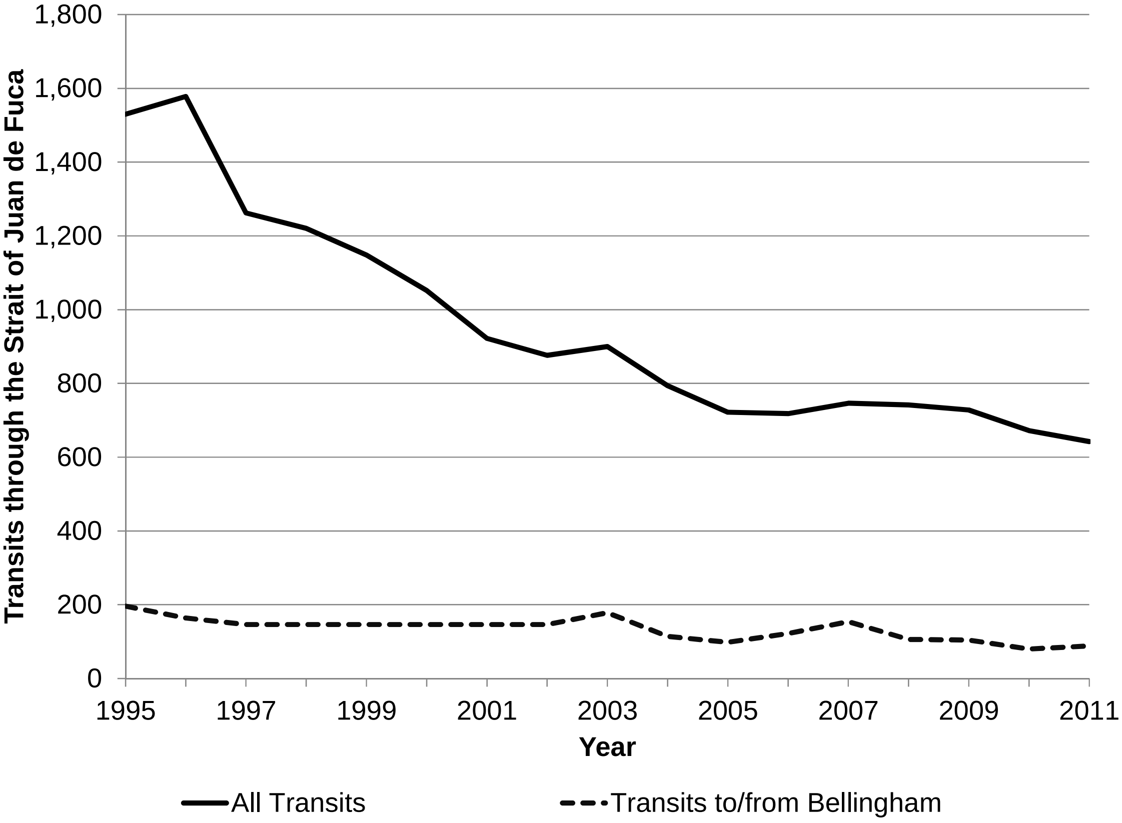
Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.

Source: Northern Economics, Inc. using NRT (Near-Real Time) data (USCG and CCG) 2010.

As shown in Figure 19 on the following page, there has been a very noticeable decline in the number of large fishing vessel transits through the Strait of Juan de Fuca between 1995 and 2011. Total transits in 2011 are only 42 percent of the estimated transits in 1995. The number of transits involving the Port of Bellingham has seen a similar decline—2011 transits are 45 percent of 1995 transits.

The decline in the number of transits is a result of changes in fishery management regimes and changes in the profitability of the fisheries. The large fishing vessels that transit through the Strait of Juan de Fuca are bound for either fishing grounds off the West Coast of Washington and Oregon, or in Alaska. Management regimes for the two regions are unrelated, but both have been transitioning to catch share management systems that in general result in fewer fishing vessels.

Figure 19. Declining Numbers of Large Fishing Vessel Transits in the Strait of Juan de Fuca, 1995–2011



Source: Developed by Northern Economics from multiple sources, 2013

2.6 Canadian-Bound Vessels

Vessels transiting the study area en route to Canadian destinations are included in our analysis, and are mapped separately from vessel traffic calling at Washington ports. Port Metro Vancouver (which includes Fraser River and Burnaby) provided the study team with historic vessel calls by type (Table 2). These data were combined with VEAT data (1995–2010) to estimate total vessel calls by type to Canadian Ports. While the study team believes that Port Metro Vancouver accounts for the majority of traffic transiting the study area en route to Canada, vessels calling at other Canadian ports along the Inside Passage were included insofar as they are incorporated into the historic VEAT data.

Table 2. Vessel Calls to Port Metro Vancouver, by Vessel Type (2008–2011)

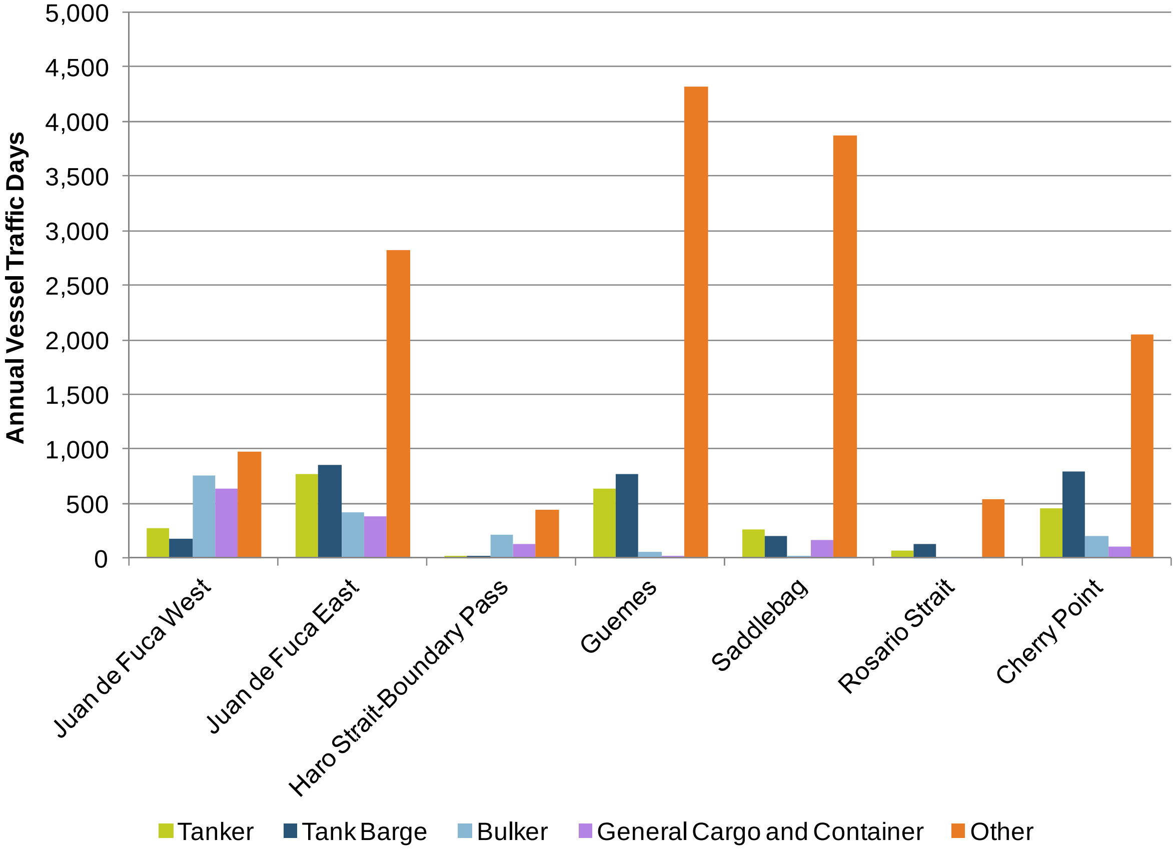
Vancouver Vessel Title	BP-VTA Vessel Names	2008	2009	2010	2011	Average (%)
Bulk Carrier / Reefer	Bulk	1,321	1,250	1,398	1,488	49.2
Container	Container	855	754	708	817	27.0
Ro-Ro / Combination	General Cargo	290	254	257	262	8.7
Tanker	Tanker	241	255	271	206	6.8
Passenger	Passenger	255	258	183	200	6.6
Miscellaneous and Offshore	Excluded from Analysis	42	20	16	51	1.7
Total		**3,004**	**2,791**	**2,833**	**3,024**	**100**

Source: Port Metro Vancouver 2012

3 Vessel Traffic Data

Using the vessel traffic patterns described in Section 2, the study team generated estimates of vessel traffic days by activity type and subarea. Figure 20 summarizes our results, showing average annual vessel traffic days by subarea. Other vessels, comprised of tugs, passenger and large fishing vessels, account for the vast majority of traffic days spent in each subarea.

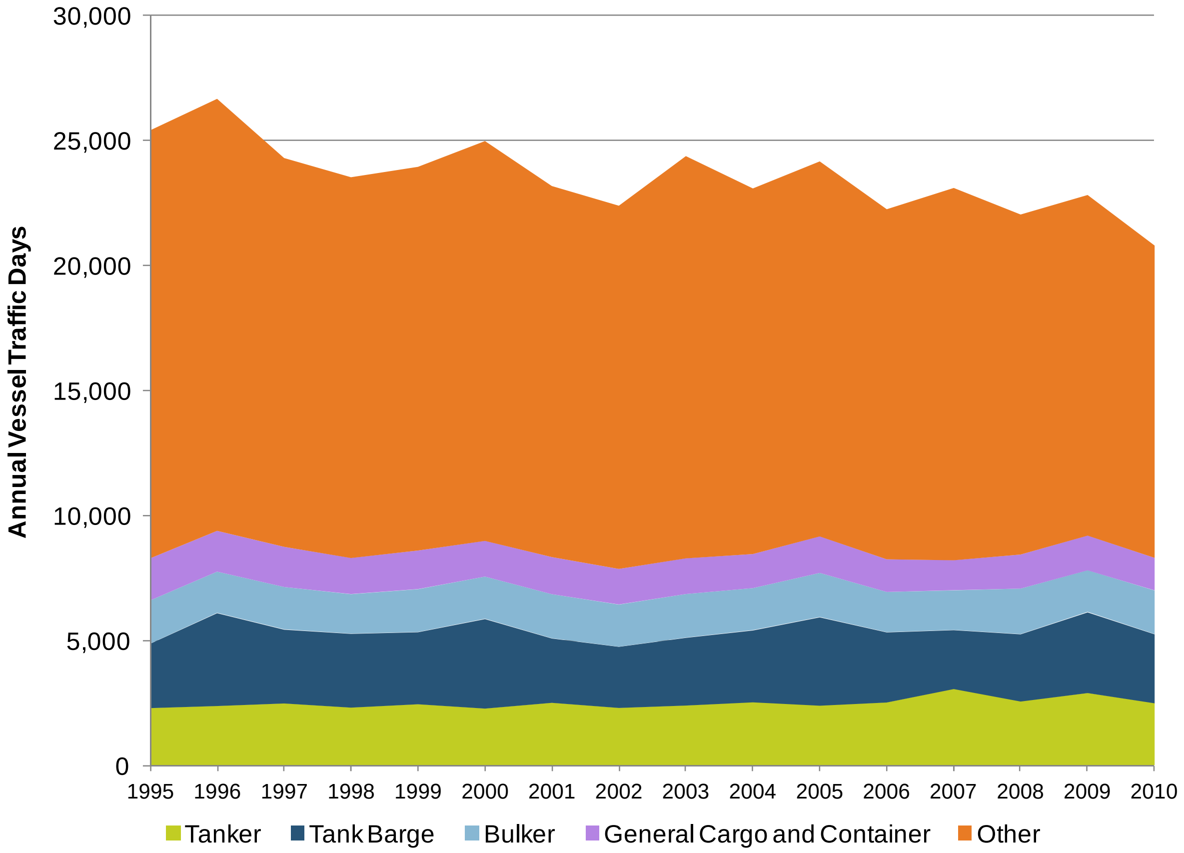
Figure 20. Vessel Traffic Days by Subarea and Vessel Type, Average (1995–2010)



Source: Northern Economics, 2013

Between 1995 and 2010, the traffic days spent in each subarea by vessel type remained somewhat consistent. The sole exception was time spent by Other vessels, for which there is an estimated decrease from 17,000 traffic days a year to less than 13,000 (Figure 21). The decrease is due primarily to a drop in the number of large fishing vessels transiting the study area. As mentioned in Section 2.5.3, large fishing vessel transits in 2011 are only 42 percent of the estimated transits in 1995. The decline in the number of transits is a result of changes in fishery management regimes and changes in the profitability of the fisheries.

Figure 21. Vessel Traffic Days by Subarea and Vessel Type, Average (1995–2010)



Source: Northern Economics, 2013

In the following sub-sections we detail the results of our analysis by vessel and activity type. Vessel types, as shown above, include tankers, tank barges, bulkers, general cargo and container, and other. Activity types include underway[3], maneuvering[4], at berth and at dock. All tables and figures generated in this section (Section 3) were produced using Northern Economics' estimates of traffic days by subarea and activity type.

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[3] Underway is defined as the time that the vessel spends transiting subareas within the study area. While underway, it is assumed that the vessel is operating at a somewhat consistent speed, en route to a given point (i.e. not loitering)

[4] Maneuvering is the time spent maneuvering to and from an anchorage or berth. While maneuvering the vessel is either operating at a reduced speed in anticipation of stopping, or is still gaining speed as it moves from an anchored or berthed position. Large vessels, such as tankers, container vessels and bulkers, are expected to require 135 minutes (2.25 hours) maneuvering to and from an anchorage, and 120 minutes (2 hours) maneuvering to and from a berth. For tugs maneuvering time is significantly less, and is estimated as somewhere between 15 (.25 hours) minutes and 75 minutes (1.25 hours), depending on whether or not the tug is maneuvering with or without a tow.

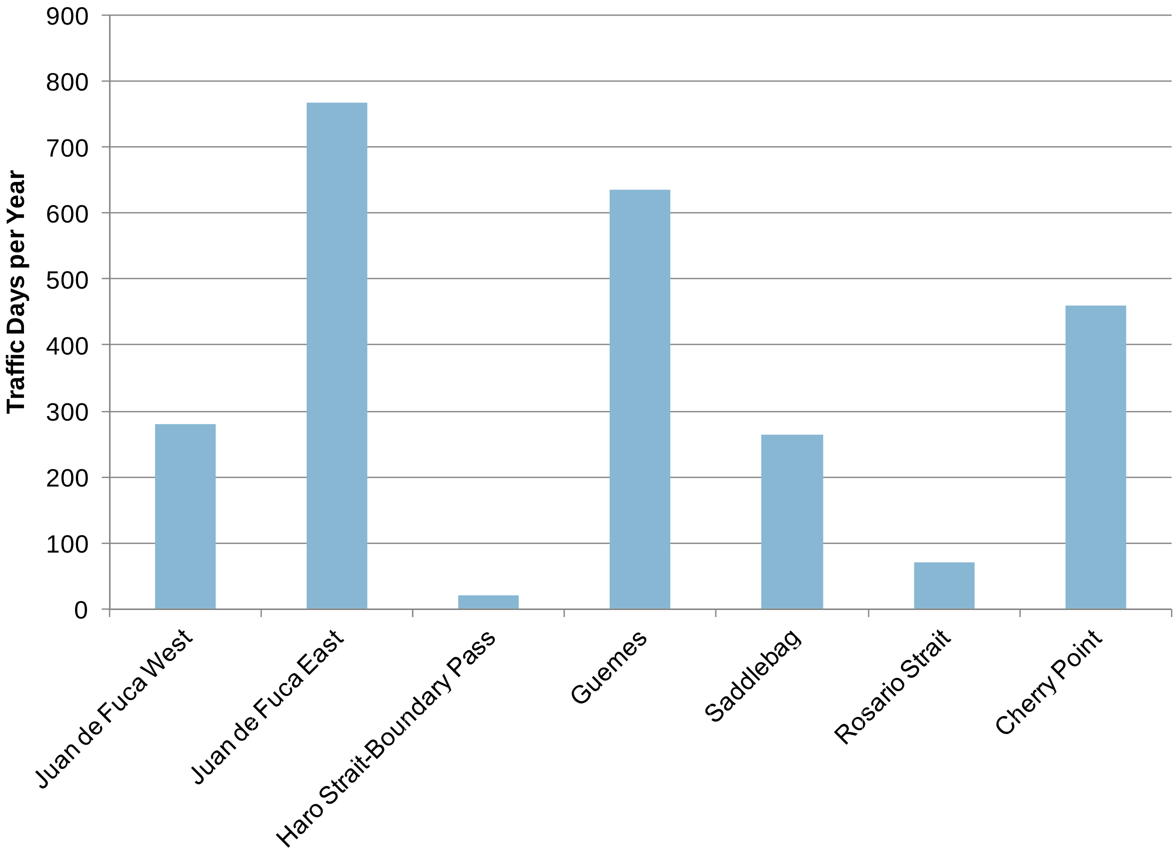
3.1 Tankers

Tankers spend most of their transiting time in Juan de Fuca West; this is not surprising given the long distance travelled in this subarea (71 miles). However, total transit time is overshadowed by time at anchor and time at dock. As shown in Table 3 and Figure 22, total time by subarea is greatest in Juan de Fuca East, Guemes Channel, and Cherry Point. The majority of the vessel traffic days in Juan de Fuca East and Guemes Channel are reflective of time at anchor at Port Angeles and Vendovi Island. The traffic days in Cherry Point are almost exclusively days at dock.

Table 3. Tanker Vessel Traffic Days by Subarea, 1995–2010

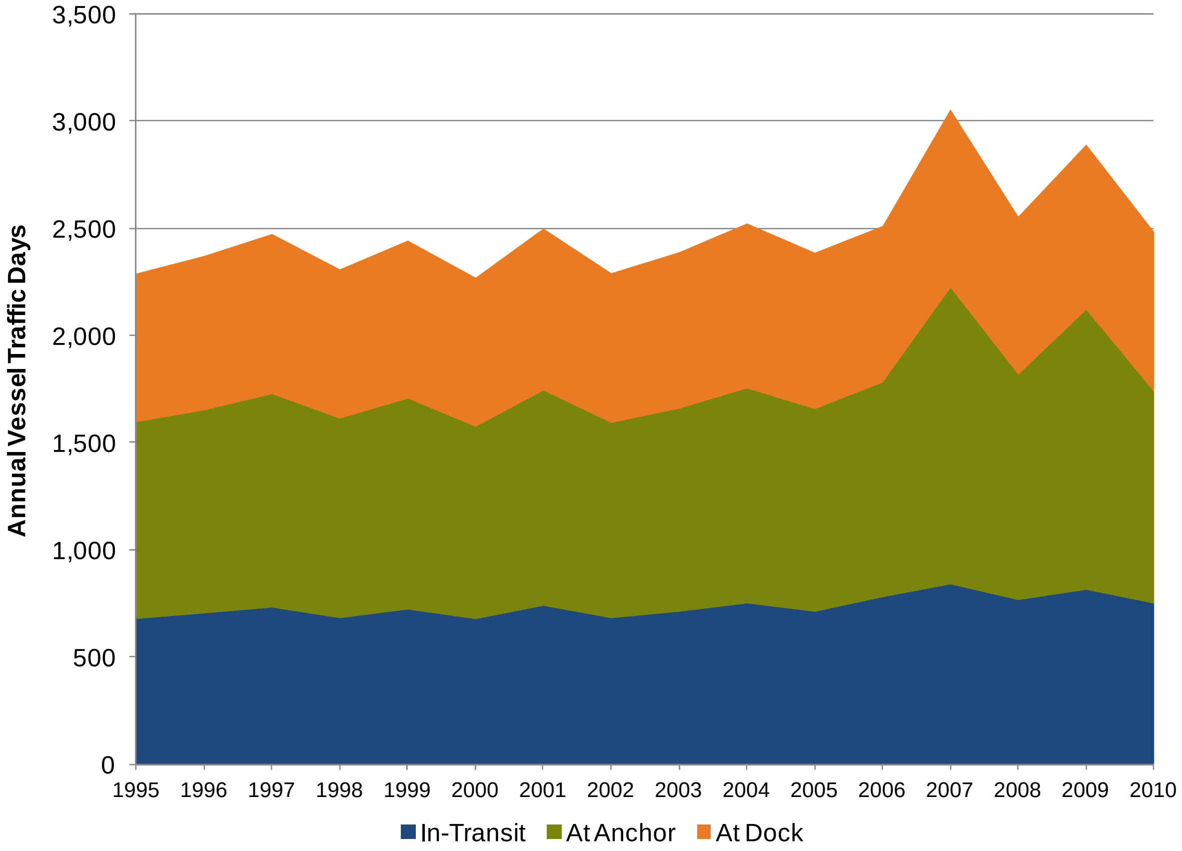
Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddle Bag	Rosario Strait	Cherry Point
1995	250.33	698.64	17.08	608.78	214.31	70.13	430.34
1996	260.23	729.97	16.28	629.87	214.75	73.08	447.13
1997	269.35	747.84	19.93	658.18	239.04	75.28	463.29
1998	250.87	694.44	19.40	614.72	227.19	70.02	431.64
1999	265.84	737.26	20.00	650.27	237.73	74.26	457.31
2000	251.82	716.70	11.64	601.17	185.40	71.19	432.01
2001	272.21	756.16	19.99	664.87	240.76	76.10	468.19
2002	252.63	713.30	13.96	607.75	198.44	71.16	433.78
2003	264.08	748.41	13.48	633.04	201.37	74.51	453.26
2004	278.11	785.25	15.36	669.03	218.41	78.33	477.53
2005	264.34	750.98	12.77	632.19	197.61	74.67	453.59
2006	318.41	850.77	27.59	589.93	266.34	58.46	399.02
2007	332.00	1019.00	27.42	703.12	425.25	65.05	480.85
2008	289.69	754.70	25.99	575.67	331.82	62.78	513.39
2009	322.42	769.59	28.25	703.34	488.35	64.48	512.97
2010	295.93	745.41	30.11	594.27	277.84	58.72	480.37

Figure 22. Tanker Vessel Traffic Days by Subarea, Average (1995–2010)



Of total time spent by tankers in the study area, 28 percent of traffic days are spent in transit, 30 percent of traffic days are spent at dock, and 42 percent of traffic days are spent at anchor (Figure 23).

Figure 23. Tanker Vessel Traffic Days by Activity Type (1995–2010)



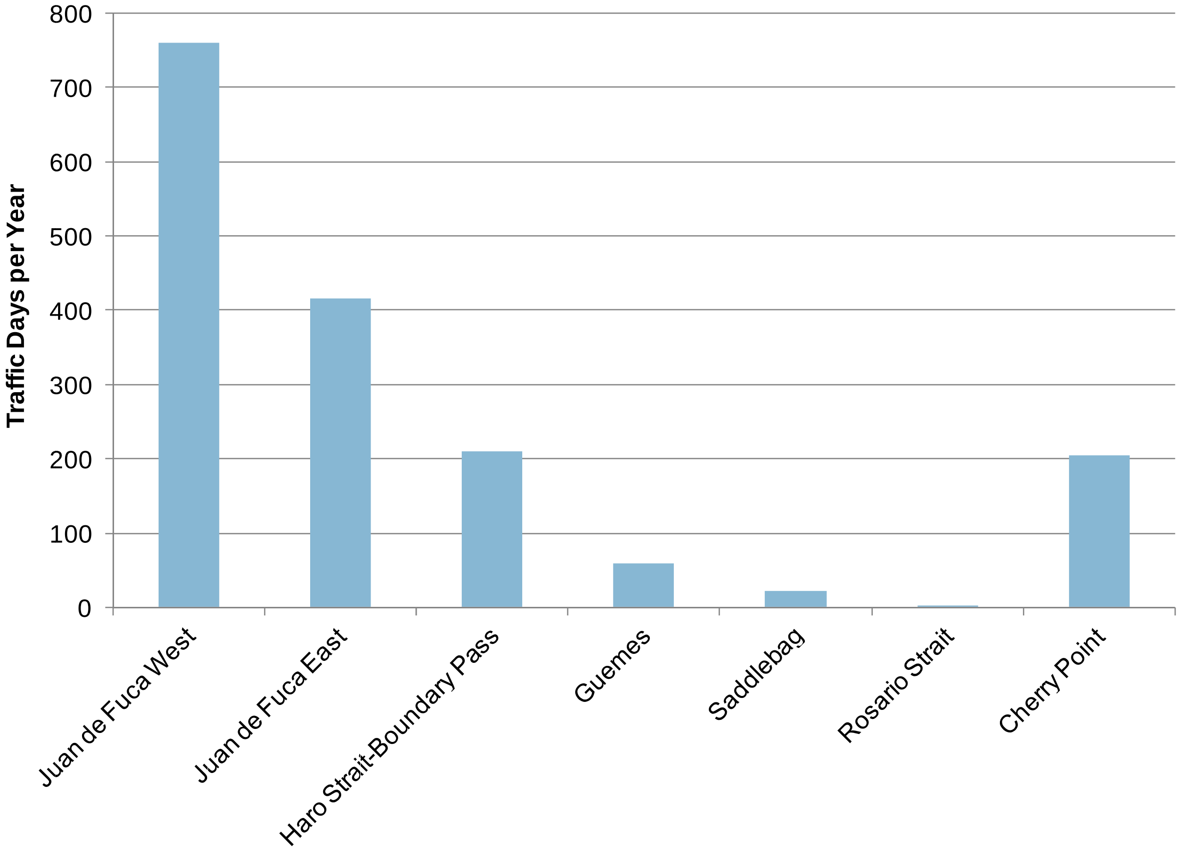
3.2 Bulker

The vast majority of bulker vessels in the study area are transiting through en route to Canadian or South Puget Sound destinations. Those going north to Canada's Inside Passage use Haro Strait almost exclusively; very few transit days are spent in Rosario Strait (Table 4). South Puget Sound bulkers, most of which are transporting grain to foreign destinations from the Port of Seattle and the Port of Tacoma, spend a significant portion of time transiting Juan de Fuca East and Juan de Fuca West.

Table 4. Bulker Vessel Traffic Days by Subarea, 1995–2010

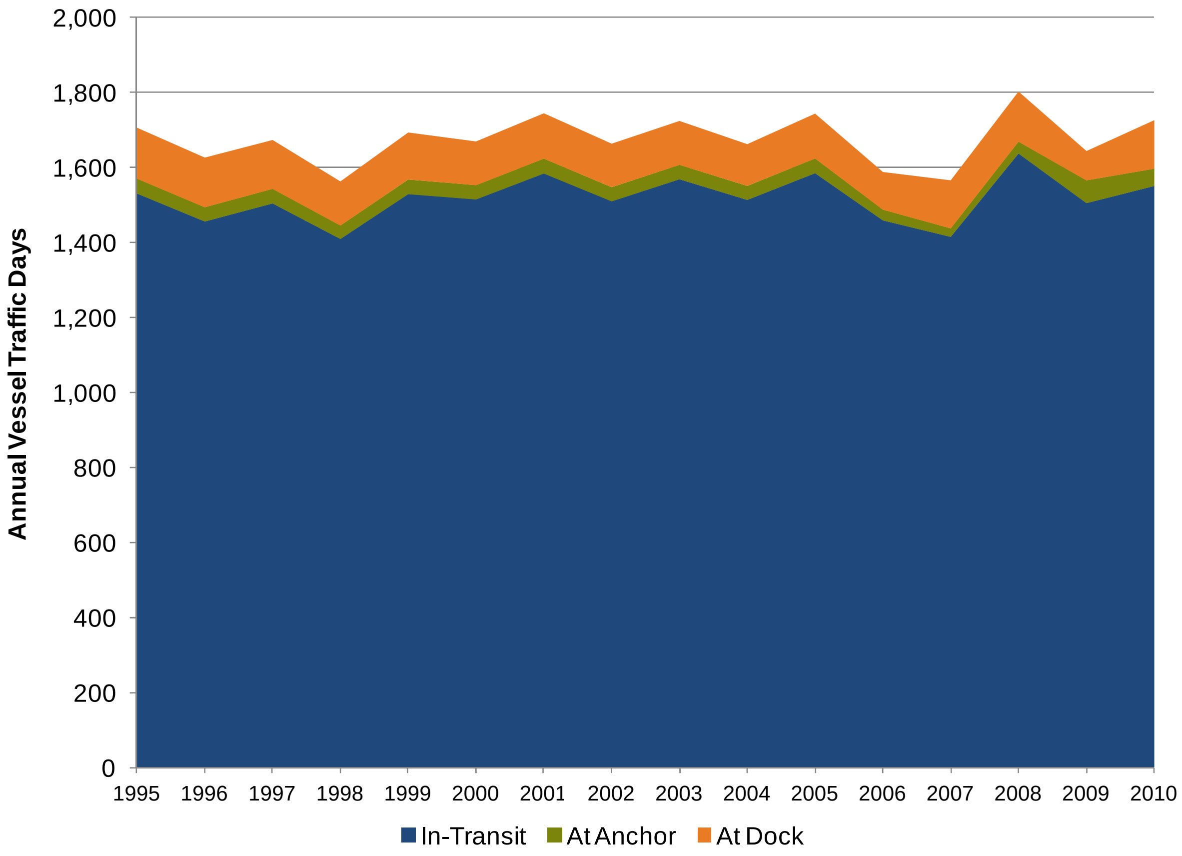
Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	783.98	420.67	208.09	76.48	25.89	4.06	186.99
1996	747.13	401.12	196.36	75.44	25.53	4.00	176.59
1997	768.95	412.36	206.22	72.23	24.45	3.83	185.15
1998	718.35	384.88	195.58	63.64	21.54	3.38	175.38
1999	778.39	416.91	213.21	67.27	22.77	3.57	191.10
2000	767.72	410.63	215.10	60.04	20.32	3.19	192.44
2001	802.23	429.01	225.51	61.76	20.91	3.28	201.71
2002	764.97	409.13	214.57	59.52	20.15	3.16	191.95
2003	792.90	423.80	224.81	58.53	19.81	3.11	200.94
2004	764.62	408.58	217.61	55.37	18.74	2.94	194.45
2005	801.96	428.76	226.31	60.60	20.51	3.22	202.35
2006	703.18	392.03	199.60	61.01	22.33	1.89	207.90
2007	683.15	377.98	191.82	48.88	33.34	2.08	228.42
2008	796.48	444.53	221.55	48.87	19.98	1.84	269.15
2009	729.80	438.29	205.66	28.95	18.07	1.54	221.54
2010	755.97	464.30	208.75	35.47	22.37	1.69	237.58

Figure 24. Bulker Vessel Traffic Days by Subarea, Average (1995–2010)



Almost all vessel traffic days for bulkers within the study are spent transiting. As shown in Figure 25, very few vessel traffic days are spent at anchor or at dock within the study area. Those bulkers that do call within the study area are most often calling at Anacortes (Guemes Channel), Bellingham (Saddle Bag) and Intalco (Cherry Point).

Figure 25. Bulker Vessel Traffic Days by Activity Type (1995–2010)



3.3 Cargo Ships

Cargo ships are comprised of container and general cargo vessels. Container vessels do not call at docks in the study area; instead they transit through en route to Seattle, Tacoma or Vancouver. Nearly all container traffic days spent within the study area are considered transit days, and are restricted to Juan de Fuca West, Juan de Fuca East, Haro Strait-Boundary Pass, and Cherry Point. The exceptions to this pattern are non-transiting traffic days spent in Guemes, Saddle Bag and Juan de Fuca East:

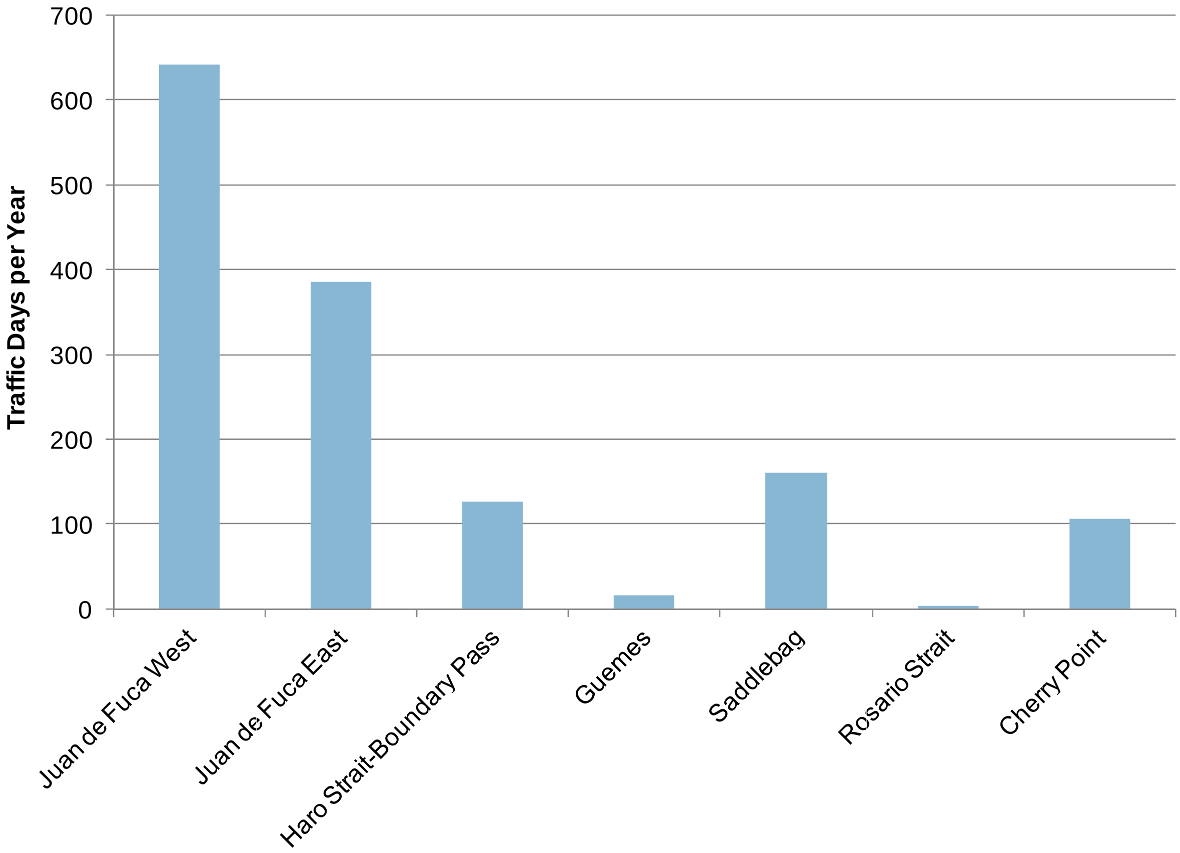
- In 2010 a single container vessel recorded a four-day period at dock in Anacortes.
- In 2006, 2007 and 2009, small numbers of vessels recorded long periods of at-dock time in Bellingham. These vessels were most likely undergoing repair.
- Every year between 2006 and 2010 a small number of container vessels stop at Port Angeles berth or anchorage. These stops are not part of a regularly scheduled transit and could have been made for bunkering or repairs.

In contrast to container vessels, general cargo vessels do make calls within the study area. General cargo vessels make a small number of calls to Anacortes and March Point (Guemes Channel) as well as calls to Port Angeles (Juan de Fuca East) each year. The majority of general cargo vessel calls recorded by the MX data show transits to and from locations in South Puget Sound and the Canadian Inside Passage (i.e. Vancouver).

Table 5. Cargo Ship Days by Subarea, 1995–2010

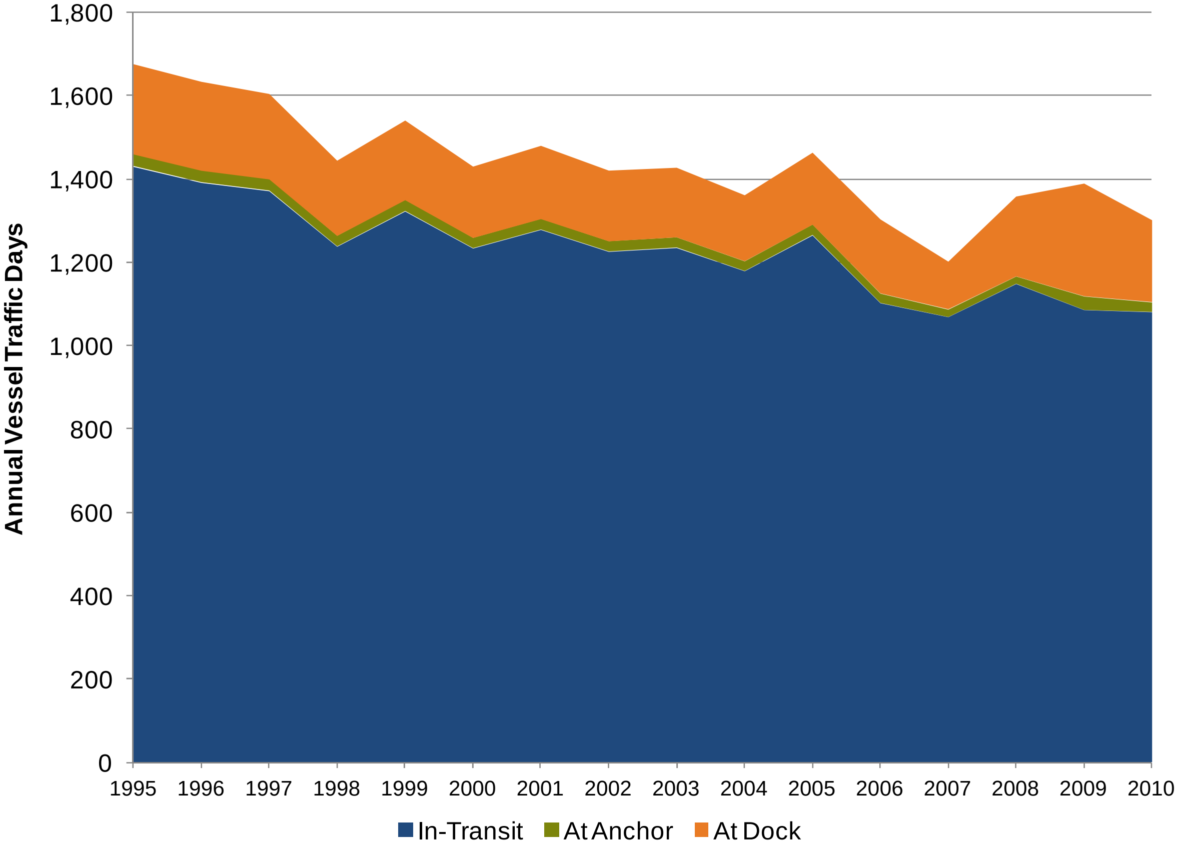
Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	753.33	454.58	141.51	19.56	186.65	4.24	115.99
1996	733.86	443.79	136.40	19.30	184.12	4.18	111.92
1997	721.55	434.36	137.12	18.48	176.29	4.00	112.26
1998	650.15	389.91	125.78	16.28	155.32	3.53	102.80
1999	693.95	415.50	135.27	17.21	164.18	3.73	110.47
2000	645.09	383.70	129.61	15.36	146.53	3.33	105.54
2001	668.03	396.93	134.85	15.80	150.74	3.42	109.76
2002	640.88	381.07	128.96	15.22	145.26	3.30	105.00
2003	644.58	381.91	131.76	14.97	142.85	3.24	107.12
2004	614.90	363.85	126.42	14.16	135.14	3.07	102.72
2005	660.70	392.08	134.12	15.50	147.91	3.36	109.10
2006	575.59	348.48	105.61	15.12	154.54	3.26	99.68
2007	558.63	328.88	102.00	11.34	100.55	3.12	95.89
2008	586.97	364.45	118.35	7.45	165.24	3.22	111.67
2009	560.29	351.87	110.05	18.35	241.58	2.81	103.58
2010	556.10	325.27	111.65	33.26	165.25	2.89	105.71

Figure 26. Cargo Ship Days by Subarea, Average (1995–2010)



Since most port calls made by cargo vessels are outside of the study area, the lion's share of the time spent within the study area is attributable to transiting (Figure 27).

Figure 27. Cargo Ship Days by Activity Type (1995–2010)



3.4 Tank Barges

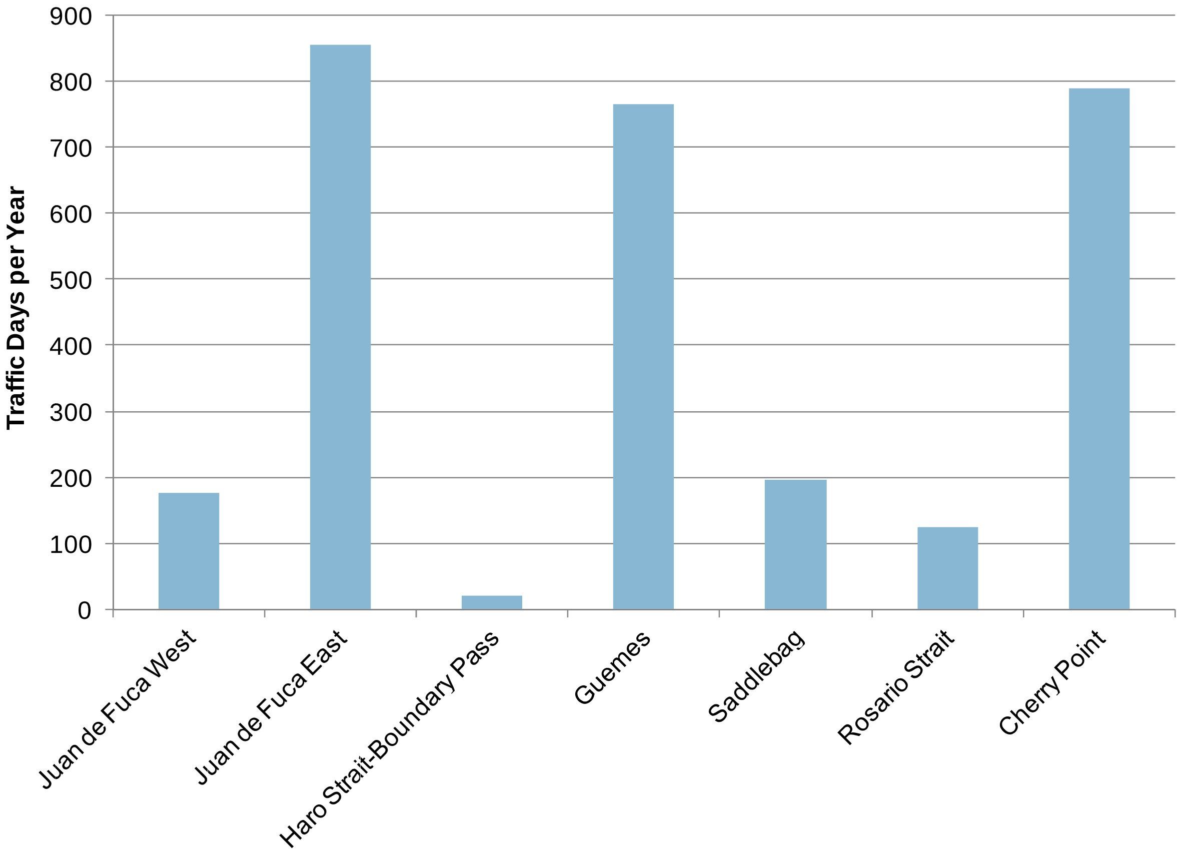
Tank barges are used to transport liquids such as petroleum products, crude oil and chemicals. Tank barge activity within the study area is tracked by the WADEC. The numbers presented in this section were adjusted downward to avoid double-counting of ATBs and ITBs. Automatic Identification System (AIS) data from the U.S. and Canadian Coast Guards were used to determine the proportion of vessel movements by subarea.

Tank barges are regularly moved within the study area, but unlike larger product tankers, do not frequent the ocean. This accounts for the much smaller proportion of total traffic days spent in Juan de Fuca West (Table 6 and Figure 28).

Table 6. Tank Barge Days by Subarea, 1995–2010

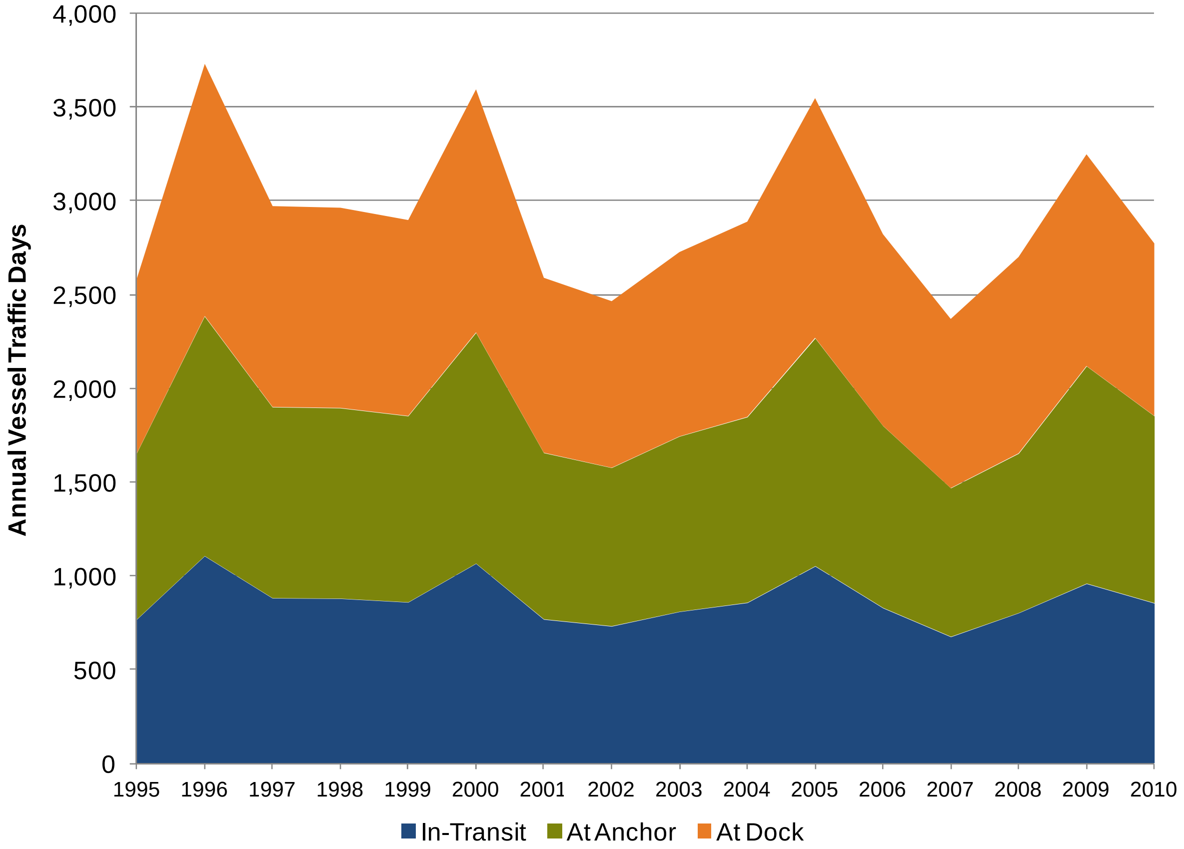
Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	155.41	755.07	18.11	676.68	174.35	109.89	696.89
1996	224.02	1088.42	26.11	975.42	251.32	158.41	1004.56
1997	178.44	866.98	20.80	776.97	200.19	126.18	800.18
1998	177.95	864.60	20.74	774.83	199.64	125.83	797.98
1999	173.98	845.28	20.27	757.53	195.18	123.02	780.16
2000	215.85	1048.74	25.15	939.85	242.16	152.63	967.93
2001	155.52	755.60	18.12	677.15	174.47	109.97	697.38
2002	148.00	719.09	17.25	644.43	166.04	104.66	663.68
2003	163.74	795.55	19.08	712.95	183.70	115.79	734.25
2004	173.49	842.90	20.22	755.39	194.63	122.68	777.96
2005	213.08	1035.24	24.83	927.76	239.04	150.67	955.48
2006	170.15	824.43	19.80	736.96	190.08	120.33	758.68
2007	134.84	643.24	14.11	676.61	149.99	95.18	654.39
2008	161.89	680.45	18.70	769.39	181.50	114.24	772.16
2009	194.04	1035.02	23.51	771.99	209.50	137.42	874.85
2010	175.25	877.19	21.30	681.94	206.19	124.10	685.17

Figure 28. Tank Barge Days by Subarea, Average (1995–2010)



Tank barges operating within the study area spend a relatively large portion of time at anchor and at berth (Figure 29). Based on knowledge of the local barge transportation industry, it is estimated that tank barges spend approximately 16 hours at berth per call; this is the time required to load or empty a full tank barge. In addition, it is estimated that tank barges take approximately 1.5 hours to maneuver to and from ports of call.

Figure 29. Tank Barge Vessel Traffic Days by Activity Type (1995–2010)



3.5 Other Vessels

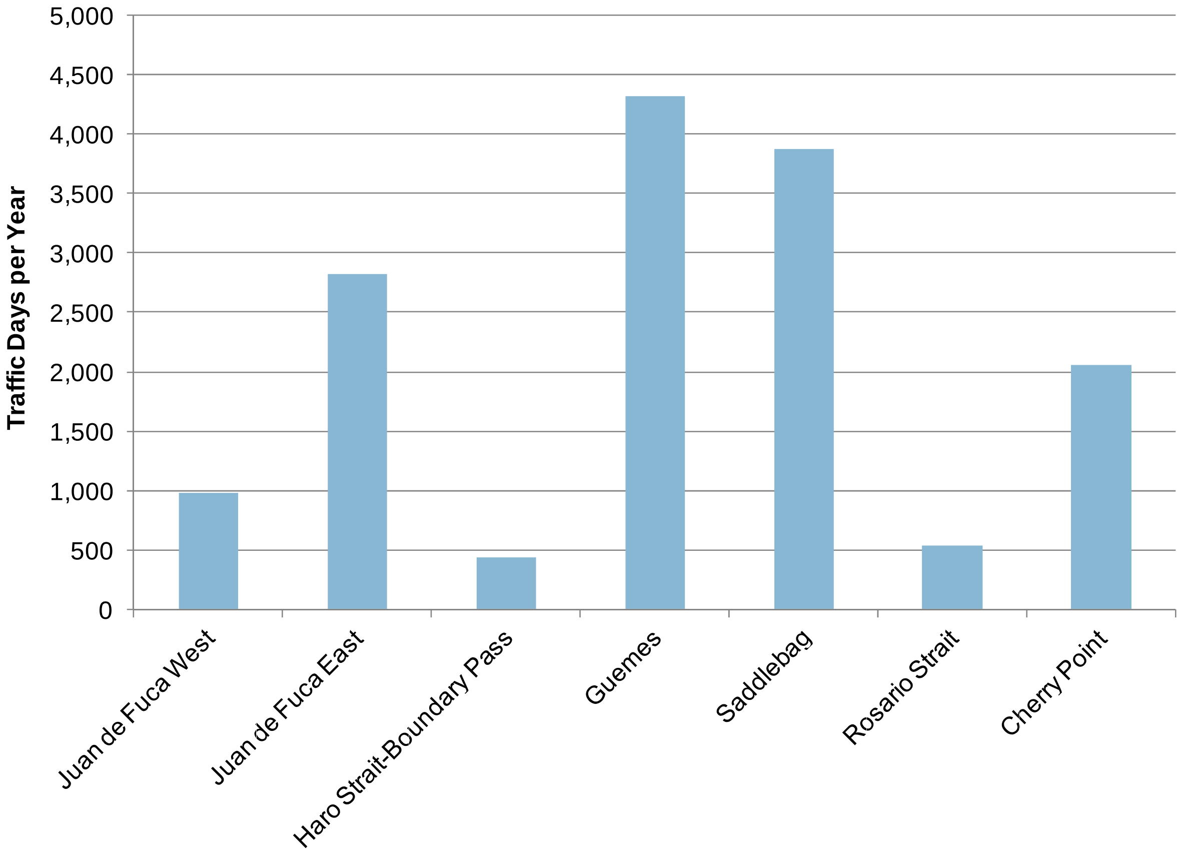
Other vessels (tugs, passenger vessels and large fishing vessels) spend the largest amount of time within the study area. As shown in Table 7 and Figure 30, Other vessels spend the most traffic days in Saddlebag, Guemes Channel and Juan de Fuca East subareas; the least amount of time is spent in Haro and Rosario Strait. These activity patterns are the result of:

- High volumes of ferry traffic transiting and docking in Juan de Fuca East and Guemes Channel
- High volumes of tug traffic transiting Juan de Fuca East and Cherry Point
- High volumes of fishing vessels transiting Juan de Fuca East and docking for extended periods in Guemes Channel and Saddlebag

Table 7. Other Vessel Traffic Days by Subarea, 1995–2010

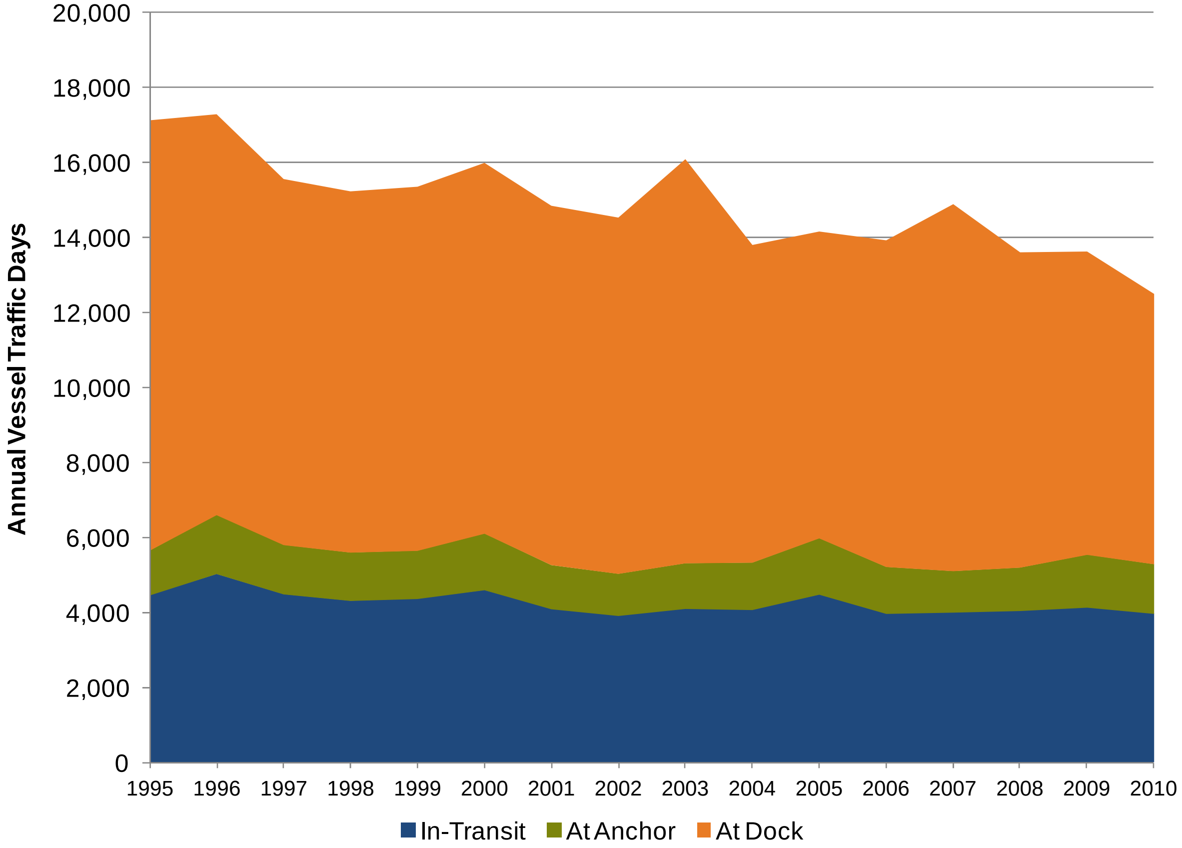
Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	1036.14	2846.98	447.78	5165.37	5106.86	531.47	1985.09
1996	1132.82	3235.63	467.96	4959.23	4507.85	615.82	2364.45
1997	977.85	2923.08	452.10	4481.88	4069.45	553.59	2097.66
1998	936.12	2840.06	440.01	4427.31	4033.33	528.75	2023.96
1999	930.16	2862.52	447.90	4448.66	4066.42	541.47	2055.69
2000	940.74	3050.74	456.23	4602.03	4095.37	583.80	2259.39
2001	837.08	2712.31	440.24	4360.59	4040.49	513.39	1939.25
2002	797.77	2617.71	431.53	4301.47	4028.60	491.45	1861.56
2003	833.32	2728.32	439.76	4874.12	4722.06	518.86	1968.61
2004	1630.16	2741.78	438.58	3913.94	3378.33	521.32	2001.77
2005	1689.63	3015.15	459.64	3868.82	3108.69	586.64	2270.83
2006	830.36	2675.29	426.02	4033.91	3529.07	522.11	1985.38
2007	756.60	2581.11	434.99	4500.14	4240.38	539.88	1834.36
2008	768.22	2561.09	428.99	3939.83	3246.43	546.01	2110.22
2009	786.08	2872.32	436.27	3763.27	3119.09	536.31	2111.58
2010	747.35	2797.03	422.37	3346.19	2675.76	516.43	1989.35

Figure 30. Other Vessel Days by Subarea, Average (1995–2010)



A large portion of other traffic days are spent at dock (Figure 31). This is a result of 'other' vessels which are homeported within the study area. For example, many of the ferries which operate as part of the Washington State Ferry System dock within the study area at night. In addition, several of the larger fishing vessels report long periods of time at dock in Bellingham or Anacortes. This results in a large number of vessel activity days at dock.

Figure 31. Other Vessel Traffic Days by Activity Type (1995–2010)



3.6 Data Sources and Methodology

To determine the number of traffic days that vessels spent by activity type in each of the study subareas, Northern Economics used data from the Washington Department of Ecology, the Marine Exchange of Puget Sound, and the United States and Canadian Coast Guards.

- **The Marine Exchange of Puget Sound** maintains a database of deep-draft, piloted vessel calls to Washington State Ports. It gathers information from numerous sources about projected vessel arrivals and then, also using a shore-based AIS network, monitors each vessel's movement activity through actual arrival, shifts, and ultimately departure. It can generate reports from its database, along with certain reports from the historical AIS data. The study obtained detailed MX data for the years 2006–2010, including information such as vessel name, type, size, commodity discharged, etc. We also obtained historic MX data for vessel deadweight tonnages from 1995–2010.
- **Near-Real Time (NRT) data,** like MX data, are derived from vessel AIS signals. However, in contrast to the MX data, NRT is the raw data format and is comparatively cumbersome and noisy. Vessels may emit signals as far as six minutes apart, or as close as 30 seconds apart; the database for recording these AIS signals is so large that there is a separate database file for each day of data. NRT data are subject to the quality of the information entered into the on-board AIS system, such as origin and destination.

Furthermore, data are captured by separate USCG and CCG Vessel Tracking Services; while the data from the two nations' systems are similar, they are not identical. For example, the Canadian data identify when a tug is towing, and whether or not the tow is laden or empty. The U.S. data do not provide information on tows. NRT data were available for 2007–2010, with the exception of two months in 2009 which were corrupt files and unavailable to the study team.

- **VEAT data,** available from the WADEC, capture one-way transits of tanker, cargo and passenger vessels 300 gross tons and larger through the Strait of Juan de Fuca. They also capture the movements of tank barges transporting oil or chemicals (of any tonnage) between two locations via Washington state waters (WADEC 2011). VEAT data were available for the length of the study period (1995–2010) and were used to determine historic traffic days. Activity type and subarea were estimated by combining VEAT statistics with more current and detailed MX data.
- **The USCG Anchorage Database** is a record of anchorage utilization by vessels within the Puget Sound anchorage reservation system. The anchorage data provided the names, dates, and lengths of stay for each vessel by anchorage.

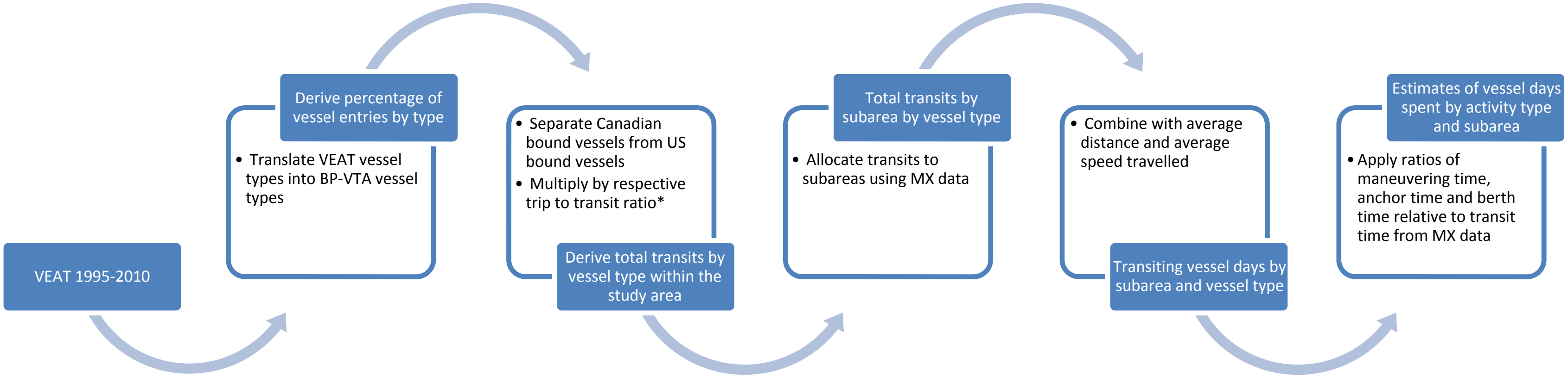
3.6.1 Tankers, Bulkers and Cargo Vessels

The study team began the traffic analysis with MX data, which provided information on piloted, deep-draft vessels, including tankers, bulkers and cargo vessels (both general cargo and container). The study team began by organizing MX vessel traffic data into grouped origin and destination (OD) pairs, and generalizing the routings between each OD pair. Routings were derived using samples of the NRT-data and information gained through interviews with local pilots and vessel captains. This process yielded estimates of vessel transit and at-dock days by subarea and type, for 2006–2010. It is estimated that there is approximately 2 hours of maneuvering time associated with each call to berth or anchor.

Time at anchor was estimated using the USCG anchorage database (discussed further in Section 3.6.2). The USCG anchorage database listed the time spent at anchor by deep-draft vessels in the study area. The anchorage database was available for the years 2006–2010. Based on these years, the study team derived an estimate of hours spent at anchor per every hour spent transiting a particular subarea.

Marine Exchange data were obtained for 2006–2010 only, NRT data were available for 2007–2010, and the aforementioned anchorage data were available from 2006–2010 only. To derive historical vessel activity days by subarea, the study team relied on the WADEC VEAT data. VEAT data are available for all non-forecast years covered by the study period (1995–2010). VEAT historic volumes were combined with transit and anchorage patterns seen in the MX, NRT and Anchorage data to derive time spent by activity type by subarea. The methodology used to parse the annual trip entries into specific activities and subareas is summarized in Figure 32.

Figure 32. Methodology for Deriving Historic Vessel Activity



*Trip to transit ratio is the average number of moves a vessel makes within the study area relative to each unique trip into the study area

3.6.2 Tank Barges

The study team relied heavily upon VEAT data for tank barge movements from 1995–2010. Tank barges are not included in the MX data, and NRT data only capture a portion of tank barge moves as the USCG does not record tow information; only the CCG compiled portion of the NRT data records tows. The VEAT data track tank barge transits, and define a transit as any significant move between two locations via Washington State waters while transporting oil or chemicals. The VEAT data provide annual loaded tank barge moves within the study area, but do not break out the locations of the moves.

To capture the proper number of transits by study area, the study team began by sampling the available NRT data. While tow data were spotty, the study team was able to identify movements of tugs that traditionally tow tank barges. Using 'oil tug' moves as a proxy for tank barge movements, the study team sampled the NRT data for the following:

1. Number of tank barge moves by subarea;
2. Number of tank barge moves in South Puget Sound relative to the rest of the study area;
3. Average number of transits through subareas per unique trip in the study area.

Using the above, the study team subtracted the portion of tank barge movements which are south-Puget Sound specific (31 percent), doubled the number of VEAT tank barge moves (to account for unloaded moves), and multiplied the resulting number of trips by 1.65 (transit to trip ratio) to obtain the total number of transits. These transits were then allocated to subareas based on the patterns seen in the NRT data.[5]

3.6.3 Other Vessels

Other vessel data were obtained from a wide variety of sources. In this section we describe the data and methodology used for tugs, passenger vessels and large fishing vessels independently.

Tugs

Tug transits (both oil and non-oil) were estimated using the NRT data. The study team sampled major transit lanes in each subarea for a count of unique tug trip IDs. These transits were then organized by OD pair to get both a count of dockings in each subarea as well as an estimate of distance travelled in each subarea.

For example, in 2010, the sampled NRT data show 348 tug transits in Rosario Straits for tugs reporting a trip between Puget Sound and Alaska. The portion of Rosario sampled is shown below in Figure 33.

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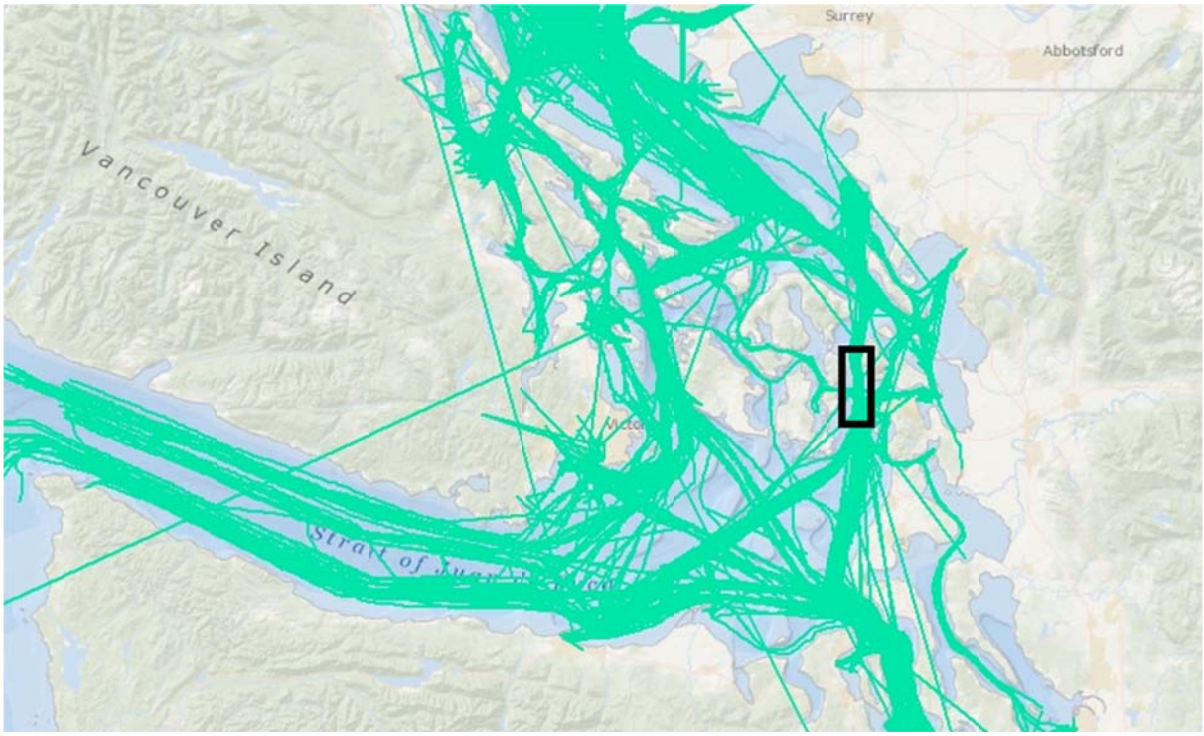
[5] Juan de Fuca West (8%), Juan de Fuca East (26%), Haro Strait-Boundary Pass (3%), Guemes Channel (8%), Saddle Bag (8%), Rosario Strait (23%), Cherry Point (29%)

Figure 33. Rosario Strait Tug Transit Sample Region



The transit associated with this OD pair is a distance of approximately 19.5 miles in Rosario Strait. At an average speed of 8.2 nautical miles per hour,[6] these transits account for 828 hours or 34.5 traffic days. Since both the origin and destination points of these transits are outside of the study area, no at-dock or maneuvering time is associated with these moves.

Passenger Vessels

Passenger vessels are comprised of cruise vessels and ferries. For the purpose of this analysis, only piloted, deep draft cruise vessels and ferries operating on regular schedules are included. Local sight-seeing boats and charter cruises are not included as their routes and frequency of travel vary significantly from year to year.

The MX data provide counts of piloted, deep draft cruise vessels calling at Washington ports; in addition to vessels calling at Washington ports, many cruise vessels calling at Canadian ports such as Vancouver, B.C. transit through the study area. Cruise vessels calling in Canada directly were estimated using counts from Port Metro Vancouver. Vessels which call at a Washington port before calling at Port Metro Vancouver were backed out of the analysis to avoid double counting.

The major ferry services operating within the study area are the Washington State Ferry, the AMHS, the B.C. Ferry, and several privately owned firms such as Black Ball, Guemes Island Ferry, Puget Sound Express, San Juan Cruises and the Victoria Clipper. The study team estimated transit time by subarea using historic estimates of annual trips, trip distance within the study area, and

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[6] Per tested NRT data this is the average speed of tugs travelling in Rosario Strait.

average speed (NRT data). In addition, the study team contacted local ferry providers to determine which vessels are docked in the study area when they are not operating. According to our estimates, a total of 10 ferries are docked in Juan de Fuca East, Haro Strait-Boundary Pass, Guemes Channel, Cherry Point and Saddle Bag. Rosario Strait and Juan de Fuca West are the only subareas in which a ferry is not docked.

Fishing Vessels

Transits of large fishing vessels (> 60′) through the study area from 1995–2010 were estimated in two Phases: 1) Fishing vessels registered to Puget Sound-based individuals and companies that are operating primarily in Alaska; and 2) Fishing vessels registered to Puget Sound residents that are permitted to operate in trawl and longline groundfish fisheries on the West Coast. In general it is assumed that large fishing vessels did not undertake harvesting activities within Puget Sound or the Strait of Juan de Fuca.

Large Alaska Fishing Vessels Registered Puget Sound Entities

Transits of large fishing vessels owned by Puget Sound entities but operating in Alaska were estimated using published reports and data from the Alaska Fishery Science Center of the National Marine Fisheries Service (NMFS-AFSC),[7] data from the Alaska Commercial Fishing Entry Commission (CFEC),[8] and a set of fishing vessel profiles developed by Northern Economics for the North Pacific Fishery Management Council (NPFMC),[9] along with discussions with industry representatives and the personal experience and expertise of the analysts.

The primary supposition with respect to these vessels is that, with only few exceptions, the vessels return to Puget Sound only when necessary for shipyard work. In other words, they spend most of their time in Alaska waters, and their only transits through the study area occur when they are travelling from Alaska to their shipyard or when they are travelling from the shipyards to Alaska. It is also assumed that all shipyards are located in Southern Puget Sound, and that when making the transit, vessels travel west of Vancouver Island and through the Strait of Juan de Fuca.

The Alaska fishing vessels were divided into seven groups as listed below. For each group we estimated the number of active vessels by year, and make assumptions about the frequency of shipyard work and the likely time of transits. We note that there are a small number of vessels that participate in the offshore trawl fishery for Pacific whiting that operate off the coasts of Washington and Oregon in the spring and occasionally early summer, and that additional transits because of these activities have been added.

1) **Motherships:** These vessels process (but do not harvest) Alaska pollock and Pacific whiting and operate almost exclusively in the open ocean. The vessels range from 300′–635′. Because they participate both in Alaska and in the Pacific whiting fishery they make two round-trip transits each year through the study area.

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[7] Hiatt, Terry, et al. 2012.

[8] CFEC 2012.

[9] Northern Economics, Inc. 2001.

2) **Floating Processors:** These vessels process primarily salmon and crab in nearshore waters and range from 200′–300′. It is assumed that these vessels make a one round-trip transit for shipyard work every two-years.
3) **Trawl Catcher Processors (CPs):** These vessels range from 125′ – 300′ and harvest pollock, flatfish and Atka Mackerel using trawl gear and process their harvests on board. They will on occasion also act as motherships by taking deliveries from other harvesters, and a few also participate in the Pacific whiting fishery on the West coast. It is assumed that on average two-thirds of these make a round-trip transit during the year.
4) **Trawl Catcher Vessels (CVs):** These vessels use trawl gear to harvest groundfish, primarily pollock, but the smaller vessels will also harvest Pacific cod and flatfish. Vessels range generally from 70′–200′. A few of the vessels also participate in the West coast Pacific whiting fishery. On average it is assumed that these vessels make one round trip between Alaska and the Puget Sound every two years.
5) **Crab CVs and CPs:** These vessels use pot gear to harvest crab in the Bering Sea and Aleutian Islands. These vessels range generally from 80′–185′ with a few that not only harvest but also process their catch. In an average year it is assumed that 50 percent of these vessels make a round-trip transit between Alaska and Puget Sound. Most of these transit for shipyard work, but some of the vessels also participate in the West Coast Dungeness crab fishery.
6) **Longline CPs:** These vessels use longline gear to harvest primarily Pacific cod and sablefish, and then process their catch on-board. In general they range from 100′–185′ with a few that are smaller. On average it is assumed that these vessels make one round trip between Alaska and the Puget Sound every two years.
7) **Longline CVs:** These vessels use longline gear to harvest primarily sablefish and halibut and range from 60′–90′. In an average year it is assumed that 50 percent of these vessels make a round-trip transit between Alaska and Puget Sound for shipyard work or to participate in the sablefish fishery on the West coast.

Large West-Coast Fishing Vessels Registered to Puget Sound Entities.

The second group of large fishing vessels operate in the Limited Entry (L.E.) groundfish fishery on the West Coast. The primary source of data for these vessels is the "*History of L.E. Permits*" available online from the Northwest Regional Office of National Marine Fisheries Service (NMFS-NWR).

The limited entry permit data for the years 1995–2011 were filtered for vessels > 60′, and organized to show vessels by length class, permitted gears and the owner's region of residence. Vessels that had already been counted as "Alaskan" fishing vessels were excluded. The following assumptions were made for the remaining vessels.

- Trawl vessels from 60′–89′ were assumed to make eight round-trips to the coast per year. On average from 1995–2011 there were 9.9 permitted vessels, but only 5 vessels in 2011.
- Vessels with both trawl and fixed gear from 60′–89′ were assumed to make 12 round-trips to the coast per year. On average from 1995–2011 there were 0.5 permitted vessels, but there were 3 vessels in 2011

- Fixed Gear vessels from 60′–89′ were assumed to make eight round-trips to the coast per year. On average from 1995–2011 there were 12.5 permitted vessels, but only 6 vessels in 2011.
- Fixed Gear Only 90′–150′ were assumed to make 12 round-trips to the coast per year. On average from 1995–2011 there were 1.5 permitted vessels, but in 2011 there were no permitted vessels in this group.

4 Anchorages

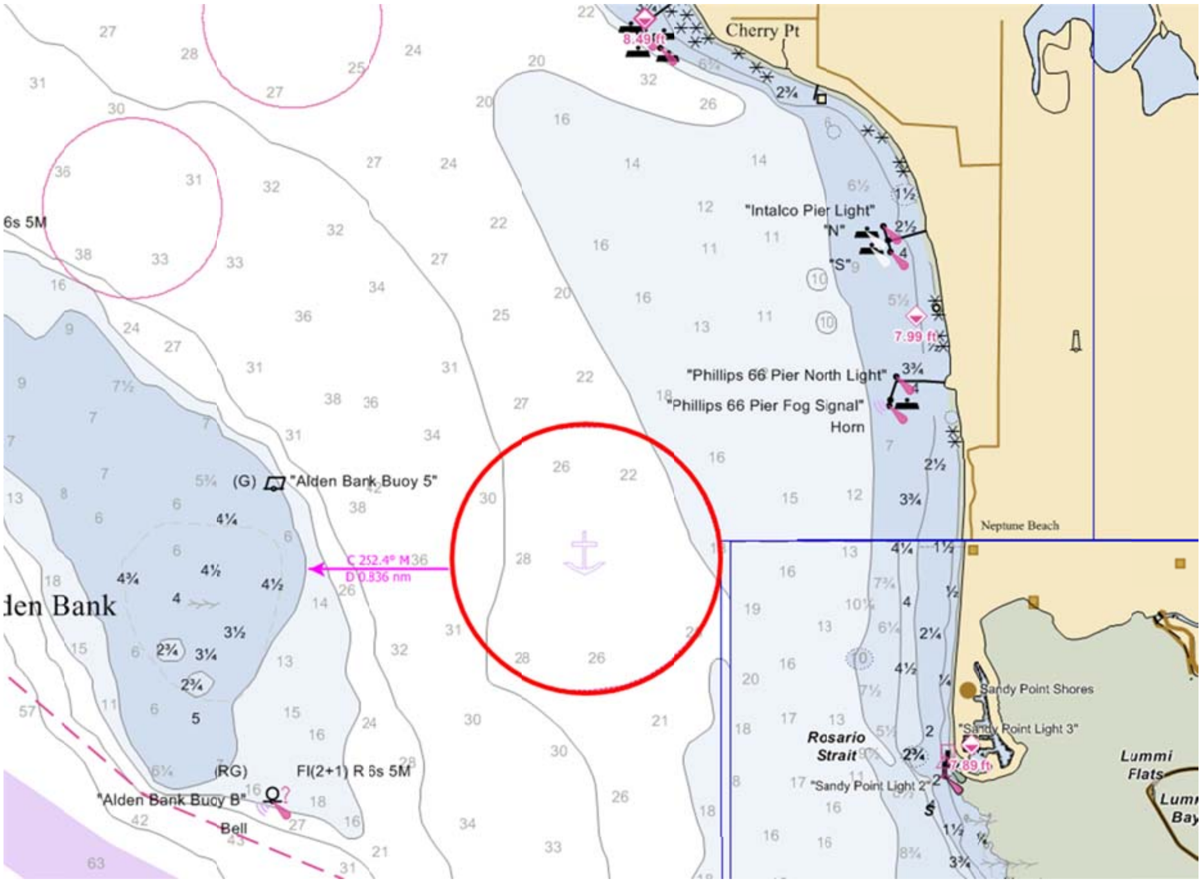
4.1 Current Anchorage Locations and Usage

The following section is divided into study subareas. Each section describes the relevant anchorages within the particular subarea, including both physical conditions and their current patterns of use.

4.1.1 Cherry Point

Cherry Point General Anchorage is managed by Vessel Traffic Service (VTS) Puget Sound on behalf of Sector Seattle and the Captain of the Port (COTP) Puget Sound. The Cherry Point General Anchorage encompasses waters within a circular area with a radius of 0.8 nautical miles (nm), having its center at 48°48'30"N., 122°46'00"W. This general anchorage will accommodate one (1) ship with a maximum stay of 30 days.

Figure 34. Cherry Point Anchorage

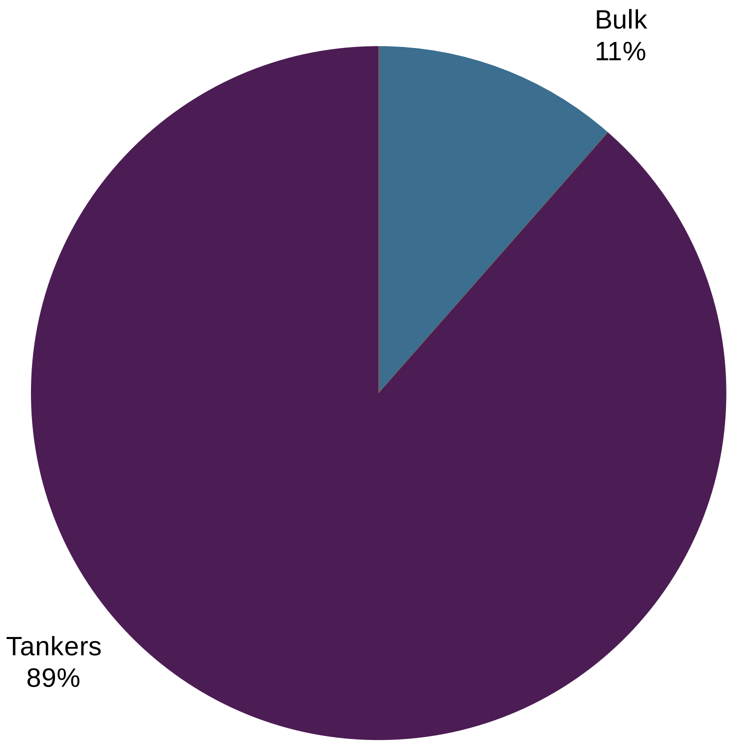


The western edge of the Cherry Point anchorage is 0.9 nm east of Alden Bank and is exposed to all wind and seas except from the East-Northeasterly quadrant (Figure 34). In the open waters of Georgia Strait, winds are usually either northwesterlies (17.6 percent of the time) or southeasterlies (32.5 percent of the time). Winds from the Southerly quadrant occur more in the winter months from October through March and can reach speeds in excess of 45 knots (Figure 39 through Figure 42); the anchorage is generally undesirable for use during this period.

Cherry Point anchorage is best suited for summer use (May–September) following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (April 2012). The Cherry Point anchorage bottom consists of primarily mud, sand, and shells, and offers a fair holding ground in good weather. In summer, winds in the Rosario and Haro Straits are usually southwesterlies. Summer breezes are variable and baffling in the San Juan Islands. Gales are uncommon, particularly in mid-summer, when storm activity diminishes. (NOAA 2012Aa).

The two types of vessels currently anchoring at Cherry Point are tankers and bulk vessels (Figure 35). Tankers include both crude and product vessels destined for the Cherry Point and Ferndale refineries. Bulk vessels are typically those calling at the Alcoa Intalco Works at Ferndale for alumina shipments.

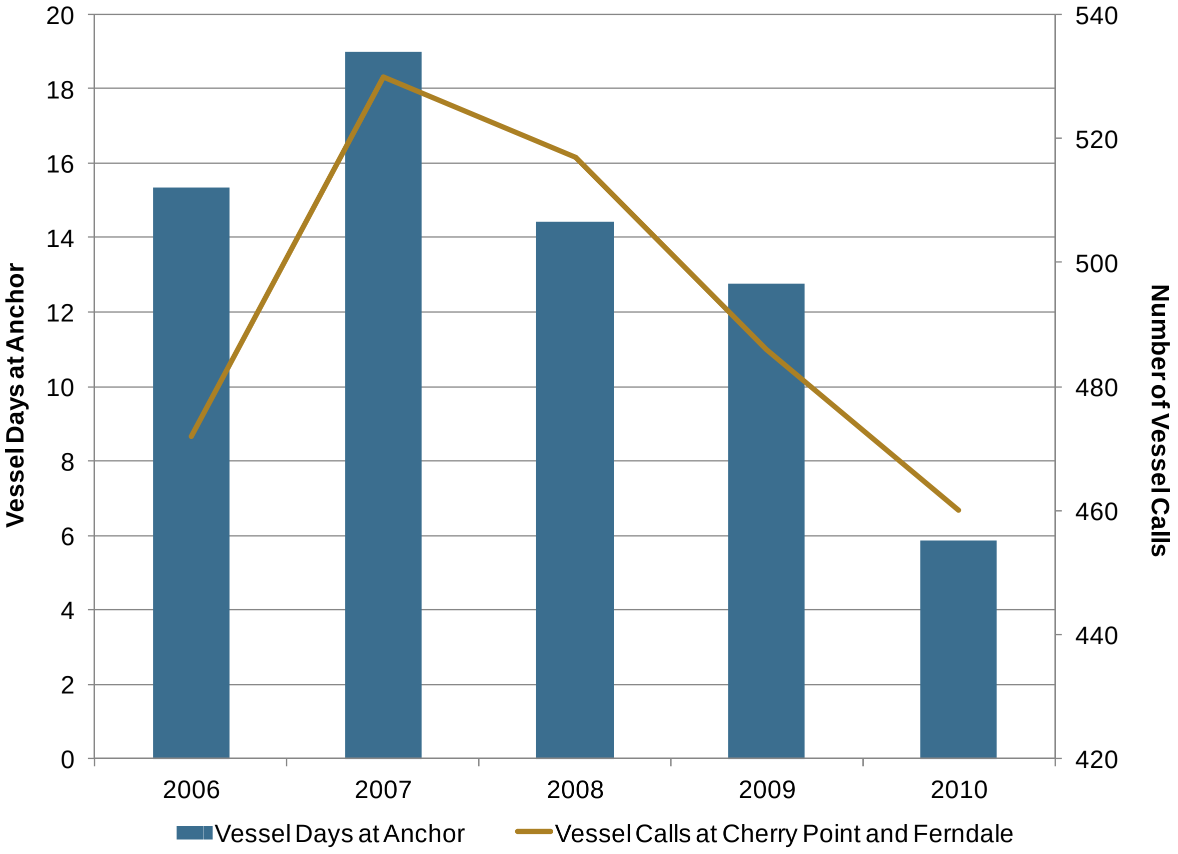
Figure 35. Use of Cherry Point Anchorage by Vessel Type, 2006–2010



Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

From 2006–2010, annual vessel traffic days at the Cherry Point Anchorage declined from a high of 19 in 2007 to a low of 6 in 2010. This trend follows a corresponding drop in vessel calls to Cherry Point and Ferndale docks from a high of 530 in 2007 to a low of 460 in 2010 (Figure 36).

Figure 36. Vessel Traffic Days at Anchor and Vessel Calls, Cherry Point Subarea (2006–2010)



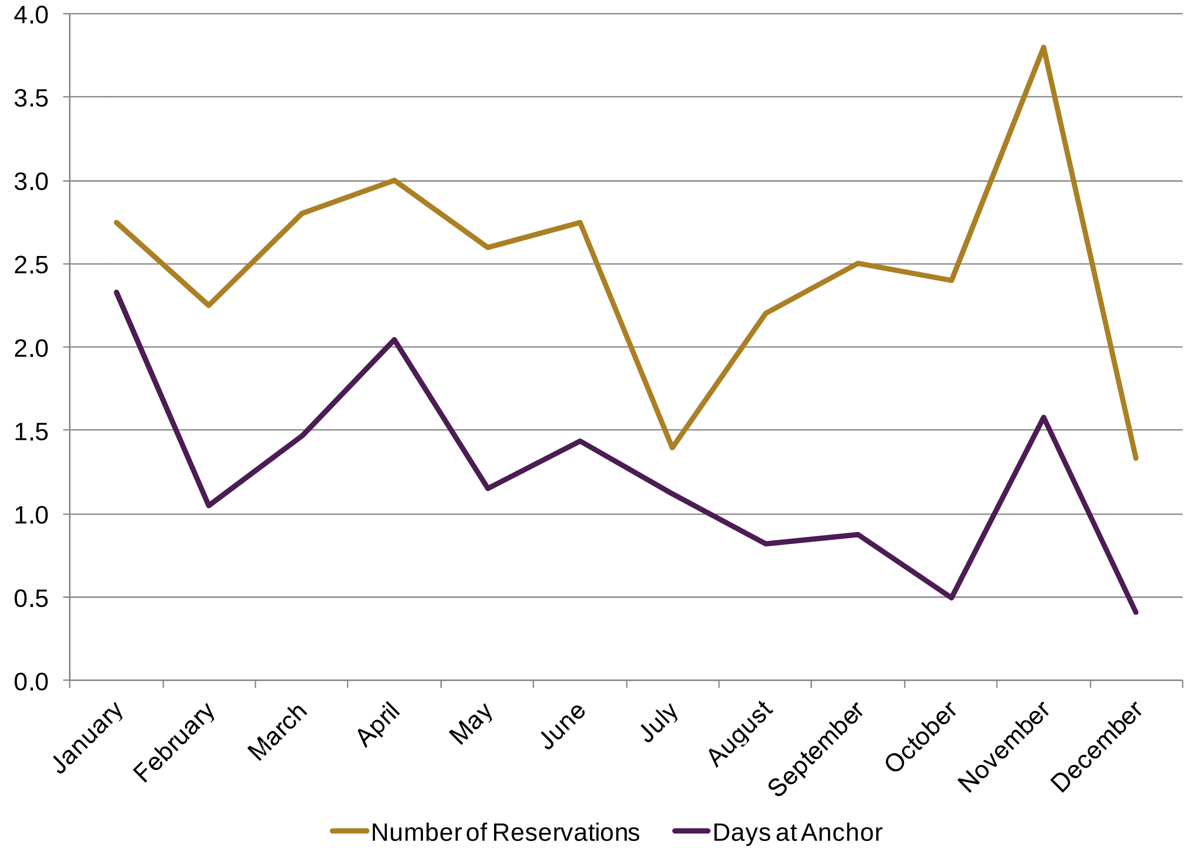
Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

Cherry Point is typically used as a short-term anchorage. As previously noted, the anchorage can accommodate only one vessel at a time, and is often exposed to harsh wind in the winter.

Figure 37 illustrates both the average number of days at anchor and the average number of monthly reservations as reported by the USCG database. By dividing the number of days at anchor by the number of reservations for any given month, it is possible to derive the average stay at anchor per vessel. On average, vessels anchor at Cherry Point for only 12 hours (0.5 traffic days) over the course of a year.

The number of monthly reservations at the Cherry Point Anchorage peaks in November. July and December are typically months of low reservation counts. The pattern of days at anchor is similar to that of reservations in that November is also the peak month for vessel time at anchor. In contrast to the reservation count, however, the data shows that the fewest traffic days at anchor occurs in October and December—which each have an average of half of one vessel day over the five years included in our analysis.

Figure 37. Average Number of Reservations and Vessel Traffic Days at Cherry Point Anchorage, by Month (2006–2010)



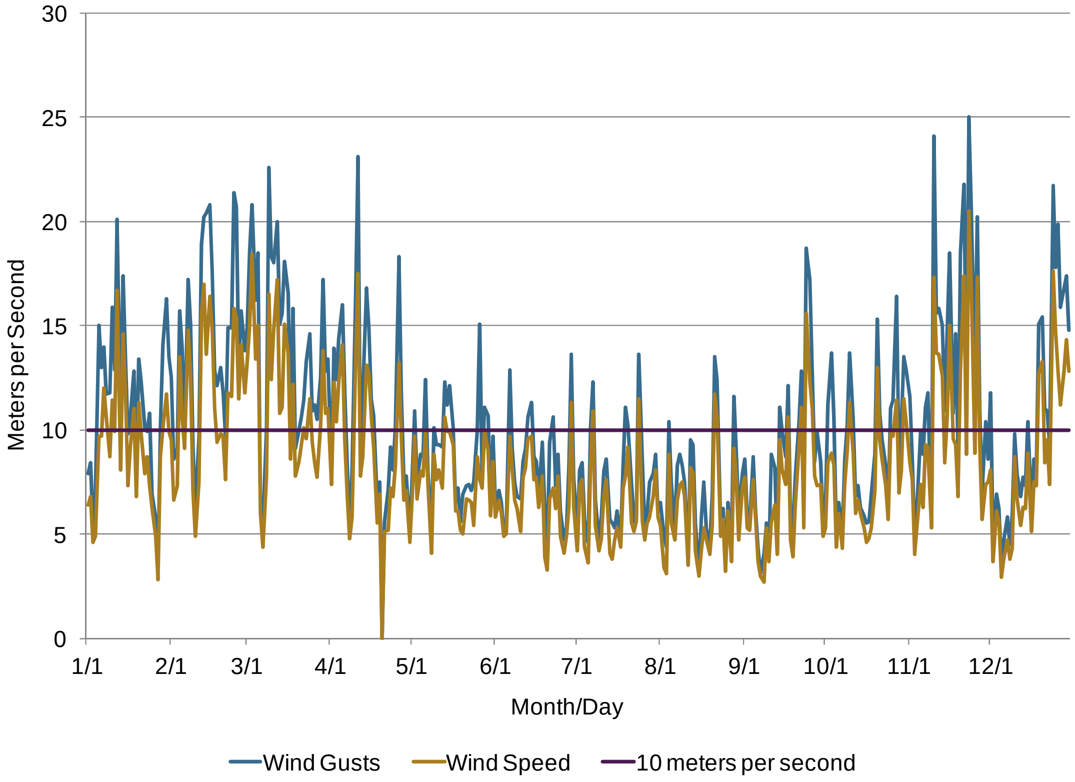
Source: Northern Economics, Inc. using USCG 2012

This means that while fewer vessels call at the anchorage in the summer months, the vessels that do call tend to stay longer than those which call in the winter. This is consistent with the study team's overview of anchorage suitability, which notes that winds in the winter months (October through March) make the anchorage less desirable.

On an annual basis, records of anchorage use in Cherry Point tell us that between 2006 and 2010, an average of 13.5 traffic days is spent at anchor. Cherry Point Anchorage can accommodate only one vessel at a time; assuming there are 365 traffic days available for use, Cherry Point Anchorage is used only 3.6 percent of the time.

It should be noted that total possible anchor time and actual available time differ significantly for Cherry Point. According to local pilots, weather in the Cherry Point area frequently prevents use of the anchorage. Figure 38 shows maximum daily recorded gusts and wind speeds at Cherry Point in 2011, and shows that for a considerable portion of the year, daily winds blow in excess of 10 meters per second, or about 20 knots.

Figure 38. Daily Wind Speed at Cherry Point, 2011



Source: Northern Economics Inc. using NOAA 2012b

According to NOAA records, maximum wind speeds (not including gusts) at Cherry Point were in excess of 10 meters per second for 93 days in 2011, or 26 percent of the year. Adjusting for this factor (i.e. subtracting these 93 days from total days the anchorage is available) increases actual use of the anchorage to five percent between 2006 and 2010 (13.5 traffic days divided by 272 available days). In addition, factors such as lack of protection from wind and seas paired with poor holding ground also limit use of the anchorage.

4.1.2 Saddlebag: Bellingham Bay and Vendovi Island

Bellingham Bay and Vendovi Island[10] are the two anchorages located within the Saddlebag subarea.

The Bellingham Bay General Anchorage is capable of accommodating up to six ships for a period of 30 days and is managed by VTS Puget Sound on behalf of Sector Seattle and the COTP Puget Sound. The predominant weather pattern for most of the year in that area are Southerly winds occurring 40 percent of the time with speeds of 20 knots or less making up about one-half that amount. The strongest winds occur during the winter months (December-March) when the Southerly winds above 20 knots occur 1.3 percent of the time. Bellingham Bay lays in the

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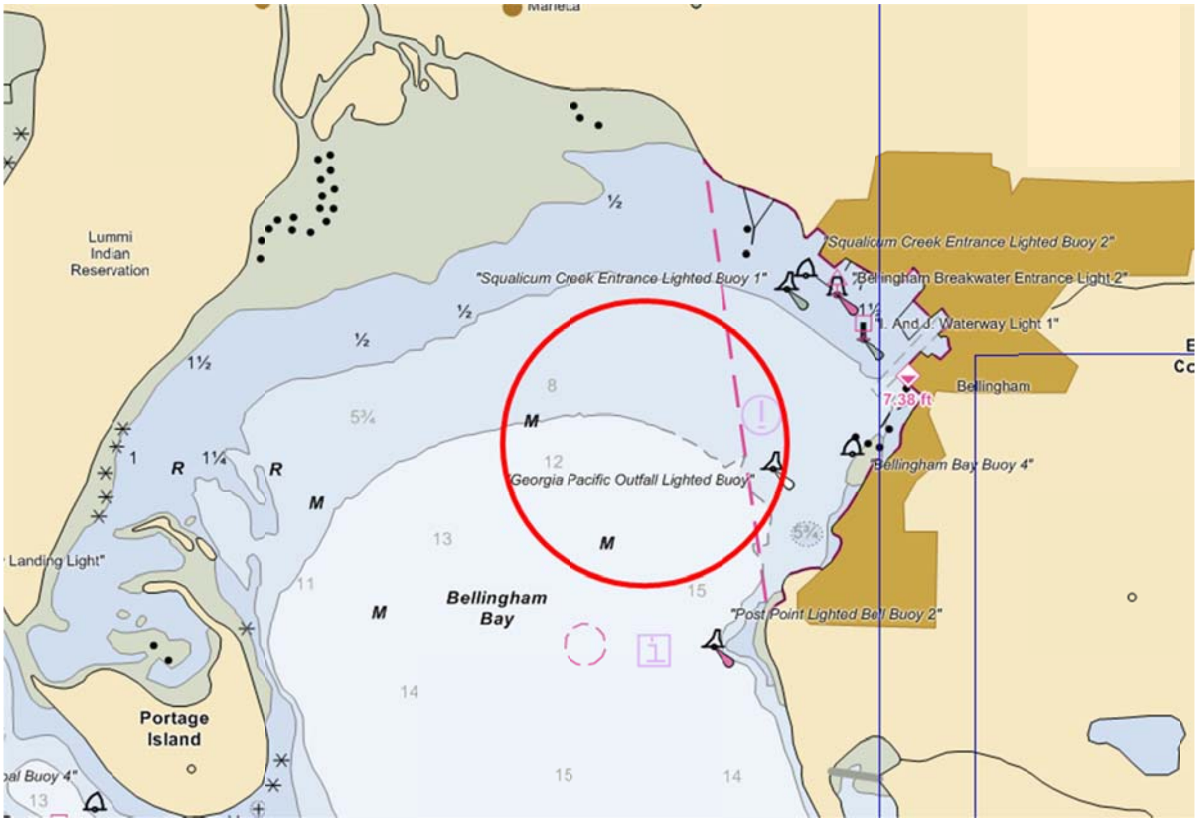
[10] Vendovi Island East and Vendovi Island South are separate anchorages, however, the USCG database does not distinguish between the two; consequently we look at them collectively as ‘Vendovi Island’.

North/South direction and thus allows winds from the South the greatest fetch into the Bay. Anchorage may be obtained almost anywhere in the bay south of the flats; the depths, over the greater portion, range from 6 to 15 fathoms. Because of the mud bottom, vessels are apt to drag anchor in heavy weather. The bottom in the anchorage is a thin accumulation over hardpan, and is not good holding ground in heavy weather (NOAA 2012A).

The Bellingham Bay General Anchorage encompasses waters of Bellingham Bay within a circular area with a radius of 2,000 yards, having its center at 48°44'15", 122°32'25" (Figure 39).

Figure 39. Bellingham Bay Anchorage



The Vendovi Island South Anchorage (VIS) is an area directly south of Vendovi Island; it is the width of the island and extends into the waterway about half the distance to Jack Island (.75 nm) (Figure 40). The depths in the anchorage range from 35 fathoms in the north near the Island, to 16 fathoms at the southern end. There is good holding ground for anchoring ships with a shell and pebble bottom.

The southern anchorage area is well protected by the nearby land masses of Guemes Island to the south, Cypress and Sinclair Islands to the west, and Blanchard to the east, and is out of the way of vessels transiting Bellingham and Padilla Bays. The anchorage is suited for year around use following the Anchoring Standards of Care established in the Puget Sound Harbor Safety Committee's *Puget Sound Harbor Safety Plan* (PSHSC 2012).

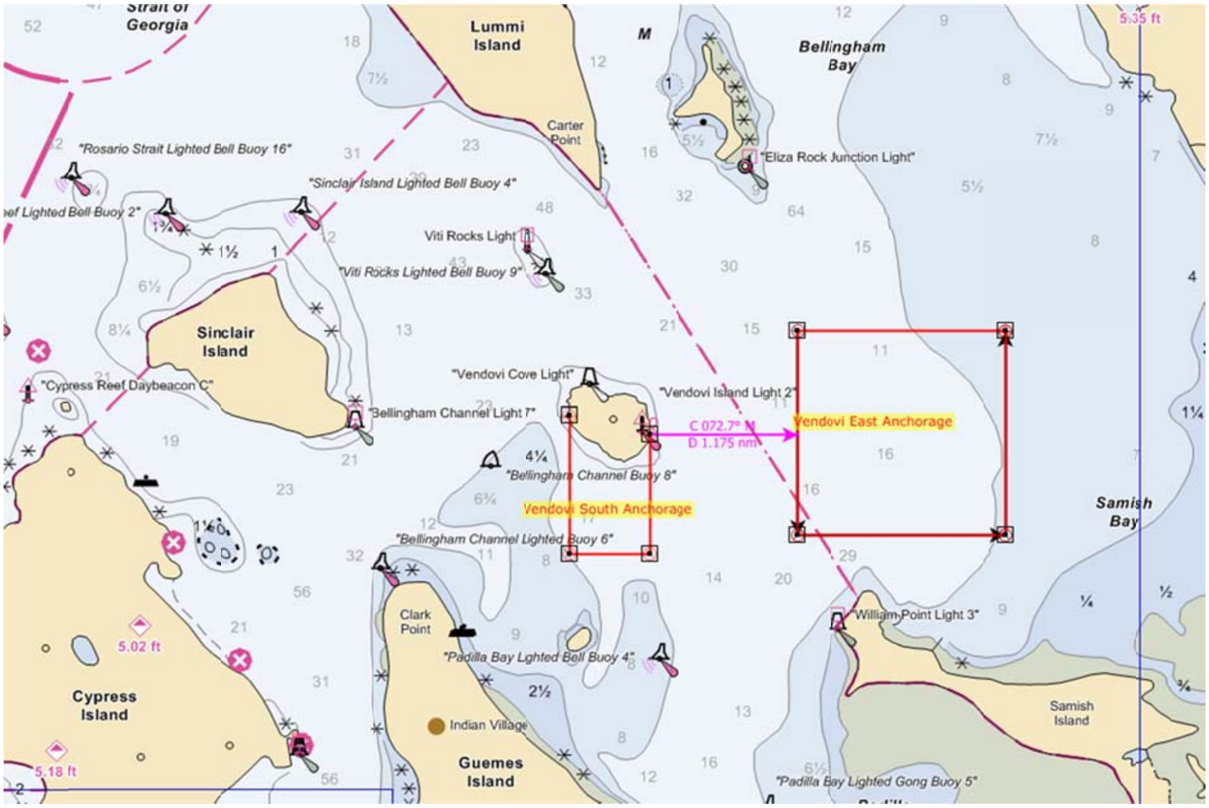
The VIS encompasses all waters shoreward of a line beginning at 48°36′40″N, 122°36′51″W; thence to 48°35′34″N, 122°36′51″W; thence to 48°35′34″N, 122°35′53.62″W; thence to

48°36′31.38″N, 122°35′53.62″W. This general anchorage will accommodate one ship with a maximum stay of 10 days and is managed by VTS Puget Sound on behalf of Sector Seattle and the COTP Puget Sound. The Vendovi Anchorages are mainly used by tanker traffic waiting for a berth at one of the nearby refineries.

The Vendovi Island East Anchorage (VIE) lies 1.17 nm east of Vendovi Island near Samish Bay. Depths in the anchorage range between 8 fathoms in the north east to 23 fathoms in the southwest corners. The bottom consists of primarily mud with some mud and shells in the southwest corner and offers suitable holding ground. The anchorage is generally protected by land mass in all but the northern quadrant where almost ten miles of fetch from Bellingham Bay exists. The anchorage is well-suited for year around use following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (PSHSC 2012) and can accommodate four ships for a period of up to 10 days.

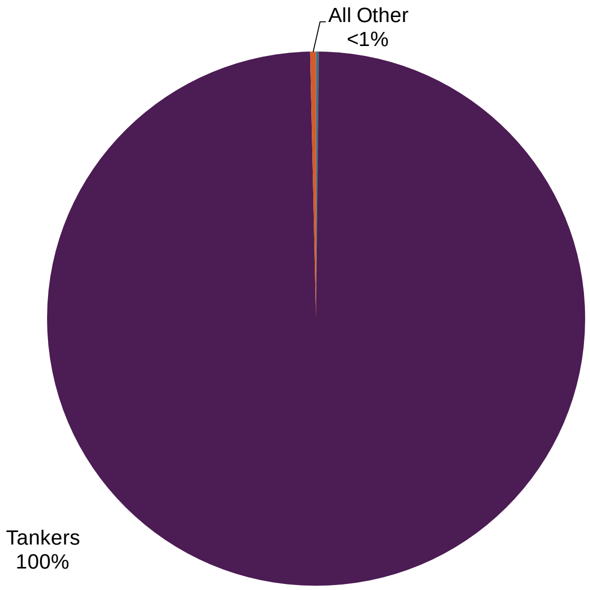
The VIE encompasses all waters in an area beginning at 48°37′20″N, 122°34′07″W; thence to 48°37′20″N, 122°31′37″W; thence to 48°35′43″N,122°31′37″W; thence to 48°35′43″N, 122°34′07″W; thence to point of origin.

Figure 40. Vendovi Island Anchorages



The Saddlebag anchorages are used almost exclusively by tanker vessels (Figure 41). Vendovi Island is used by crude and product tankers while Bellingham Bay is used by ATBs, which typically require a shallower anchoring depth.

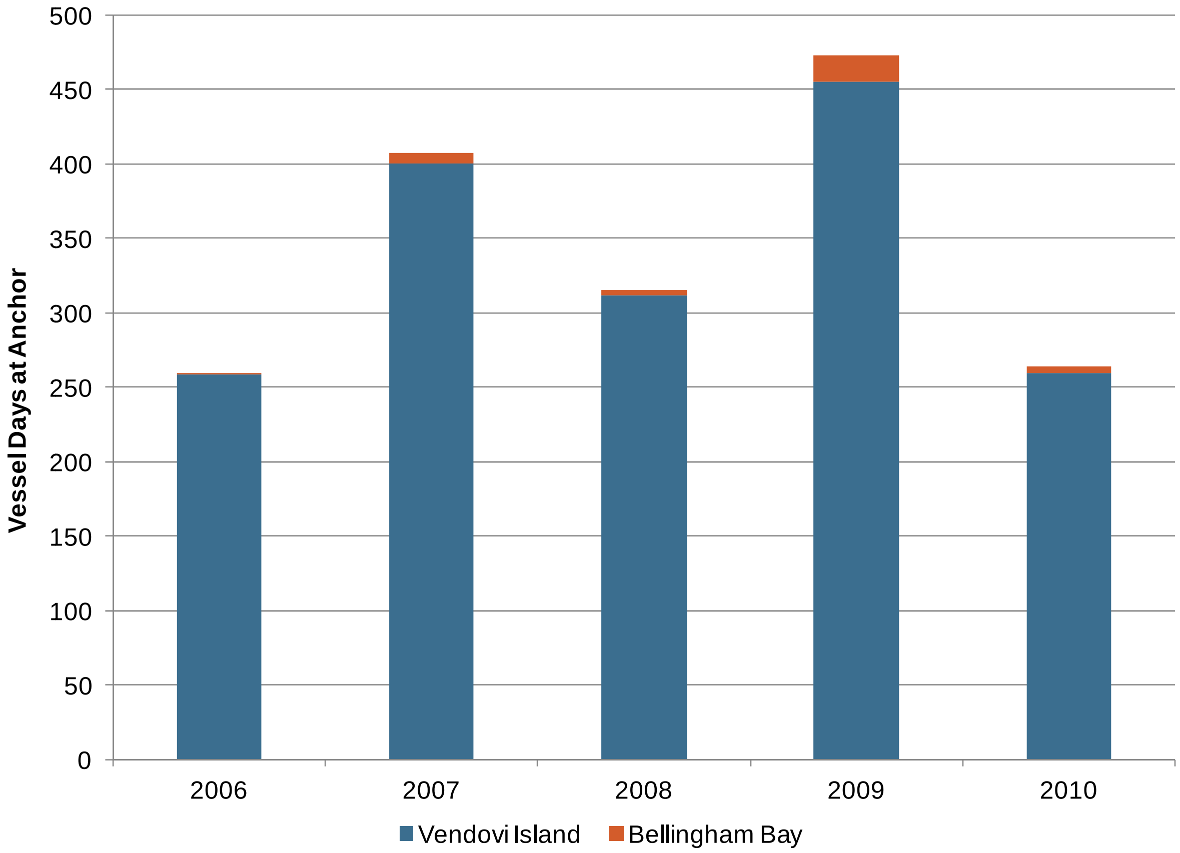
Figure 41. Use of Saddlebag Anchorages (Vendovi and Bellingham Bay) by Vessel Type, 2006–2010



Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

Bellingham Bay is the largest anchorage included in our analysis; with a 2,000 yard radius, it can accommodate up to six vessels at a time. However, while wide, the anchorage is shallower than most, ranging in depth from 6 to 15 fathoms. In addition, the anchorage's soft mud bottom makes it unsuitable for holding ground in heavy weather. Vendovi Island, which can accommodate up to five vessels at a time, has greater depths ranging from 8 to 35 fathoms. The benefits of using Vendovi Island are confirmed by the USCG database; Bellingham Bay accounts for only two percent of all days at anchor in Saddlebag over the five year period. Vendovi Island accounts for the remaining 98 percent (Figure 42).

Figure 42. Vessel Traffic Days at Anchor, Saddlebag Anchorages, 2006–2010

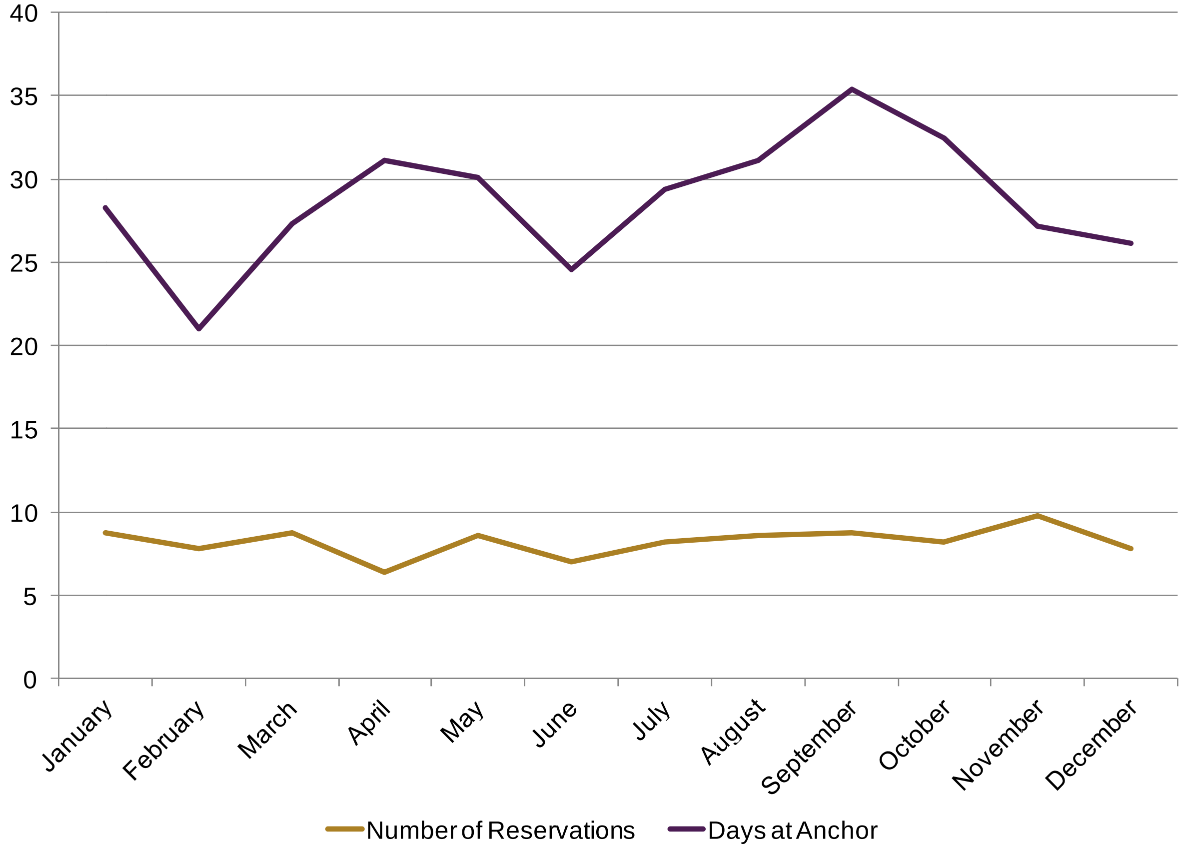


Source: Northern Economics, Inc. using USCG 2012

Our data show that the majority of traffic at Vendovi Island anchorage is related to activity in the Cherry Point subarea. Of the vessels anchored at Vendovi Island between 2006 and 2010, approximately 36 percent recorded their last port of call as Cherry Point or Ferndale, and 74 percent recorded their next port of call as Cherry Point or Ferndale. Note that many vessel trips show both last port and next port as Cherry Point; these vessels shifted from Cherry Point to anchor at Vendovi Island, then returned. Several factors can account for these moves including wind and wave conditions at the docks, and the refineries' needs to adjust the flow of crude oil and petroleum products through their facilities.

Reservations at the Saddlebag anchorages remain consistent throughout the year, averaging between 6 and 10 each month. Traffic days at anchor show greater variation, with peaks in the spring and fall accompanied by dips in the winter and summer (Figure 43). On average, vessels at the Saddlebag anchorages spend 3.5 days at anchor; this is nearly seven times the amount of time spent at the Cherry Point anchorage.

Figure 43. Average Number of Reservations and Vessel Traffic Days at Saddlebag Anchorages, by Month
(2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Between 2006 and 2010, a total of 494 reservations were made at Saddlebag anchorages; these vessels spent a total of 1,719 days at anchor. When averaged out, annual days at anchor are estimated at 344. As previously noted, Bellingham Bay is not suitable for most deep-draft vessels anchoring in the study area, and accounts for only a small fraction of the Saddlebag traffic days at anchor. To have a more accurate gauge of anchorage availability, the Bellingham Bay days at anchor are removed from the total, leaving an annual average of 337. Assuming that Vendovi Island anchorages are accessible 365 days a year, average anchorage use is approximately 18 percent.

4.1.3 Guemes Channel: Anacortes

Guemes Channel anchorages are comprised of Anacortes East, Anacortes Center, and Anacortes West. The Coast Guard established these three general anchorages on June 2, 2005, to reduce the risk of collisions, provide a more orderly movement of tanker traffic in and out of nearby oil refineries, and keep the approaches to Guemes Channel open to transiting traffic.

These three general anchorage areas are located North of March Point and will accommodate one ship each for a period of 10 days. They are managed by VTS Puget Sound on behalf of Sector Seattle and the COTP Puget Sound. The anchorages are mainly used by tanker traffic waiting for a berth at one of the nearby refineries.

These anchorages lie east of Anacortes and southeast of Guemes Island and remain well protected from both Southerly and Northerly winds in the winter months. The anchorage is suited for year around use following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (PSHSC 2012).

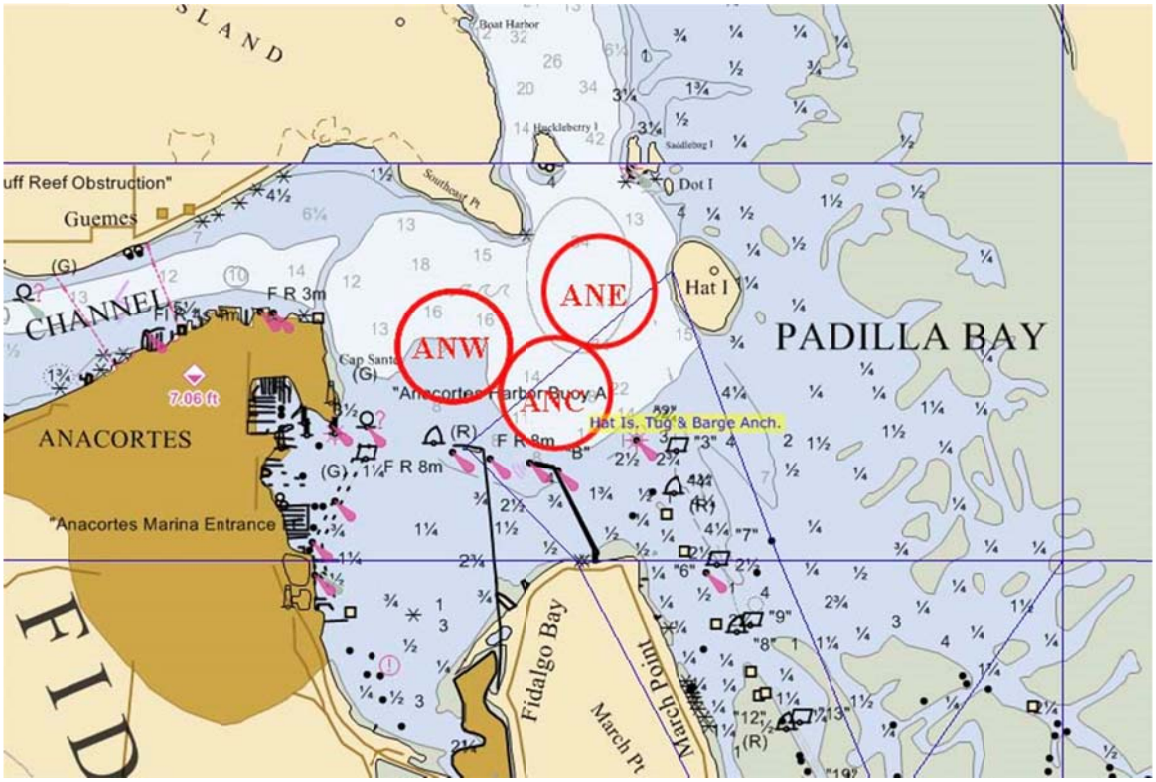
The holding ground consists mainly of a combination of sand with some shells; the bottom is more than adequate for an anchorage of this type.

Anacortes East Anchorage Area (ANE) encompasses the waters within a circular area with a radius of 600 yards, having its center at 48°31'27"N., 122°33'45"W. This general anchorage will accommodate one ship with a maximum stay of 10 days.

Anacortes Center Anchorage Area (ANC) encompasses the waters within a circular area with a radius of 600 yards, having its center at 48°30'54"N., 122°34'06"W. This general anchorage will accommodate one ship with a maximum stay of 10 days.

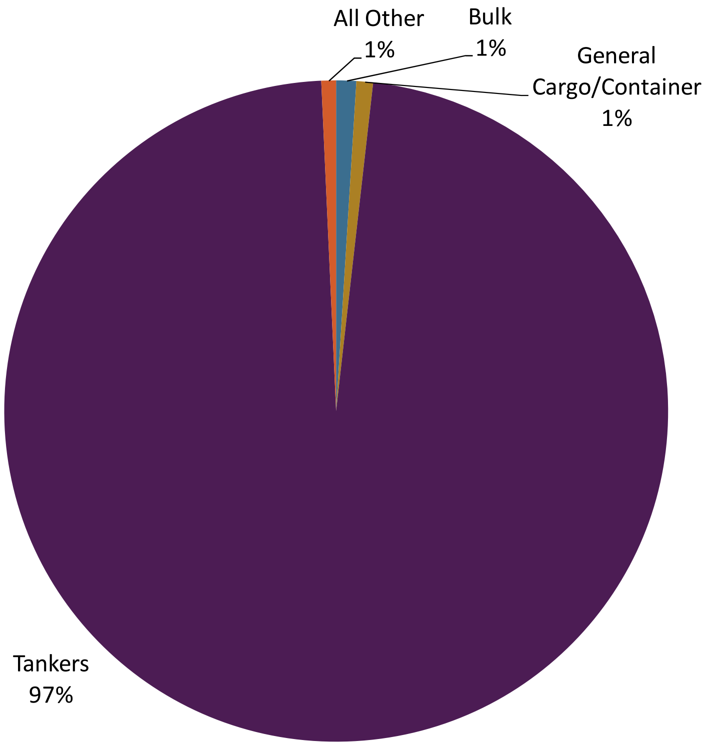
Anacortes West Anchorage Area (ANW) encompasses the waters within a circular area with a radius of 600 yards, having its center at 48°31'09"N., 122°34'55"W.

Figure 44. Anacortes Anchorages



While the majority of vessels using the Guemes Channel anchorages are tankers moving crude and petroleum products to and from local refineries, some bulk and general cargo vessels also make use of the Anacortes anchorages (Figure 45).

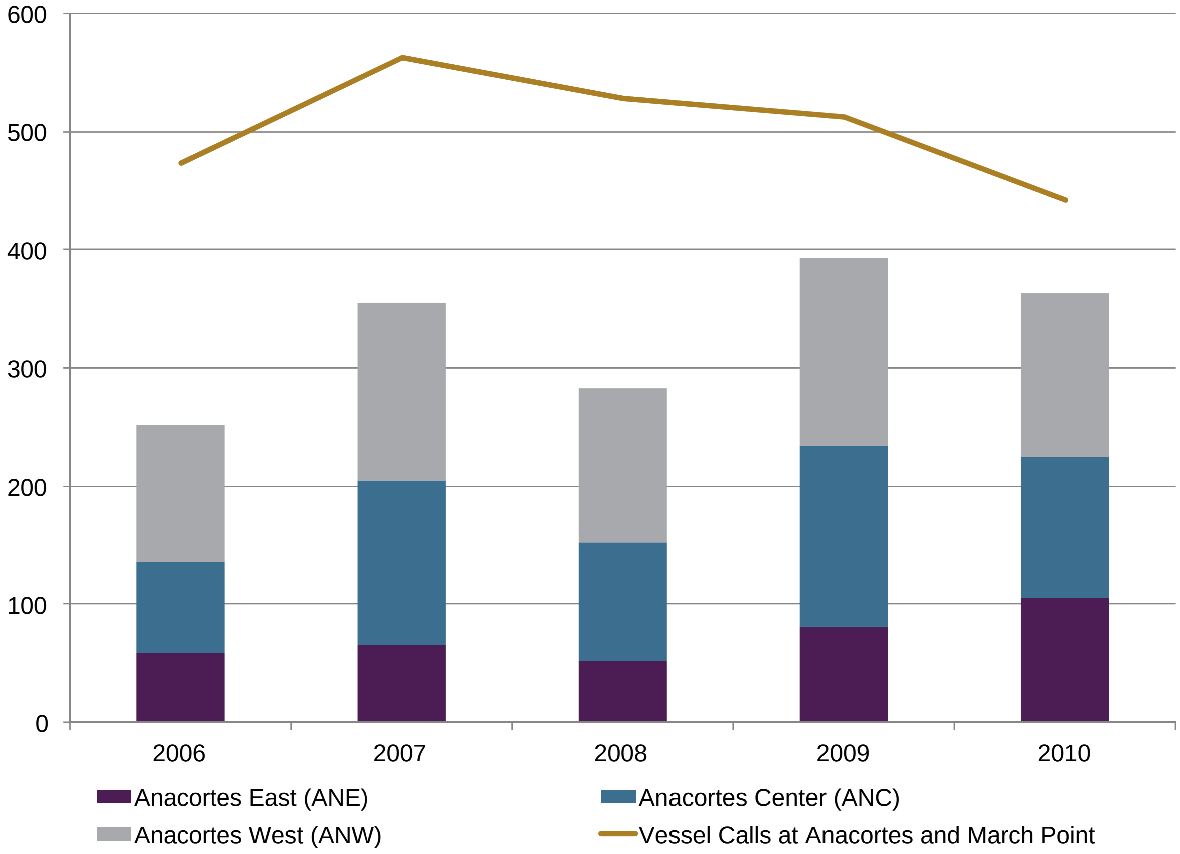
Figure 45. Use of Anacortes Anchorages by Vessel Type, 2006–2010



Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

The two main drivers of traffic at the Anacortes anchorage are the Anacortes and March Point refineries. Annual traffic days at anchor in Guemes Channel fluctuated between a low of 250 in 2006, to a high of nearly 400 in 2009. While not exactly in line with anchor days, vessel calls at the Anacortes and March Point Docks show a similar shift in magnitude, from a low of 442 in 2010 to a high of 562 in 2007 (Figure 46).

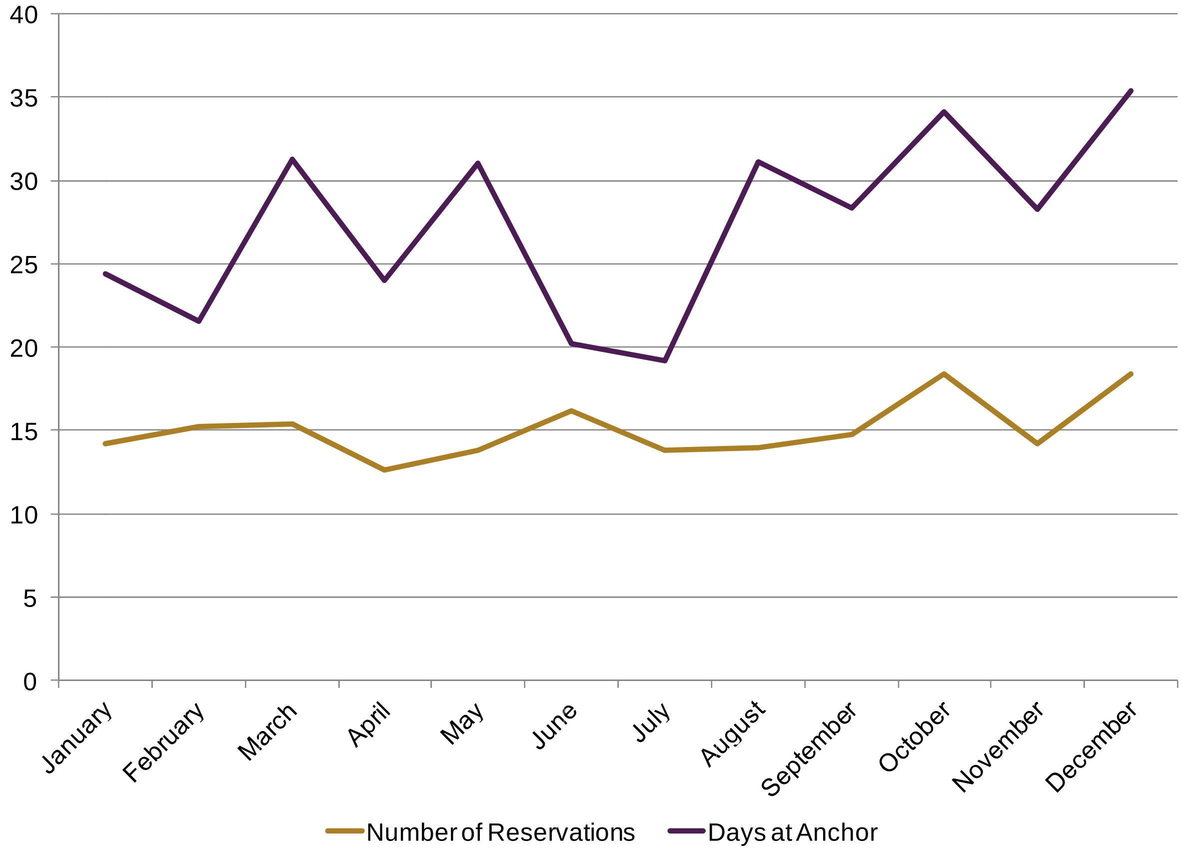
Figure 46. Vessel Traffic Days at Anchor and Vessel Calls, Guemes Channel Subarea (2006–2010)



Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

On a monthly basis, reservations at the Anacortes anchorages remain within a four reservations band, from a low of 14 to a high of 18. However, monthly days at anchor demonstrate greater volatility, spiking nearly every other month (Figure 47), and ranging from 19 days to 35 days.

Figure 47. Average Number of Reservations and Vessel Traffic Days at Guemes Channel Anchorages, by Month (2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Between 2006 and 2010, a total of 905 reservations were made at Guemes anchorages. These vessels spent a total of 1,644 hours at anchor. Annual days at anchor are estimated at 328; on average, each vessel spent 1.8 days at anchor.

Annual vessel traffic days at anchor in Guemes Channel are similar when compared to vessel traffic days at Saddlebag anchorages. However, it should be noted that nearly twice the number of reservations are made in Guemes, but that vessels stay at anchor in Guemes nearly half the amount of time that they spend in Saddlebag anchorages.

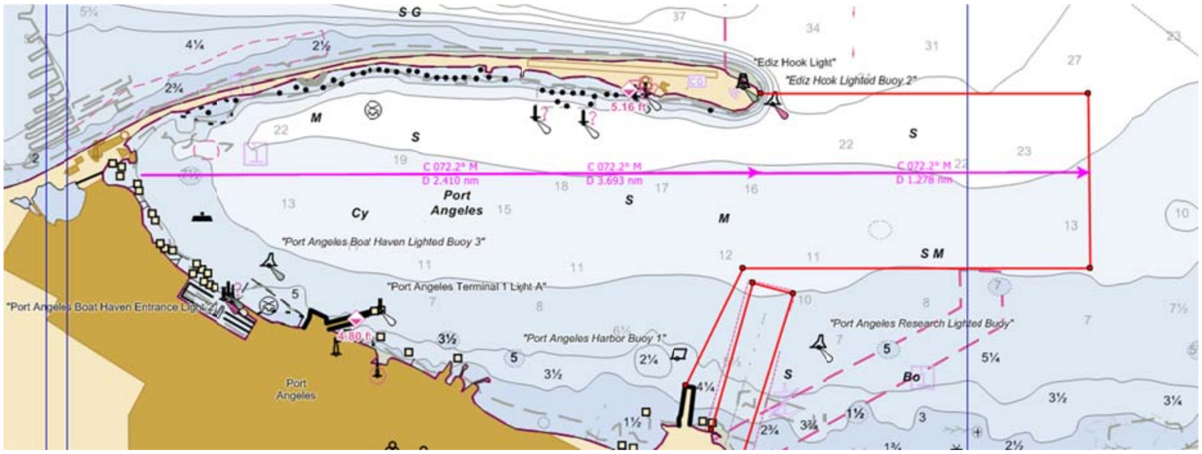
4.1.4 Juan de Fuca East: Port Angeles

Port Angeles is the busiest anchorage included in the study area as measured by both reservations and total days at anchor, as ships await berth availability in Puget Sound, bad weather or bunkers; the Port also offers ship repair, crew transportation and general cargo facilities. Located in Juan de Fuca East, Port Angeles is the first full-service operating port available to eastbound ships on the Strait of Juan de Fuca (Port of Port Angeles 2012), and the last port to bunker before they depart westbound to sea.

Port Angeles Anchorage is located between Ediz Hook to the north and the Port Angeles land mass to the south. The harbor is about 2.4 nm long with the anchorage extending east an additional 1.3 nm past Ediz Hook light for a total length of 3.7 nm. It is protected in all quadrants but the east, and the harbor is protected from all except easterly winds, which occasionally blow during the winter. During South East winter gales, the wind is not usually felt, but some swells are generated in the Strait and roll into the anchorage. The depths are greatest on the north shore and decrease from 30 to 15 fathoms in the middle of the harbor; from the middle, the depths decrease regularly to the south shore, where the 3-fathom curve in some places in the East part is nearly 0.2 mile from the beach (NOAA Undated). The bottom of the anchorage is primarily sand but turns into mud and shells in the west end near the lagoon.

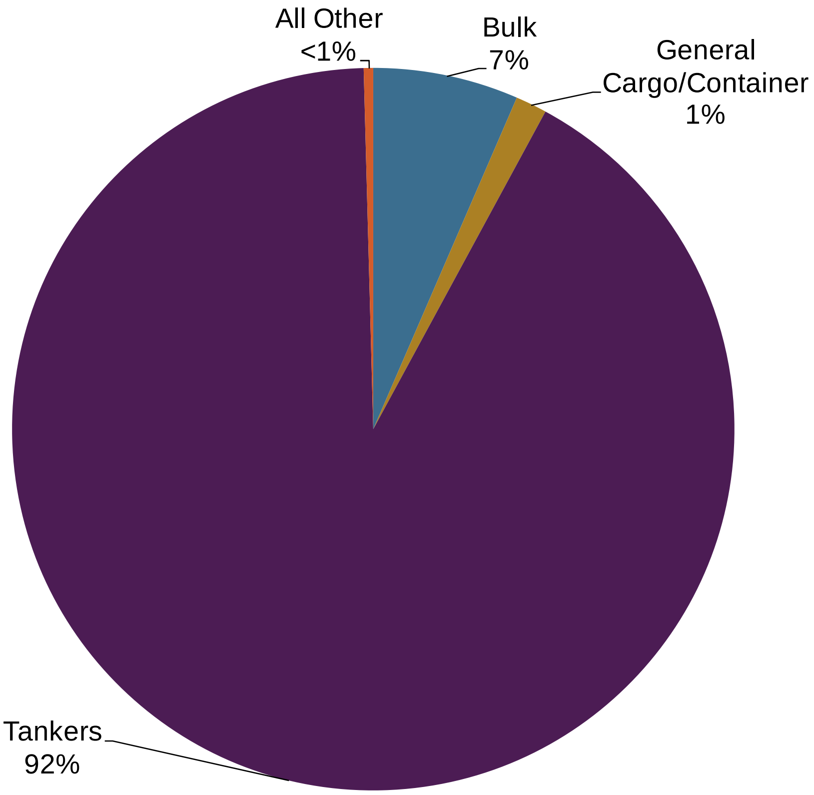
The anchorage is suitable for year around use following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (PSHSC 2012) and can accommodate five ships for a period of up to 10 days with a sixth ship in the easternmost anchorage when approved by the Captain of the Port for inspection or other emergent need during good weather. The Port Angeles Harbor Anchorage Area (PA) (NOAA Undated) encompasses all waters in Port Angeles Harbor that lie west of a line drawn from Ediz Hook, 48°08′23″N, 123°24′02″W; to 48°08′23″N, 123°22′07″W; thence to 48°07′42″N, 123°22′07″W; thence to 48°07′42″N, 123°24′08″W; thence to 48°07′14.9″N, 123°24′28.2″W.

Figure 48. Port Angeles Anchorage



Most vessels anchoring in Port Angeles are tankers; however, both bulk and general cargo vessels also frequent the anchorage (Figure 49).

Figure 49. Use of Port Angeles Anchorage by Vessel Type, 2006–2010



Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

Traffic data from the Marine Exchange show that vessels stop to berth or anchor at Port Angeles while transiting both east and west in the Strait. Each year more than 30 percent of the vessels calling at Port Angeles are coming from Cherry Point and Guemes Channel; these vessels are likely tankers transiting through the Strait of Juan de Fuca on their way out to sea. Another 40 percent are from Alaska or other US ports, transiting the Strait in the opposite direction and destined for a Washington port of call (Table 8).

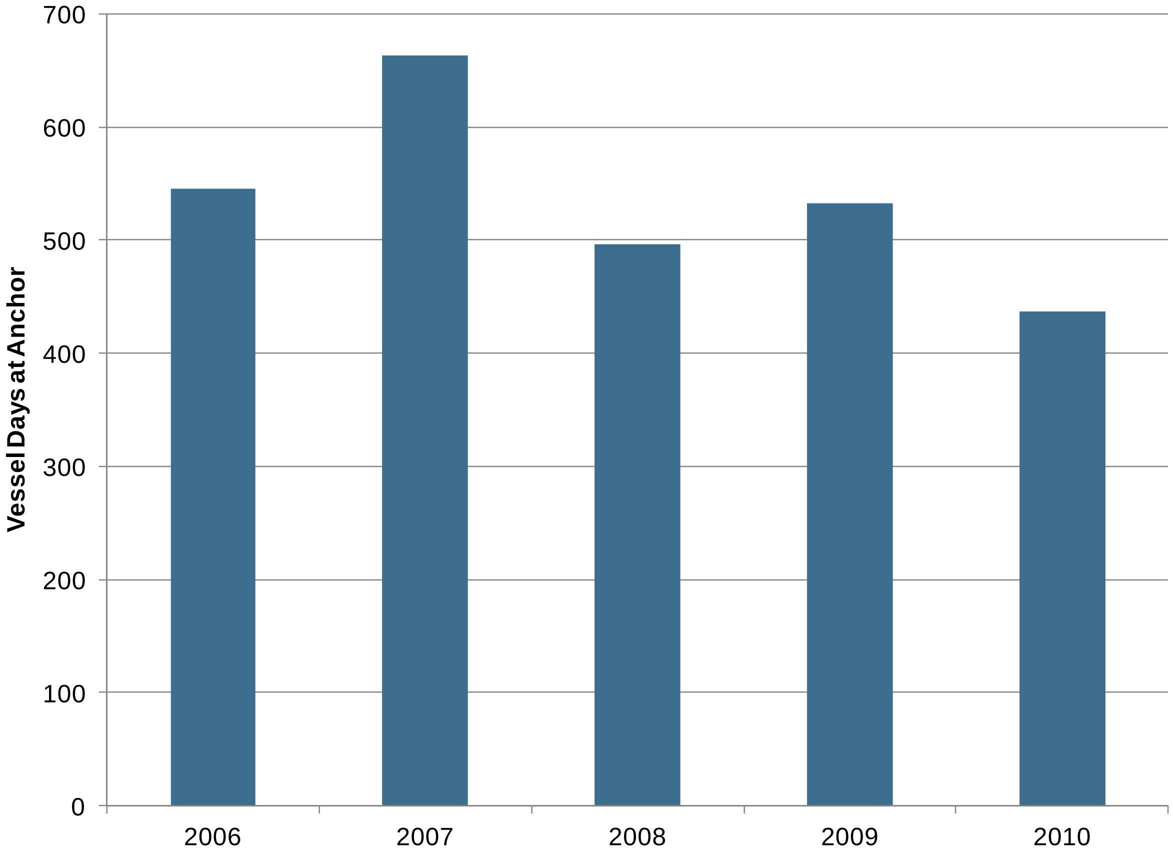
Table 8. Recorded Last Port of Call before Port Angeles, 2006–2010

	2006	2007	2008	2009	2010
Region of Last Port of Call			**Percent**		
Cherry Point and Guemes Channel	31	31	30	35	32
Alaska and Other US	37	43	40	39	41
Puget Sound	5	7	7	5	6
Foreign	20	14	20	18	16
Other	7	6	3	4	4
Total	**100**	**100**	**100**	**100**	**100**

Source: Marine Exchange of Puget Sound, 2012

In addition to bunkering, vessels may anchor at Port Angeles while they wait for better weather at sea, or to undergo mechanical repairs. Port Angeles anchorage is occupied for more than 400 vessel traffic days each year (Figure 50).

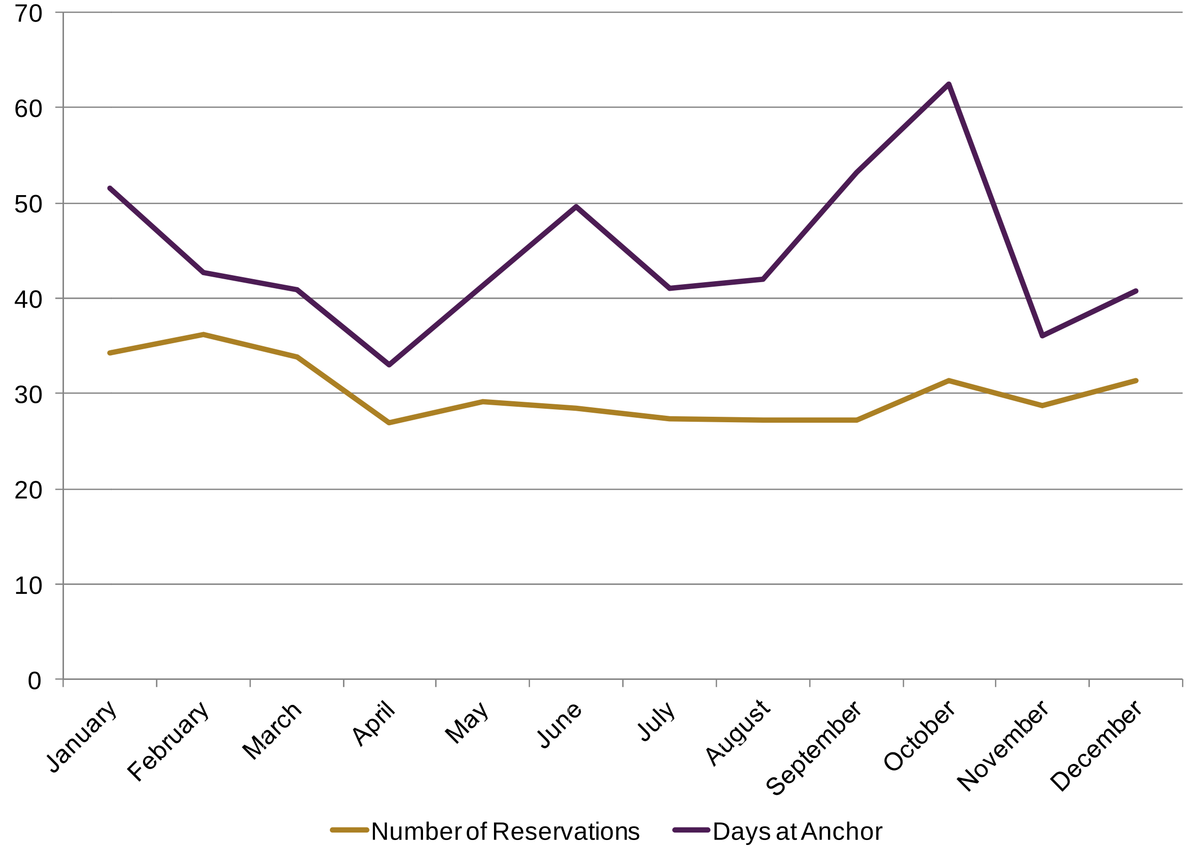
Figure 50. Vessel Traffic Days at Anchor, Juan de Fuca East Anchorage, 2006–2010



Source: Northern Economics, Inc. using USCG 2012

The number of vessels calling Port Angeles anchorage stays close to 30 per month. These vessels tend to stay at anchor longer in the winter months, perhaps due in part to winter weather delays at Washington destinations (Figure 51). Vessels calling Port Angeles between 2006 and 2010 stayed for an average of 1.5 days per visit.

Figure 51. Average Number of Reservations and Vessel Traffic Days at Juan de Fuca East Anchorage, by Month (2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Port Angeles can accommodate up to five vessels at anchor at one time. Assuming all five anchorages are available each day each year, the anchorage operates at approximately 30 percent of its capacity.

4.2 Anchorage Activity Comparison

In order to assess the use of anchorages in North Puget Sound, the study team contacted USCG Sector Puget Sound. USCG Sector Puget Sound is designated as the Captain of the Port's authorized representative. According to applicable regulations, no vessel shall anchor in any of the general anchorages examined in this study without prior permission from either the Captain of the Port or his authorized representative. In addition, regulations state that all vessels should seek permission at least 48 hours prior to arrival at the anchorage area in order to avoid unnecessary delays (33 CFR 110.230 (b)(1)), effectively creating a reservation system. USCG Sector Puget Sound maintains a database of these anchorage reservations; the study team believes that these data serve as the most accurate and consistent record of activity at North Puget Sound anchorages, and uses them as the basis for our analysis.

Upon request, USCG Sector Puget Sound provided the study team with a history of vessels at anchor for 2006–2010. The data provided by the USCG show several fields; those used for our analysis are shown below in Table 9. For each record, the study team noted the anchorage (area), name of the vessel, actual time of arrival, and actual time of departure.

Table 9. Sample of USCG Anchorage Data

Area	Vessel Name	Actual Time of Arrival	Actual Time of Departure
PA	ALASKAN EXPLORER	1/15/2006 2:16:00 PM	1/19/2006 1:28:00 AM

Note: PA=Port Angeles
Source: Northern Economics, Inc. using USCG 2012

The USCG database does not contain information regarding vessel type, and also omits any unique identifier such as International Maritime Organization number or Maritime Mobile Service Identity number, which would allow a user to accurately identify the vessel through independent sources. To assess anchorage use by vessel type, the study team utilized MX data. Vessel names in the USCG database were paired with those in the MX data; vessel type was assigned based on this association. It should be noted that some vessel names in the two databases did not match due to what the study team believes to be clerical error. Data cleaning was required to resolve likely misspellings, differences in capitalization, punctuation, and spacing.

In addition to assigning vessel type, the study team assigned study area location using the mapping shown in Table 10. Note that there are no designated deep draft anchorages in three of the subareas, Juan de Fuca West, Rosario Strait and Haro Strait-Boundary Pass.

Table 10. Anchorages Assigned to Study Subareas

General Anchorages	Study Subareas Location
Cherry Point	Cherry Point
Bellingham Bay	Saddlebag
Anacortes West	Guemes Channel
Anacortes Central	Guemes Channel
Anacortes East	Guemes Channel
Non-Designated Anchorages	
Vendovi Island South	Saddlebag
Vendovi Island East	Saddlebag
Port Angeles Harbor	Juan de Fuca East

Source: Northern Economics, Inc.

Table 11 shows how the information sourced from the USCG (Table 8) was transformed for the purpose of the BP-VTA study.

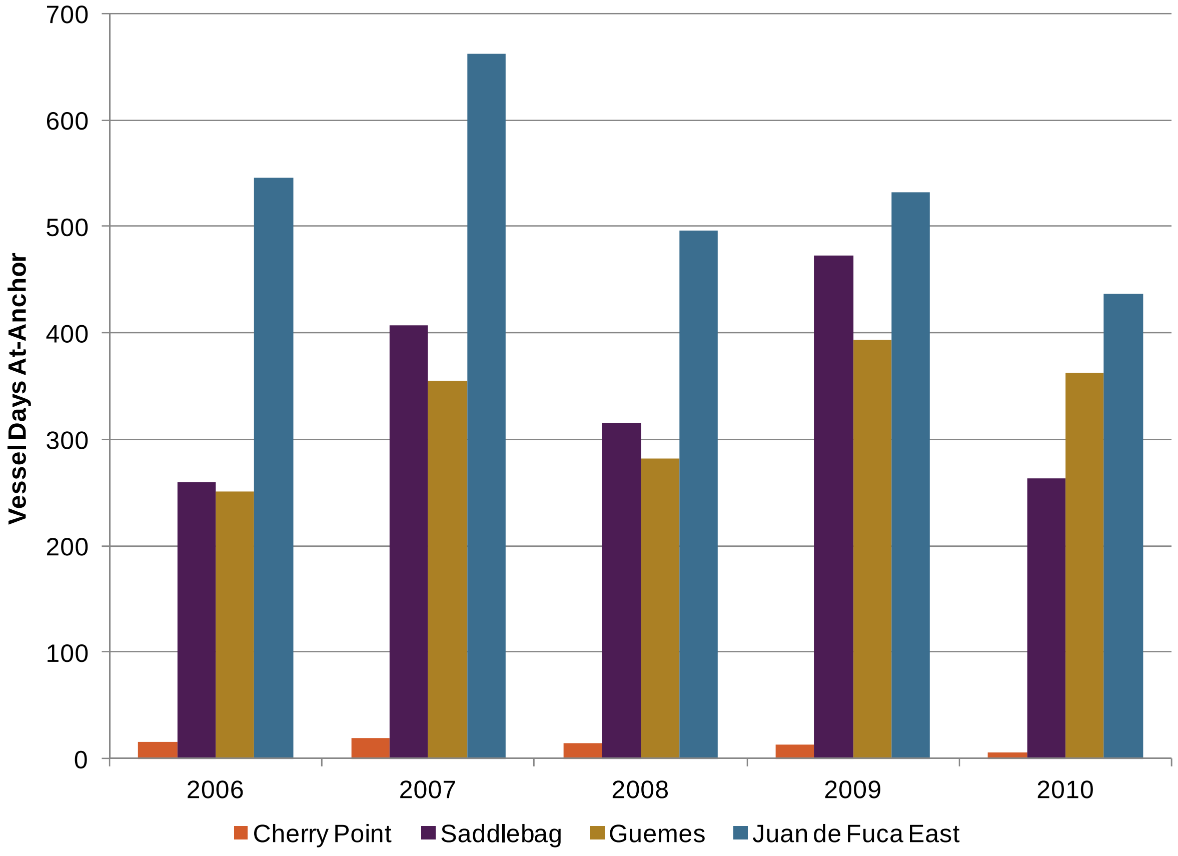
Table 11. Example of Anchorage Data Used for Analysis

Study Area Location	Year	Vessel Type	Days at Anchor
Juan de Fuca East	2006	CRUDE CARRIER	3.47

Source: Northern Economics, Inc.

As previously noted, the USCG database contains data for 2006–2010. Using the approach outlined above, the study team summarized anchorage activity in each of the study subareas for the five years available. Results of this analysis are summarized in Figure 52 and Table 12.

Figure 52. Vessel Traffic Days at Anchor by Subarea (2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Juan de Fuca East, which includes Port Angeles anchorage, is the busiest of all of the study subareas. Cherry Point, which can accommodate only one vessel at a time, is by far the least active of all of the anchorages.

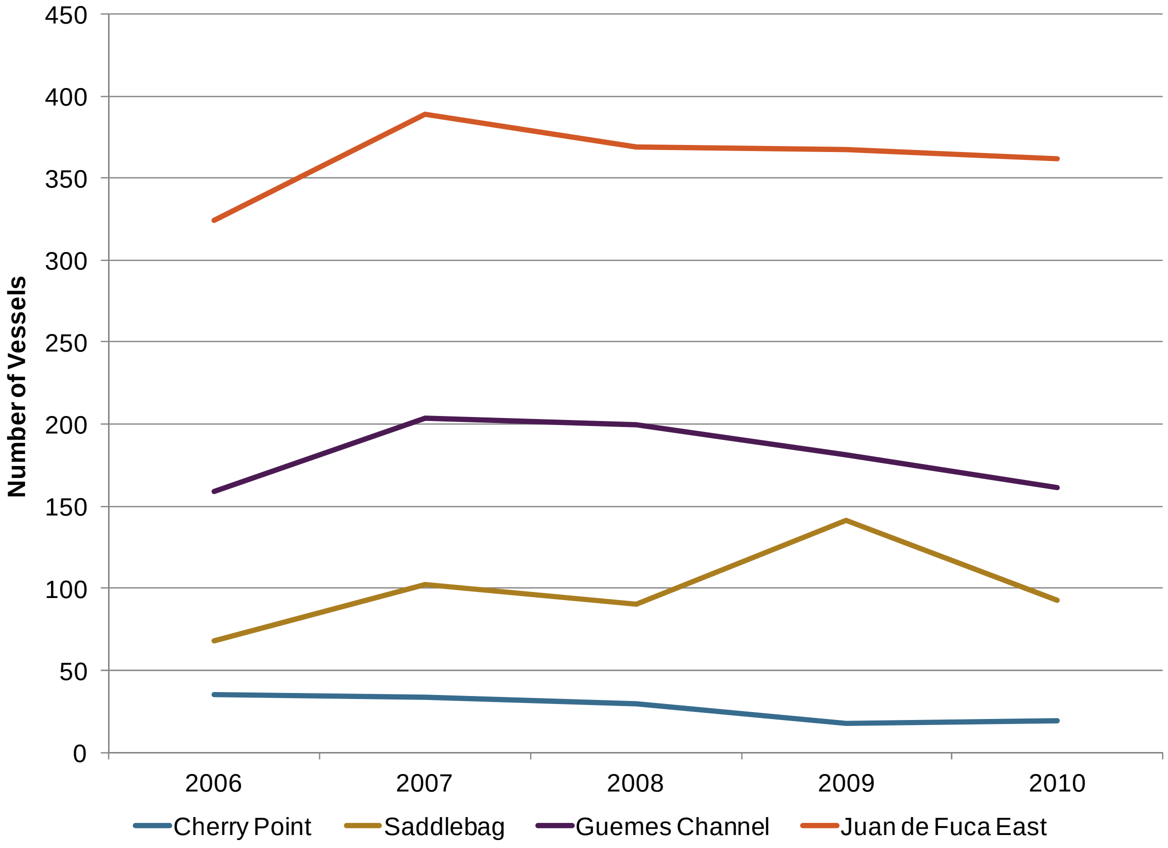
Table 12. Vessel Traffic Days at Anchor by Subarea (2006–2010)

SubArea	2006	2007	2008	2009	2010
Cherry Point	15.3	19.0	14.4	12.8	5.9
Saddlebag	259.3	407.7	315.1	473.3	263.8
Guemes	251.3	354.7	282.2	393.1	363.0
Juan de Fuca East	545.4	662.7	495.9	532.0	437.1
Total	**1,071.4**	**1,444.0**	**1,107.6**	**1,411.2**	**1,069.8**

Source: Northern Economics, Inc. using USCG 2012

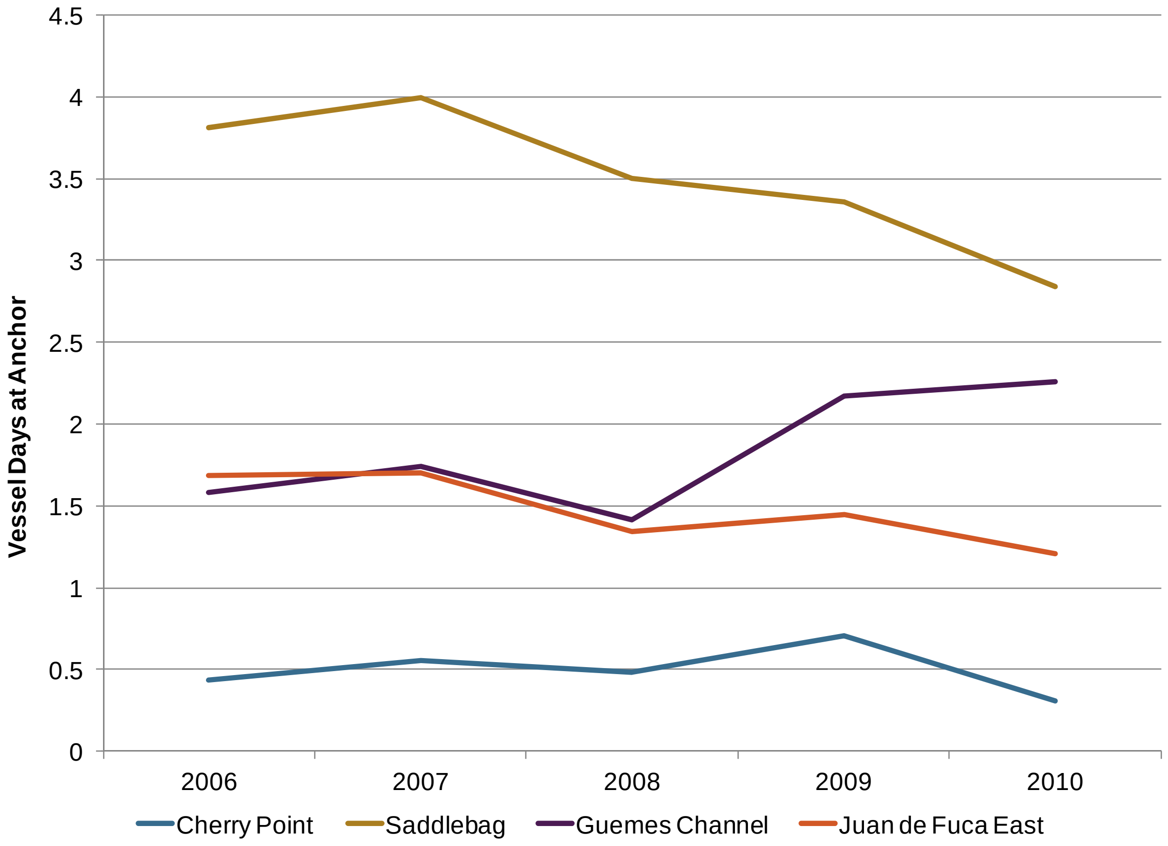
The two variables which determine total time at anchor are the number of anchoring vessels, and the duration each of these vessels anchor. As shown in Figure 53 and Figure 54, anchorages which record the highest number of vessels each year do not necessarily report the longest duration of time at anchor.

Figure 53. Annual Number of Anchoring Vessels, by Subarea (2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Figure 54. Average Vessel Traffic Days per Anchor, by Subarea (2006–2010)



Source: Northern Economics, Inc. using USCG 2012

Table 13. At-Anchor Times by Vessel Type and Year, by Subarea

	Anchorage							
Vessel Type/ Year	**Juan de Fuca West**	**Juan de Fuca East**	**Haro Strait-Boundary Pass**	**Guemes**	**Saddle-bag**	**Rosario Strait**	**Cherry Point**	**Total**
Tanker								
2006	0.00	489.85	0.00	243.81	253.42	0.00	14.71	1,001.78
2007	0.00	620.58	0.00	340.45	405.80	0.00	16.25	1,383.09
2008	0.00	446.13	0.00	278.29	314.03	0.00	12.98	1,051.43
2009	0.00	442.42	0.00	384.52	465.92	0.00	12.40	1,305.26
2010	0.00	375.32	0.00	347.77	261.14	0.00	3.32	987.55
Grain Bulk								
2006	0.00	6.27	0.00	0.00	0.00	0.00	0.00	6.27
2007	0.00	2.93	0.00	0.00	0.00	0.00	0.00	2.93
2008	0.00	17.44	0.00	0.00	0.00	0.00	0.00	17.44
2009	0.00	19.20	0.00	0.00	0.00	0.00	0.00	19.20
2010	0.00	20.00	0.00	4.29	0.00	0.00	0.00	24.30
Other Bulk								
2006	0.00	14.89	0.00	6.94	0.45	0.00	0.62	22.90
2007	0.00	15.35	0.00	0.22	1.85	0.00	2.74	20.15
2008	0.00	13.24	0.00	0.00	0.00	0.00	1.45	14.69
2009	0.00	39.14	0.00	1.71	0.59	0.00	0.37	41.80
2010	0.00	16.95	0.00	2.87	0.00	0.00	2.55	22.37
Container								
2006	0.00	5.04	0.00	0.00	0.00	0.00	0.00	5.04
2007	0.00	2.21	0.00	0.00	0.00	0.00	0.00	2.21
2008	0.00	7.37	0.00	0.00	0.00	0.00	0.00	7.37
2009	0.00	3.93	0.00	0.00	0.00	0.00	0.00	3.93
2010	0.00	5.43	0.00	0.00	0.00	0.00	0.00	5.43
Gen Cargo								
2006	0.00	16.24	0.00	0.58	0.00	0.00	0.00	16.82
2007	0.00	12.95	0.00	2.64	0.00	0.00	0.00	15.59
2008	0.00	8.48	0.00	1.29	0.00	0.00	0.00	9.77
2009	0.00	21.22	0.00	6.91	0.00	0.00	0.00	28.13
2010	0.00	15.52	0.00	1.89	0.00	0.00	0.00	17.41

Source: Northern Economics, Inc. using USCG 2012 and Marine Exchange of Puget Sound 2012

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Appendix B Incident Database

BP Cherry Point Vessel Traffic Study

Characterization of Historical Vessel Incidents

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8 October 2013

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Executive Summary

A total of 1,116 vessel incidents that occurred in the study area during the years 1995 through 2010 were analyzed. The largest percentage (62%) of vessels fell into the "Miscellaneous" category, which included fishing vessels, pleasure craft, workboats, and other vessels that less than 60 feet in length, freight barges of any size, as well as all vessels that may exceed 60 feet for which there are no traffic data available in the traffic study. The vessels for which there are no traffic data included: research vessels, military (public) vessels, passenger vessels other than regularly-scheduled ferries and cruise ships, offshore supply vessels, oil recovery vessels, industrial vessels, anchor handlers, and workboats. The remaining 429 vessel incidents included those involving bulkers (15), general cargo vessels (50), tankers (40 crude tankers and 50 product tankers), "tug and tank barges" (36), tugs (89), and passenger/fishing vessels (149 large fishing vessels, cruise ships, and ferries). Vessels other than those in the Miscellaneous category were called VTS (for Vessel Traffic Study) vessels for the purposes of these analyses.

Six groups of incident causes were analyzed – allisions, collisions, groundings, cargo transfer errors, bunkering errors, and other, non-impact incidents. The activity at the time of the incident – anchored, docked, underway, or maneuvering – were also analyzed. Each vessel incident was analyzed with regard to whether a spill occurred or did not occur.

Incidents were classified into seven geographic subareas - Juan de Fuca West, Juan de Fuca East, Guemes, Saddlebag, Haro Strait-Boundary Pass, Rosario Strait, and Cherry Point.

The key findings of these analyses was the following:

- There was a steady increase in the number of incidents for all vessels over the time period. The increase for the VTS vessels was more gradual. Note that these increases were not adjusted based on any increases in vessel traffic. These increases may reflect a number of factors: increases in vessel traffic, increases in the reporting rates of spills, and/or actual increases in the probabilities of incidents per unit traffic day. The incident rates per vessel traffic days are analyzed in other parts of the study.

For the analyses conducted specifically on the VTS vessels, the following are the key findings:

- Overall, there was an average of nearly 27 incidents per year, or one incident approximately every 0.04 years (every two weeks).
- Of the total incidents, nearly 20 incidents annually were in the other, non-impact category. This category includes: equipment failure, fire, explosion, operator error, structural failure, and incidents with unknown cause.
- Other, non-impact incidents encompassed 73% of all incidents, with 42% of all incidents being "other, non-impact" incidents involving "other" vessels. The next largest category of incidents

was transfer errors, which accounted for nearly 18% of incidents. Transfer errors includes both bunker errors and cargo transfer errors.

- For all vessel types, other, non-impact incidents encompassed the largest percentage of incidents.
- For tankers and tug and tank barges the next highest percentage of incidents were attributed to transfer errors.
- Allisions, collisions, and groundings accounted for 4%, 1.6%, and 3.5% of all incidents, respectively.
- Incidents while underway and docked had nearly the same annual incident number, about 11 and 12 incidents annually, respectively. Incidents occurring while anchored or maneuvering accounted for about one and three annual incidents annually, respectively.
- For bulkers, the greatest percentage (40%) of incidents occurred due to other, non-impact causes while underway. The same was true for general cargo vessels with a percentage of 58%, for tankers with a percentage of 30%, and for passenger/fishing vessels with a percentage of 38%.
- Tug and tank barges were most likely to have a transfer incident while docked, which accounted for 33% of tank barge incidents, followed closely by other, non-impact-related incidents at dock, which accounted for 31% of tug and tank barge incidents.
- For allisions, the greatest number occurred with other vessels while maneuvering for an average of less than one incident annually. Collisions were most likely to occur with a tug and tank barge while maneuvering or underway, with one incident occurring about once in four years.
- Groundings occurred about once a year all from vessels while underway.
- Allisions occurred at a rate of just over once a year, with the greatest number occurring in the Guemes subarea.
- Collisions occurred at a rate of about once every two and one-quarter years with an equal number occurring in Juan de Fuca West, Juan de Fuca East, and Cherry Point.
- Groundings occur about oncee a year with the greatest number occurring in Juan de Fuca West.
- Transfer incidents occurred at a rate of nearly five per year with most occurring in Cherry Point followed by Guemes.
- Other, non-impact incidents occurred at a rate of about 20 per year with the highest number occurring in Juan de Fuca East followed by Guemes.

When an incident occurs there is a potential for spillage of oil and/or other cargo. There were no incidents of non-oil cargo being spilled. This is most likely because these incidents have not been tracked nearly as closely as oil spills. Overall, the probability of spillage (i.e., the proportion of incidents that resulted in spillage of any volume, including very small amounts) was 0.44. That means that 44% of incidents resulted in spillage. The highest probability of spillage was with tugs and tank barges for which 75% of incidents resulted in spillage of some amount. The next highest percentage of spillage was for tankers for which 47% of incidents resulted in spillage.

The incidents most likely to result in spillage were cargo transfer errors where 89% of reported incidents with the potential for spillage did result in a spill. Bunker errors resulted in 80% spillage. Groundings, collisions, and allisions resulted in 40%, 29%, and 6% spillage, respectively. Other, non-impact incidents resulted in 37% spillage rates.

The greatest potential spill volume, with regard to the largest worst-case discharge, would be for tankers, which in the study period had two allisions, half of which resulted in some spillage, and one collision and two groundings, none of which resulted in any spillage of oil. This does not mean that a worst-case discharge or larger volume incident could not occur in the future.

Notes on Data

Data Sources

Data on vessel incidents were derived from the databases developed for all vessel incidents used in the BP Cherry Point Vessel Traffic Study. The original data were collated from US Coast Guard records, Washington Department of Ecology records, and various proprietary databases developed by Environmental Research Consulting (ERC) for projects conducted for Washington Department of Ecology, Washington State Joint Legislative Audit and Review Committee, National Academy of Sciences, and the American Petroleum Institute.

Information on individual vessels were obtained from the US Coast Guard PSIX Vessel Database, Washington Department of Ecology, and various proprietary databases on vessels.

Data Limitations

Data on vessel incidents were for reported and recorded incidents only. While incidents involving larger vessels, impact accidents, and incidents over the 1995-2010 study period that involved spillage are highly likely to have been reported, it is possible that other incidents may not have been reported to federal and/or state authorities and thus would not have appeared in these records.

Caution on Interpretation of Return Periods

A return period or recurrence interval gives an indication of the likelihood of an event, e.g., a collision once every 200 years. This does not imply that the event will happen regularly every 200 years or that it may occur only once in 200 years. In any given 200-year period, the event may occur once, twice, more often, or not at all. The return period is merely a reflection of the frequency with which the event has occurred in the past and is likely to occur in the future given various parameters. An event with a return period of two years is much more likely to occur than one with a return period of 20 or 200 years, but it is important to remember that "unlikely" events can occur. A so-called "100-year flood" may occur more than once in 100 years, or may not occur at all. A "100-year flood" should be interpreted as a flood event of a magnitude that has a 1 percent probability of occurrence during any year.

Data Description and Terminology

Vessel incident data for the BP Cherry Point Vessel Traffic Study geographic area was analyzed for the years 1995 through 2010. Vessel incidents included in the study encompassed all incidents in which spillage occurred or that had the potential for spillage of oil and/or bulk cargo. For each incident, the data shown in Table 1 were included.

Table 1: Data Collected on Historical Vessel Incidents

<table>
<tr><th>Data Field</th><th colspan="3">Categories</th></tr>
<tr><td>BPCP Subarea</td><td colspan="3">Juan de Fuca West
Juan de Fuca East
Guemes
Saddlebag
Haro Strait-Boundary Pass
Rosario Strait
Cherry Point</td></tr>
<tr><td rowspan="2">Vessel Type</td><td>Bulk
General Cargo
Tanker
Tug and Tank Barge
Passenger/Fishing
Tug</td><td>Vessels in Vessel Traffic Study (VTS Vessels)</td><td rowspan="2">All Vessels</td></tr>
<tr><td>Miscellaneous</td><td></td></tr>
<tr><td>Incident Cause</td><td colspan="3">Allision
Collision
Grounding
Other, Non-Impact
Bunker Error
Cargo Transfer Error</td></tr>
<tr><td>Activity Type</td><td colspan="3">Anchored
Docked
Maneuvering
Underway</td></tr>
</table>

Notes on Vessel Types

- The “Bulk” category refers to bulkers or bulk carriers that carry dry cargo.
- The “Tug and Tank Barge” includes tank barges that are not attached to tugs at the time of the incident, as well as tank barges that are attached to a tug. The incidents involving “tugs and tank barges” only include the incidents that involve the actual or potential spillage from the tank barges and not from the tugs. Tugs are separately tracked.
- “Tugs” include tugboats that pull barges and towboats that push barges. Incidents involving tugs can occur when the tug is attached to a barge (or barges) or when it is separate from barges. It involves actual or potential spillage from the tug and not from any barges that it may be pulling or pushing.
- The “Tanker” category is split into “product tankers” and “crude tankers” based on their general size for the purposes of the historical incident analysis only. In the vessel traffic study product and crude tankers are merged into one category regardless of size or cargo type.
- Articulated tug barges (ATBs) and integrated tug barges (ITBs) are considered to be tankers.
- “General Cargo Vessels” includes freight vessels, car carriers, cargo vessels, and container ships that do not fall under the category of bulkers or tankers.
- “Passenger/Fishing Vessels” includes fishing vessels over 60 feet, cruise ships,[1] and regularly-scheduled ferries regardless of size.

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[11] Cruise vessels are 300 GT or larger, deep draft, and require a Puget sound pilot.

- "Miscellaneous Vessels" includes fishing vessels, pleasure craft, workboats, and other vessels that are less than 60 feet in length, freight barges of any size, as well as all vessels that may exceed 60 feet for which there are no traffic data available in the traffic study. The vessels for which there are no traffic data include: research vessels, military (public) vessels, offshore supply vessels, oil recovery vessels, industrial vessels, anchor handlers, workboats, and passenger vessels over 60 feet that are not specifically ferries or cruise ships.
- The term "VTS Vessels" is used in the analyses of historical incident data to refer to all vessel categories except for "Miscellaneous" vessels. These vessels are part of the vessel traffic study portion of the overall study because vessel traffic data exists for those vessel categories and because there is a risk of spillage from those vessels.

The numbers of incidents by vessel type are show in Table 2. The incidents are further detailed by vessel type in Table 3.

Table 2: Numbers of Incidents by Vessel Type 1995 – 2010

Vessel Type	Number of Incidents		
	Each Vessel Group	With Combined Tankers	VTS Vessels
Bulk	15	15	15
General Cargo	50	50	50
Tanker – Crude	40	90	90
Tanker – Product	50		
Tug and Tank Barge	36	36	36
Passenger/Fishing	149	149	149
Tug	89	89	89
Miscellaneous	687	687	0
Total	**1,116**	**1,116**	**429**

Table 3: Numbers of Incidents by Detailed Vessel Type 1995 – 2010

Vessel Type Detail	Number of Incidents All Vessels	VTS Vessel Type	Number of Incidents for VTS Vessels
Cargo Vessel-Bulk Carrier	15	**Bulker**	15
Cargo Vessel-Car Carrier	4	**General Cargo Vessel**	4
Cargo Vessel-Container	30	**General Cargo Vessel**	30
Cargo Vessel-General	16	**General Cargo Vessel**	16
Fishing Vessel	42	**Passenger/Fishing Vessel**	42
Fishing Vessel-Small	216	**Miscellaneous**	0
Freight Barge	9	**Miscellaneous**	0
Other-Patrol Boat	1	**Miscellaneous**	0
Other-Workboat	1	**Miscellaneous**	0
Other Vessel	1	**Miscellaneous**	0
Other Vessel - Dredger	1	**Miscellaneous**	0
Other Vessel-Anchor Handling	1	**Miscellaneous**	0
Other Vessel-Dredger	1	**Miscellaneous**	0
Other Vessel-Industrial	2	**Miscellaneous**	0
Other Vessel-Offshore Supply	1	**Miscellaneous**	0
Other Vessel-Oil Recovery	8	**Miscellaneous**	0
Other Vessel-Public	18	**Miscellaneous**	0
Other Vessel-Research	6	**Miscellaneous**	0
Passenger Vessel	15	**Miscellaneous**	0

Table 3: Numbers of Incidents by Detailed Vessel Type 1995 – 2010

Vessel Type Detail	Number of Incidents All Vessels	VTS Vessel Type	Number of Incidents for VTS Vessels
Pleasure Craft	406	**Miscellaneous**	0
Fishing Vessel-Factory	7	**Passenger/Fishing Vessel**	7
Fishing Vessel-Reefer	1	**Passenger/Fishing Vessel**	1
Fishing Vessel-Trawler	27	**Passenger/Fishing Vessel**	27
Passenger Vessel-Cruise	2	**Passenger/Fishing Vessel**	2
Passenger Vessel-Ferry	70	**Passenger/Fishing Vessel**	70
Towboat/Tugboat	89	**Tug**	89
Tank Ship-ATB	9	**Tanker (Product)**	9
Tank Ship-Crude	40	**Tanker (Crude)**	40
Tank Ship-ITB	9	**Tanker (Product)**	9
Tank Ship-Product	32	**Tanker (Product)**	32
Tank Barge	36	**Tug and Tank Barge**	36
Total	**1,116**	**Total**	**429**

Notes on Incident Cause Types

- All incidents are included that cause the potential for a spill of cargo and/or bunkers or that cause the potential for spillage.
- Allisions occur when a moving object makes contact with a stationary object, such as when a moving vessel hits a pier, or a stationary vessel is hit by another vessel.
- “Groundings” include power and drift groundings.
- “Transfer Errors” include incidents that cause actual or potential spillage during oil cargo transfers or bunkering.
- “Other, Non-Impact” incidents include: structural failure; equipment failure; intentional discharges; accidental discharges that occur due to a variety of reasons including errors during operations; leakage; fires; explosions; and unknown reasons. Note that an unknown cause may actually be one of the other categories that was not identified or not present in incident records. The cause may actually be an impact incident (allision, collision, or grounding) that was not identified or properly recorded at the time of the incident.

Table 4 shows a breakdown of detailed causes for all vessels and the breakdown of VTS cause types and numbers of VTS vessels only.

Table 4: Numbers of Incidents by Detailed Cause Type 1995 – 2010

Cause Type Detail	Number of Incidents All Vessels	Number of Incidents VTS Vessels	VTS Cause Type	Number of Incidents for VTS Vessels
Allision	23	18	**Allision**	18
Bunker Error	91	41	**Bunker Error**	41
Collision	13	7	**Collision**	7
Discharging	278	37	**Other, Non-Impact**	37
Equipment Failure	73	45	**Other, Non-Impact**	45
Fire/Explosion	20	11	**Other, Non-Impact**	11
Grounding	42	15	**Grounding**	15
Operator Error	27	7	**Other, Non-Impact**	7
Other	34	10	**Other, Non-Impact**	10
Structural Failure	176	132	**Other, Non-Impact**	132

Table 4: Numbers of Incidents by Detailed Cause Type 1995 – 2010

Cause Type Detail	Number of Incidents All Vessels	Number of Incidents VTS Vessels	VTS Cause Type	Number of Incidents for VTS Vessels
Transfer Error	47	35	**Transfer Error**	35
Unknown	292	71	**Other, Non-Impact**	71
Total	**1,116**	**429**	**Total**	**429**

Subareas

The geographic subareas used in the study and in these analyses are shown in Figure 1.

Figure 1: Geographic Subareas in Study Area

Table 5 shows a breakdown for incidents by subarea for all vessels and for the VTS vessels only.

Table 5: Numbers of Incidents by Subarea 1995 – 2010

Subarea	Number of Incidents All Vessels	Number of Incidents VTS Vessels
Juan de Fuca West	173	53
Juan de Fuca East	201	103
Guemes Channel	226	108
Saddlebag	234	67
Rosario Strait	21	11
Haro Strait-Boundary Bay	10	4
Cherry Point	251	83
Total	**1,116**	**429**

Incident Analysis

Annual Incident Analysis

During the years 1995 through 2010, there were a total of 1,116 incidents in the study area involving all vessel types, as shown in Table 6 and Figure 2. Note that the annual number of incidents increased over the 16-year time period. This has not been adjusted for the increase in vessel traffic. The total number of incidents has increased at a higher rate than the number of incidents for the VTS vessels alone. The increase between 1995 and 2010 was 5.03 additional incidents per year for all vessels, and 1.69 incidents per year for the VTS vessels.

Table 6: Numbers of Incidents by Year 1995 – 2010

Year	Total Number of Incidents	
	All Vessels	VTS Vessels Only
1995	57	14
1996	29	16
1997	36	19
1998	39	20
1999	61	15
2000	57	13
2001	42	22
2002	76	40
2003	73	39
2004	83	32
2005	63	28
2006	75	26
2007	105	33
2008	96	35
2009	113	31
2010	112	46
Total	**1,116**	**429**

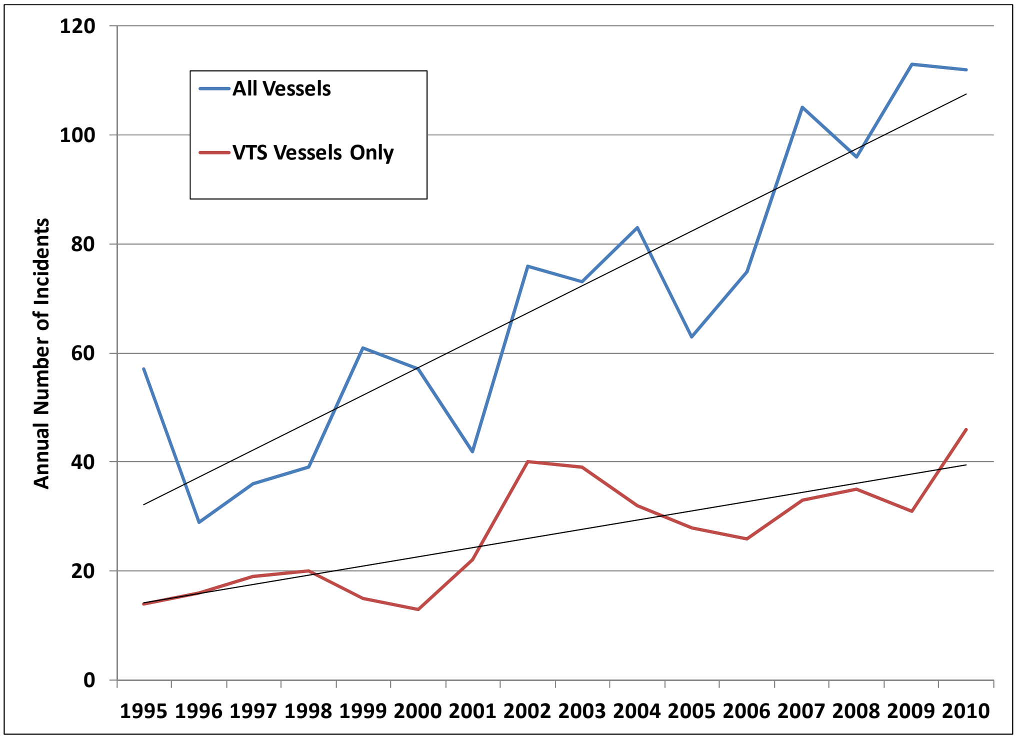

Figure 2: Annual Number of Incidents for All Vessels

Breakdown of Incidents by Subarea

The incidents are broken down by subarea and year for all vessels in Table 7 and Figures 3 and 4. VTS vessels only are shown in Table 8 and Figures 5 and 6. The breakdowns by individual vessel types are shown in Tables 9 through 18. Figures 7 through 13 show maps of incidents by vessel type.

Table 7: Incidents Involving All Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	13	10	10	13	0	2	9	**57**
1996	3	10	5	5	0	0	6	**29**
1997	9	2	5	10	0	1	9	**36**
1998	7	6	11	9	0	0	6	**39**
1999	14	14	12	14	1	0	6	**61**
2000	5	13	10	18	1	2	8	**57**
2001	4	8	12	5	0	0	13	**42**
2002	8	18	13	12	0	4	21	**76**
2003	4	15	24	13	0	2	15	**73**
2004	11	12	25	15	2	1	17	**83**
2005	10	10	20	11	1	1	10	**63**
2006	7	16	18	13	3	4	14	**75**
2007	18	13	23	13	0	1	36	**104**
2008	10	19	10	28	1	1	27	**96**
2009	31	19	13	26	1	1	22	**113**
2010	19	16	15	29	0	1	32	**112**
Total	**173**	**201**	**226**	**234**	**10**	**21**	**251**	**1,116**

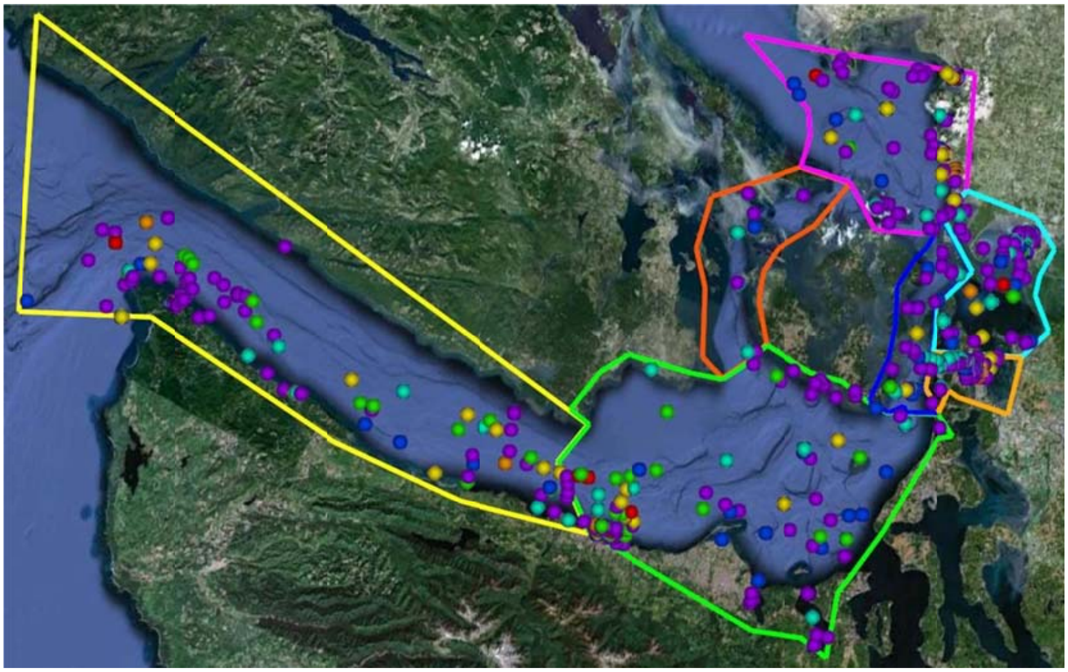

Figure 3: Map of All Vessel Incidents by Subarea

Red = bulkers; orange = tug and tank barges; yellow = tankers; green = general cargo vessels; aqua = passenger/fishing vessels; blue = tugs; purple = miscellaneous vessels. Note that because of the large number of incident location markers on the map and multiple incidents in the same location there is overlap of markers in many cases.

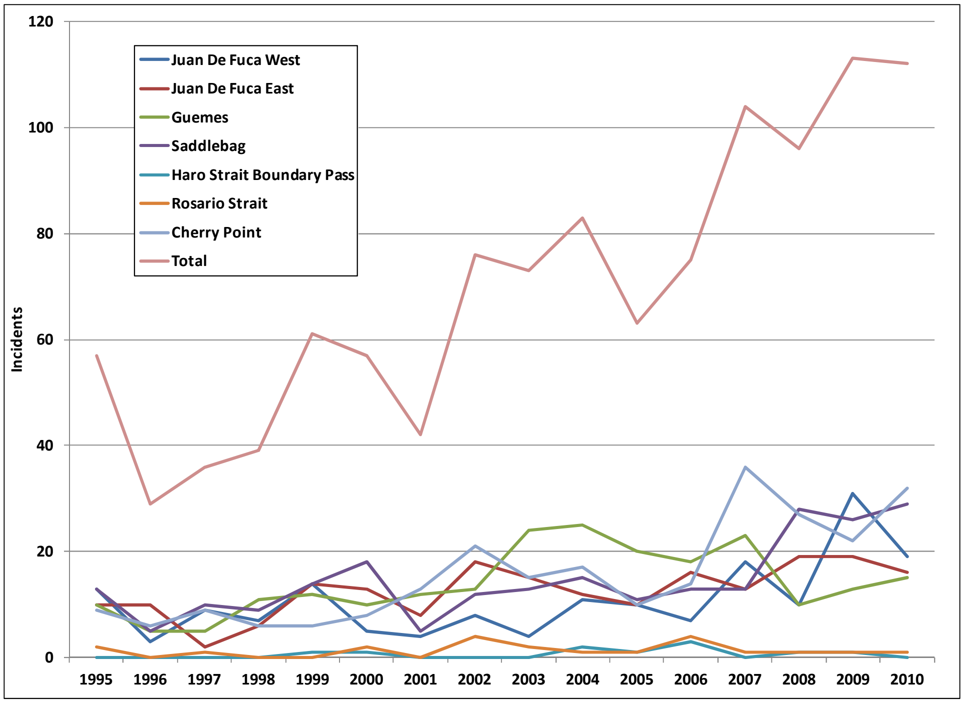

Figure 4: Annual Incidents Involving All Vessels by Geographic Subarea

Table 8: Incidents Involving VTS Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	2	4	2	1	0	1	4	**14**
1996	2	7	4	1	0	0	2	**16**
1997	4	2	3	4	0	1	5	**19**
1998	1	4	6	6	0	0	3	**20**
1999	2	5	3	3	0	0	2	**15**
2000	0	3	2	3	1	0	4	**13**
2001	1	3	7	4	0	0	7	**22**
2002	2	9	8	6	0	2	13	**40**
2003	3	8	14	8	0	1	5	**39**
2004	4	8	11	7	0	0	2	**32**
2005	2	7	11	3	1	1	3	**28**
2006	4	10	7	0	1	2	2	**26**
2007	10	7	9	4	0	0	3	**33**
2008	4	10	3	8	1	1	8	**35**
2009	6	6	7	3	0	1	8	**31**
2010	6	10	11	6	0	1	12	**46**
Total	**53**	**103**	**108**	**67**	**4**	**11**	**83**	**429**

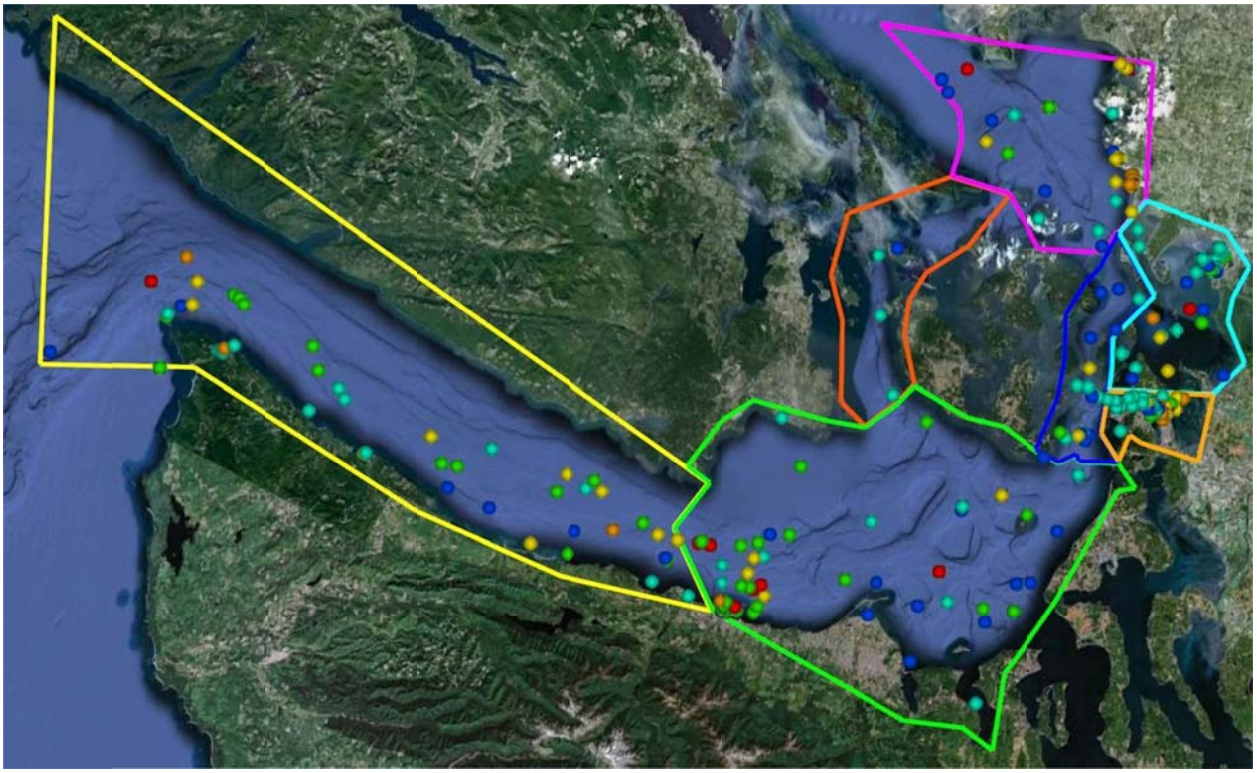

Figure 5: Map of All VTS Vessel Incidents by Subarea

Red = bulkers; orange = tug and tank barges; yellow = tankers; green = general cargo vessels; aqua = passenger/fishing vessels; blue = tugs. Note that because of the large number of incident location markers on the map and multiple incidents in the same location there is overlap of markers in many cases.

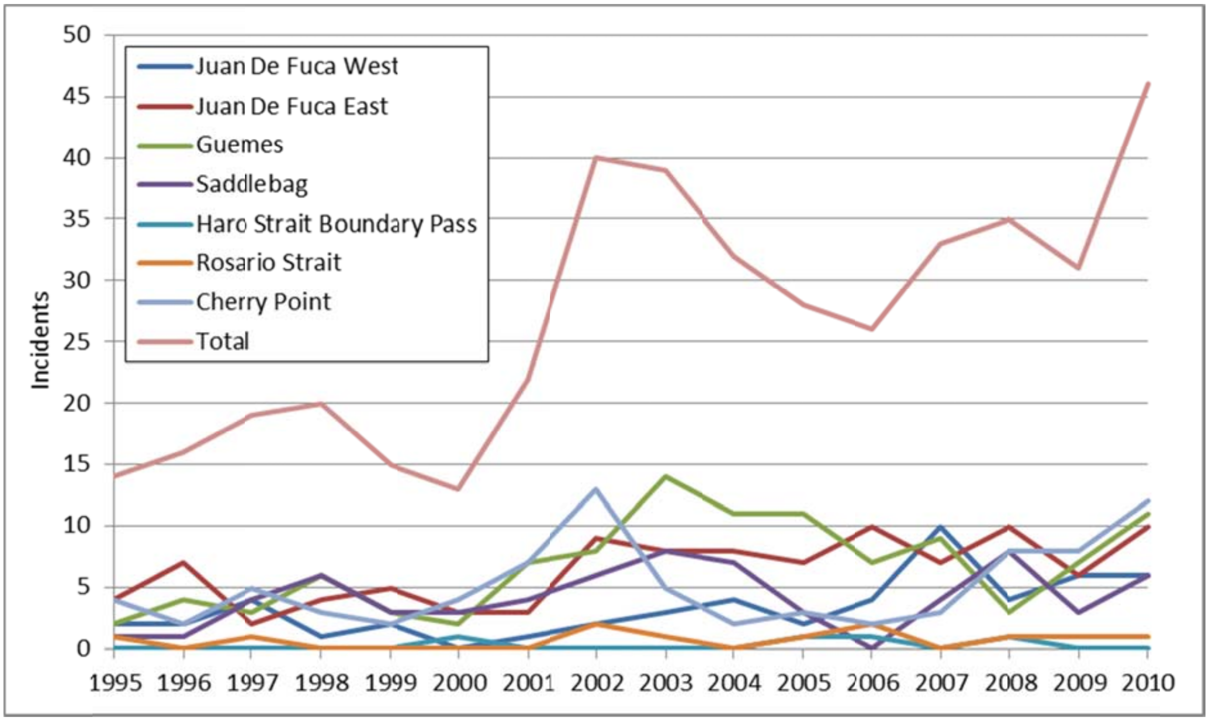

Figure 6: Annual Incidents Involving VTS Vessels by Geographic Subarea

Table 9: Subarea Totals 1995 – 2010 for VTS Vessel Incidents				
Geographic Zone	**Total Incidents**	**% Total**	**Average Incidents/Year**	**Return Years**
Juan De Fuca West	48	11.2%	3.00	0.33
Juan De Fuca East	103	24.0%	6.44	0.16
Guemes	75	17.5%	4.69	0.21
Saddlebag	73	17.0%	4.56	0.22
Haro Strait Boundary Pass	2	0.5%	0.13	7.69
Rosario Strait	7	1.6%	0.44	2.27
Cherry Point	121	28.2%	7.56	0.13
Total	**429**	**100.0%**	**26.81**	**0.04**

Table 10: Incidents Involving Bulkers by Year and Subarea 1995 – 2010								
Year	**Juan De Fuca West**	**Juan De Fuca East**	**Guemes**	**Saddlebag**	**Haro Strait Boundary Pass**	**Rosario Strait**	**Cherry Point**	**Total**
1995	0	1	0	0	0	0	0	**1**
1996	0	1	1	0	0	0	0	**2**
1997	0	0	0	0	0	0	0	**0**
1998	0	0	0	0	0	0	0	**0**
1999	0	0	0	0	0	0	0	**0**
2000	0	0	0	0	0	0	0	**0**
2001	0	0	0	0	0	0	0	**0**
2002	0	0	0	0	0	0	1	**1**
2003	0	2	0	0	0	0	0	**2**
2004	1	1	0	0	0	0	0	**2**
2005	0	1	0	0	0	0	0	**1**
2006	0	0	1	0	0	0	0	**1**
2007	0	1	0	1	0	0	0	**2**
2008	0	1	0	0	0	0	0	**1**
2009	0	0	0	0	0	0	0	**0**
2010	0	0	0	0	0	0	2	**2**
Total	**1**	**8**	**2**	**1**	**0**	**0**	**3**	**15**

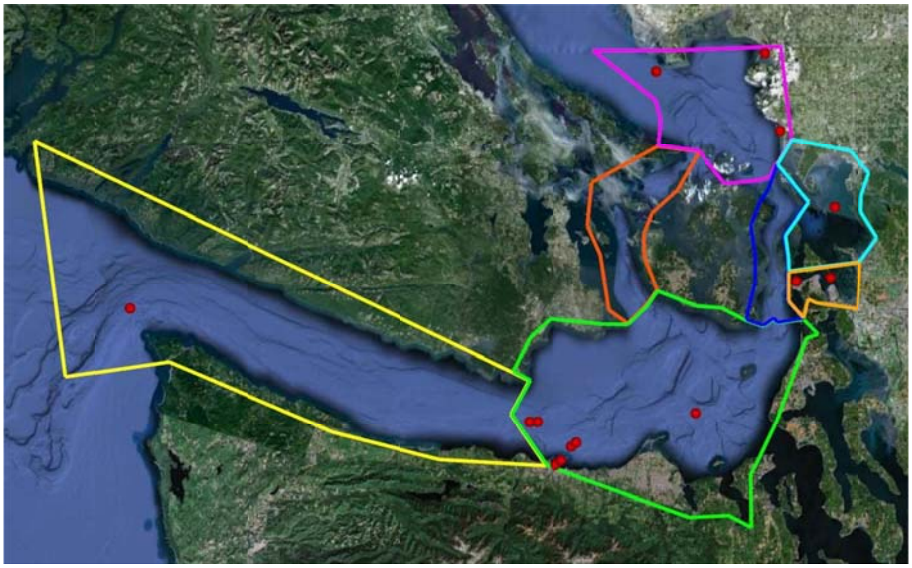

Figure 7: Map of Bulker Incidents 1995 – 2010

Table 11: Incidents Involving General Cargo Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	0	0	1	0	0	0	0	**1**
1996	0	3	0	0	0	0	0	**3**
1997	0	1	1	0	0	0	0	**2**
1998	0	1	2	1	0	0	0	**4**
1999	0	2	0	0	0	0	0	**2**
2000	0	1	0	0	0	0	0	**1**
2001	1	1	0	0	0	0	0	**2**
2002	0	1	0	1	0	0	0	**2**
2003	0	2	0	0	0	0	0	**2**
2004	2	2	0	0	0	0	0	**4**
2005	0	1	0	0	0	0	0	**1**
2006	1	4	0	0	0	0	0	**5**
2007	4	3	0	0	0	0	0	**7**
2008	2	3	0	0	0	0	0	**5**
2009	2	2	0	1	0	0	0	**5**
2010	1	1	0	0	0	0	2	**4**
Total	**13**	**28**	**4**	**3**	**0**	**0**	**2**	**50**

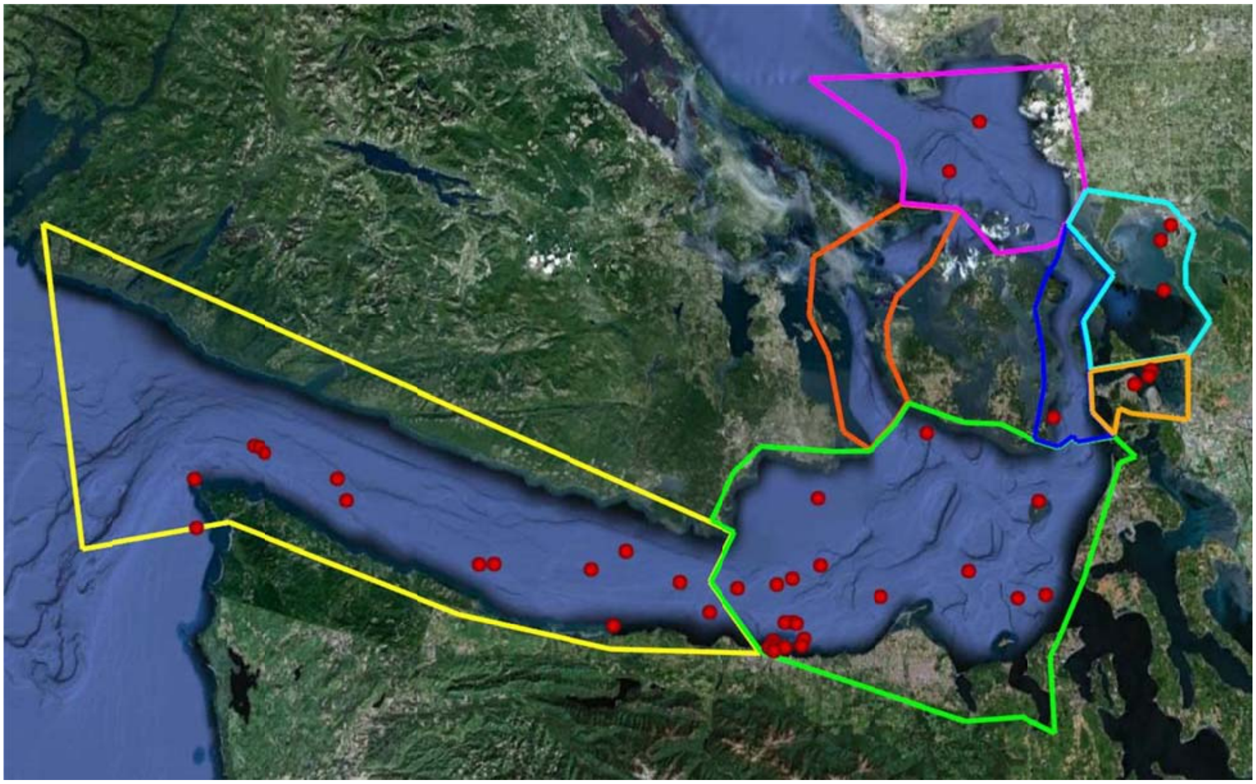

Figure 8: Map of General Cargo Vessel Incidents 1995 – 2010

Table 12: Incidents Involving Crude Tankers by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	0	0	0	0	0	0	0	**0**
1996	0	0	0	0	0	0	0	**0**

Table 12: Incidents Involving Crude Tankers by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1997	0	0	0	0	0	0	1	**1**
1998	0	1	0	0	0	0	1	**2**
1999	1	0	0	0	0	0	1	**2**
2000	0	0	0	0	0	0	2	**2**
2001	0	0	1	0	0	0	1	**2**
2002	0	1	1	0	0	0	3	**5**
2003	0	1	0	0	0	0	1	**2**
2004	0	1	2	0	0	0	1	**4**
2005	0	0	2	0	0	0	0	**2**
2006	1	1	0	0	0	0	1	**3**
2007	0	3	0	0	0	0	0	**3**
2008	0	2	0	0	0	0	1	**3**
2009	1	0	0	0	0	1	4	**6**
2010	1	1	0	0	0	0	1	**3**
Total	**4**	**11**	**6**	**0**	**0**	**1**	**18**	**40**

Table 13: Incidents Involving Product Tankers by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	1	0	0	0	0	0	2	**3**
1996	0	0	1	0	0	0	1	**2**
1997	1	0	1	0	0	0	1	**3**
1998	0	0	0	1	0	0	1	**2**
1999	0	0	2	0	0	0	1	**3**
2000	0	0	0	0	0	0	1	**1**
2001	0	1	2	0	0	0	2	**5**
2002	1	2	0	0	0	0	4	**7**
2003	1	0	1	0	0	0	1	**3**
2004	0	0	1	1	0	0	0	**2**
2005	0	1	0	0	0	0	0	**1**
2006	0	0	1	0	0	0	0	**1**
2007	1	0	1	1	0	0	0	**3**
2008	0	1	0	0	0	0	1	**2**
2009	0	0	2	0	0	0	2	**4**
2010	2	3	2	0	0	0	1	**8**
Total	**7**	**8**	**14**	**3**	**0**	**0**	**18**	**50**

Table 14: Incidents Involving Product and Crude Tankers by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	1	0	0	0	0	0	2	**3**
1996	0	0	1	0	0	0	1	**2**
1997	1	0	1	0	0	0	2	**4**
1998	0	1	0	1	0	0	2	**4**
1999	1	0	2	0	0	0	2	**5**
2000	0	0	0	0	0	0	3	**3**
2001	0	1	3	0	0	0	3	**7**
2002	1	3	1	0	0	0	7	**12**
2003	1	1	1	0	0	0	2	**5**
2004	0	1	3	1	0	0	1	**6**

Table 14: Incidents Involving Product and Crude Tankers by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
2005	0	1	2	0	0	0	0	**3**
2006	1	1	1	0	0	0	1	**4**
2007	1	3	1	1	0	0	0	**6**
2008	0	3	0	0	0	0	2	**5**
2009	1	0	2	0	0	1	6	**10**
2010	3	4	2	0	0	0	2	**11**
Total	**11**	**19**	**20**	**3**	**0**	**1**	**36**	**90**

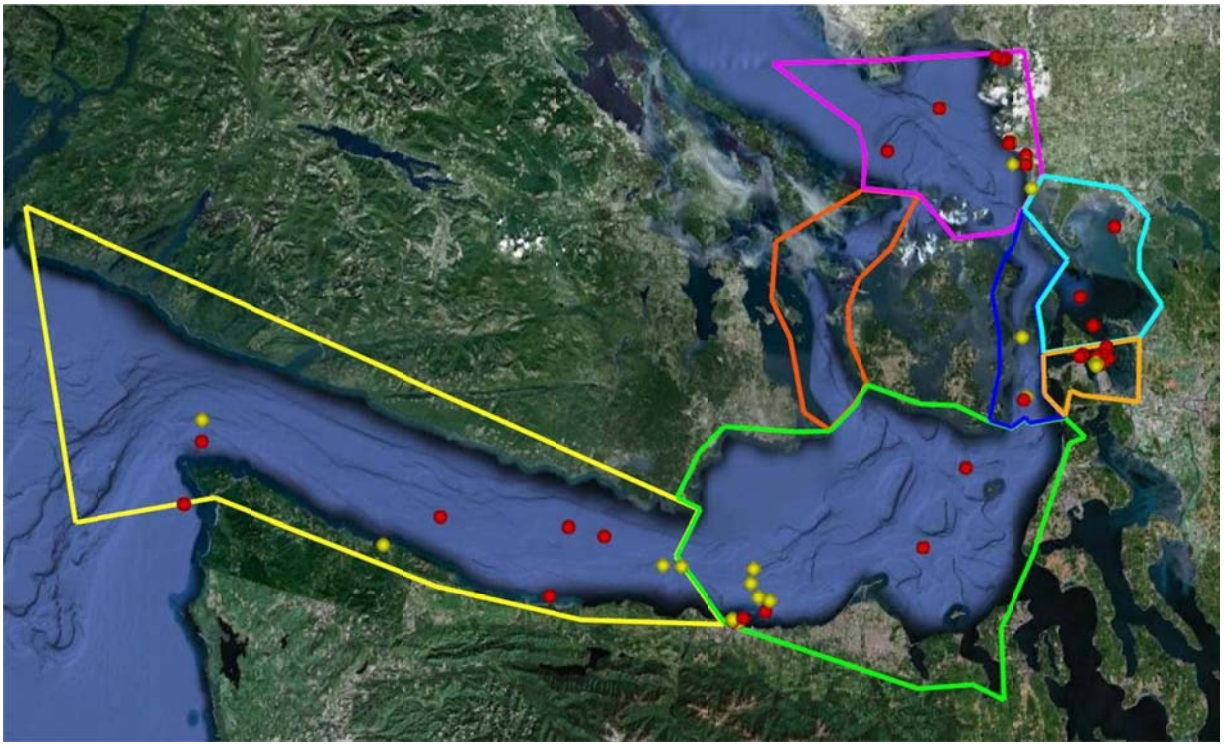

Figure 9: Map of Tanker Incident Locations 1995 – 2010

Red indicates product tankers and yellow indicates crude tankers.

Table 15: Incidents Involving "Tug and Tank Barges" by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	0	0	0	0	0	0	1	**1**
1996	1	0	1	0	0	0	0	**2**
1997	0	0	0	0	0	0	3	**3**
1998	0	0	0	0	0	0	1	**1**
1999	0	0	0	0	0	0	0	**0**
2000	0	0	0	0	0	0	0	**0**
2001	0	0	3	0	0	0	1	**4**
2002	0	2	2	1	0	0	3	**8**
2003	0	1	0	0	0	0	0	**1**
2004	0	0	2	0	0	0	1	**3**
2005	0	0	1	0	0	0	2	**3**
2006	0	0	2	0	0	0	0	**2**
2007	0	0	2	0	0	0	0	**2**

Table 15: Incidents Involving "Tug and Tank Barges" by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
2008	1	0	0	1	0	0	1	**3**
2009	1	1	0	0	0	0	0	**2**
2010	0	0	0	1	0	0	0	**1**
Total	**3**	**4**	**13**	**3**	**0**	**0**	**13**	**36**

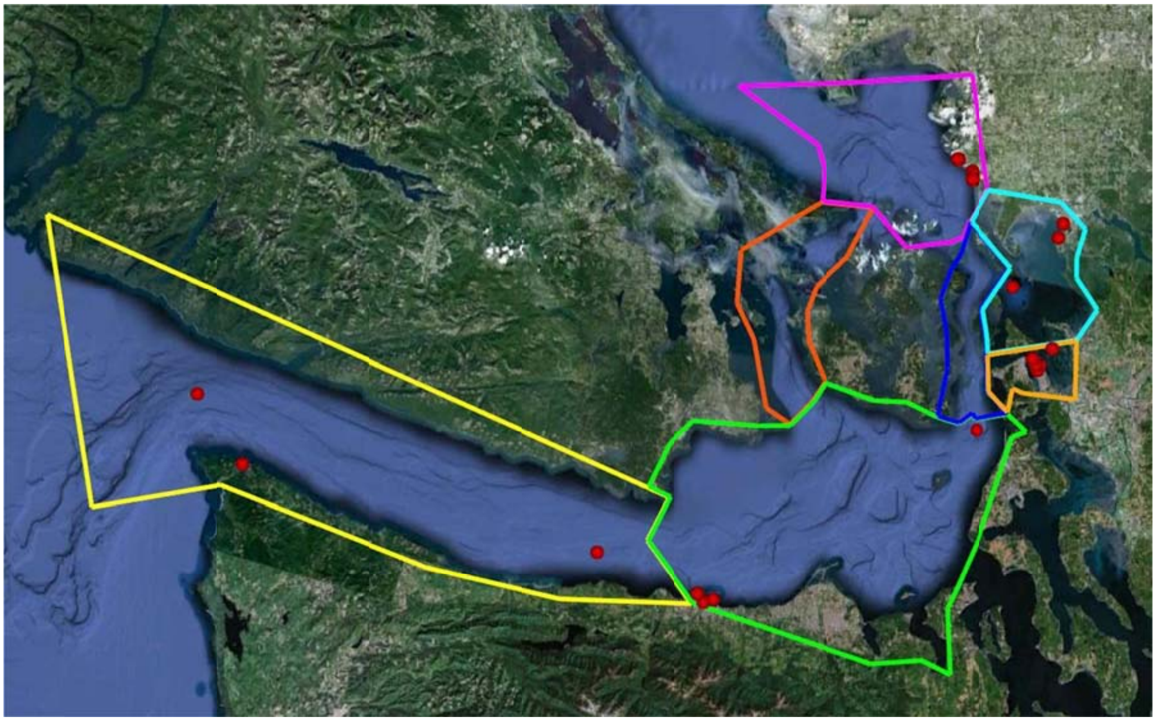

Figure 10: Map of "Tug and Tank Barge" Incident Locations 1995 – 2010

Table 16: Incidents Involving Passenger Vessels, Fishing Vessels, and Tugboats by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	1	3	1	1	0	1	1	**8**
1996	1	3	1	1	0	0	1	**7**
1997	3	1	1	4	0	1	0	**10**
1998	1	2	4	4	0	0	0	**11**
1999	1	3	1	3	0	0	0	**8**
2000	0	2	2	3	1	0	1	**9**
2001	0	1	1	4	0	0	3	**9**
2002	1	3	5	4	0	2	2	**17**
2003	2	2	13	8	0	1	3	**29**
2004	1	4	6	6	0	0	0	**17**
2005	2	4	8	3	1	1	1	**20**
2006	2	5	3	0	1	2	1	**14**
2007	5	0	6	2	0	0	3	**16**
2008	1	3	3	7	1	1	5	**21**
2009	2	3	5	2	0	0	2	**14**
2010	2	5	9	5	0	1	6	**28**

Table 16: Incidents Involving Passenger Vessels, Fishing Vessels, and Tugboats by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
Total	**25**	**44**	**69**	**57**	**4**	**10**	**29**	**238**

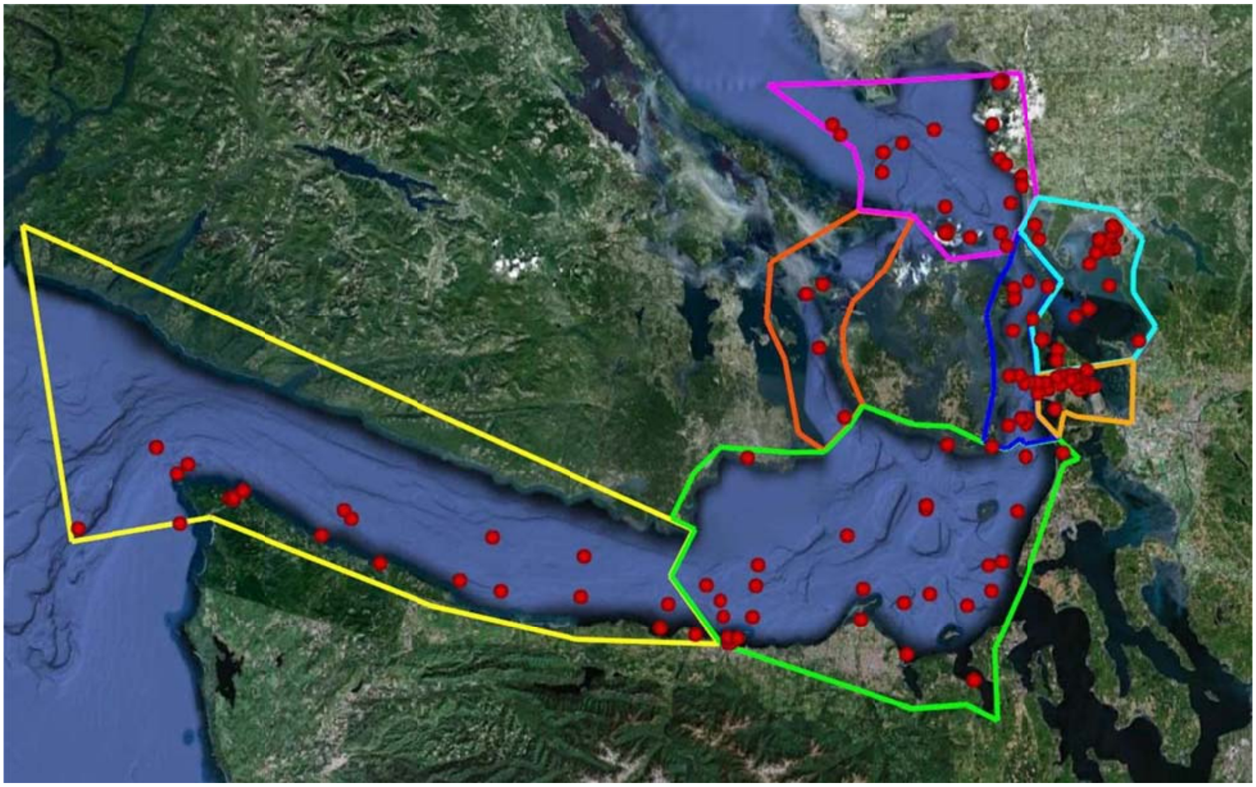

Figure 11: Map of Passenger Vessel, Fishing Vessel, and Tugboat Incident Locations 1995 – 2010

Table 17: Incidents Involving Miscellaneous Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	11	6	8	12	0	1	5	**43**
1996	1	3	1	4	0	0	4	**13**
1997	5	0	2	6	0	0	4	**17**
1998	6	2	5	3	0	0	3	**19**
1999	12	9	9	11	1	0	4	**46**
2000	5	10	8	15	0	2	4	**44**
2001	3	5	5	1	0	0	6	**20**
2002	6	9	5	6	0	2	8	**36**
2003	1	7	10	5	0	1	10	**34**
2004	7	4	14	8	2	1	15	**51**
2005	8	3	9	8	0	0	7	**35**
2006	3	6	11	13	2	2	12	**49**
2007	8	6	14	9	0	1	33	**71**
2008	6	9	7	20	0	0	19	**61**
2009	25	13	6	23	1	0	14	**82**
2010	13	6	4	23	0	0	20	**66**

Table 17: Incidents Involving Miscellaneous Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
Total	**120**	**98**	**118**	**167**	**6**	**10**	**168**	**687**

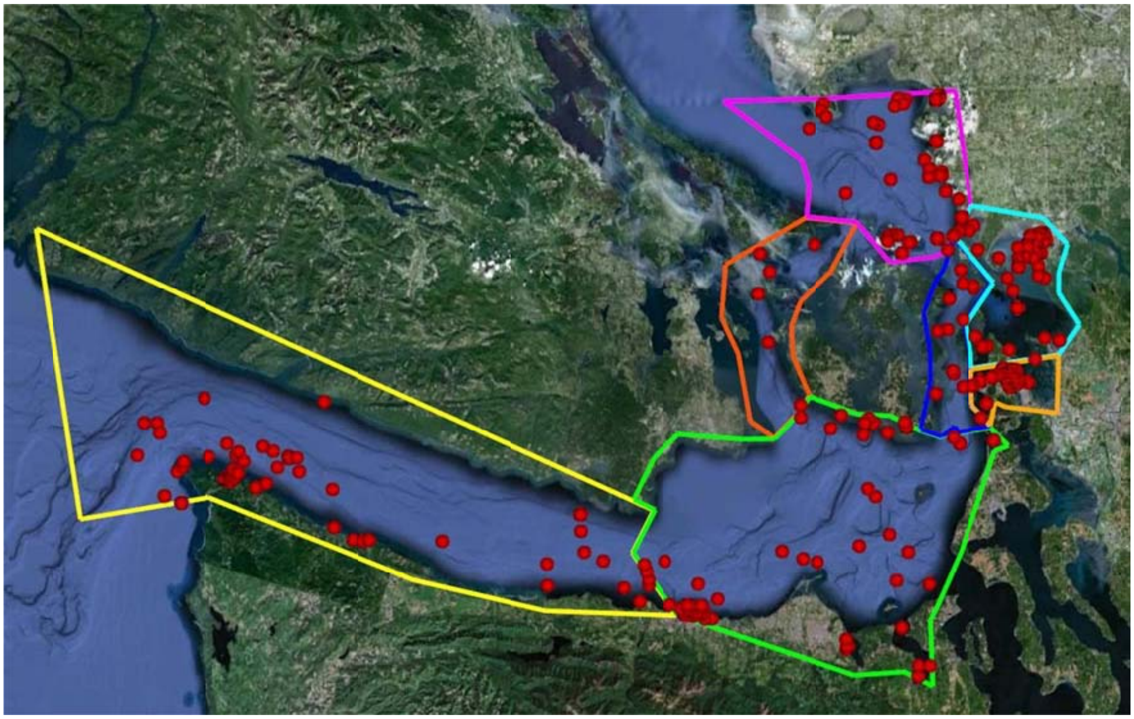

Figure 12: Map of Miscellaneous Vessel Incident Locations 1995 – 2010

Table 18: Incidents Involving Miscellaneous Vessels by Year and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
1995	11	6	8	12	0	1	5	**43**
1996	1	3	1	4	0	0	4	**13**
1997	5	0	2	6	0	0	4	**17**
1998	6	2	5	3	0	0	3	**19**
1999	12	9	9	11	1	0	4	**46**
2000	5	10	8	15	0	2	4	**44**
2001	3	5	5	1	0	0	6	**20**
2002	6	9	5	6	0	2	8	**36**
2003	1	7	10	5	0	1	10	**34**
2004	7	4	14	8	2	1	15	**51**
2005	8	3	9	8	0	0	7	**35**
2006	3	6	11	13	2	2	12	**49**
2007	8	6	14	9	0	1	33	**71**
2008	6	9	7	20	0	0	19	**61**
2009	25	13	6	23	1	0	14	**82**
2010	13	6	4	23	0	0	20	**66**
Total	**120**	**98**	**118**	**167**	**6**	**10**	**168**	**687**

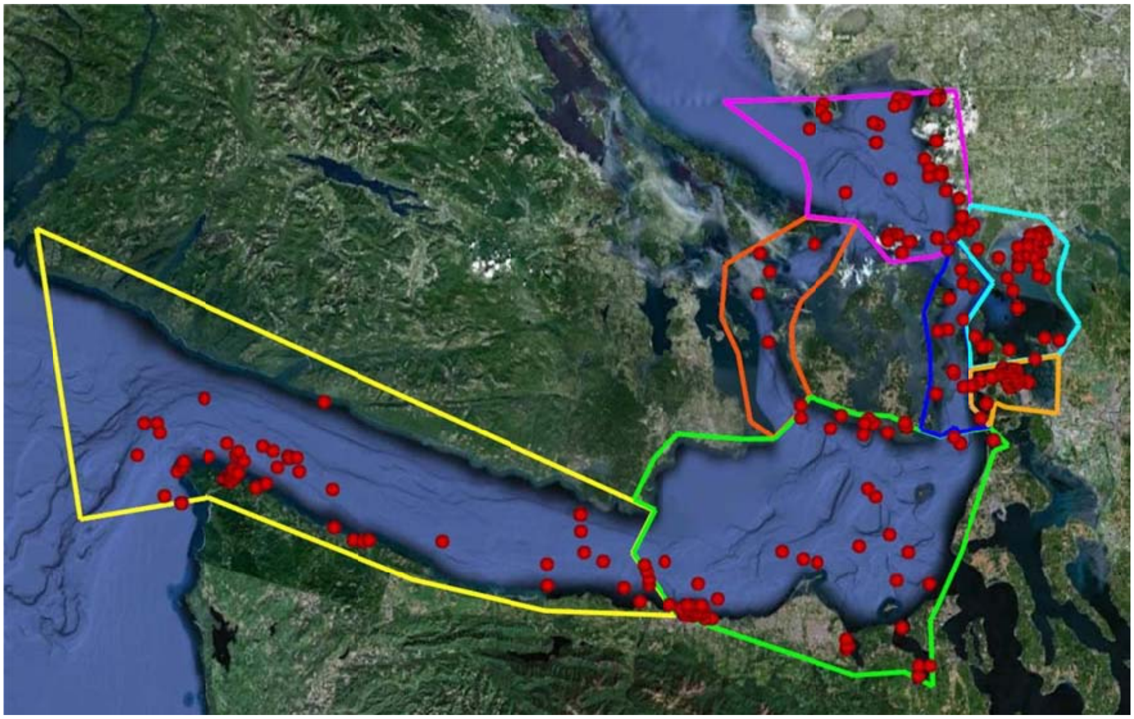

Figure 13: Map of Miscellaneous Vessel Incident Locations 1995 – 2010

Further Analysis for VTS Vessel Incidents Only

Breakdown of VTS Vessel Incidents by Cause and Activity

Table 19 shows a breakdown of VTS vessel incidents by vessel type and incident cause. Table 20 shows the percentages of total incidents involving VTS vessels.

Table 19: VTS Vessel Incidents by Vessel Type and Incident Cause 1995 – 2010

Cause	Bulk	Gen. Cargo	Tanker	Tug/ Tank Barge	Pass/ Fish	Tug	Total	Avg. Per Year	Return Years
Allision	1	1	2	1	8	5	**18**	1.13	0.89
Collision	1	0	1	4	1	0	**7**	0.44	2.29
Grounding	0	0	2	0	11	2	**15**	0.94	1.07
Other, Non-Impact	11	46	58	19	114	65	**313**	19.56	0.05
Bunker Error	2	3	1	3	15	17	**41**	2.56	0.39
Transfer Error	0	0	26	9	0	0	**35**	2.19	0.46
Total	**15**	**50**	**90**	**36**	**149**	**89**	**429**	**26.81**	**0.04**

Table 20: VTS Vessel Incidents by VesselType/Incident Cause 1995 – 2010 (% All VTS Incidents)

Cause	Percentage of All VTS Vessel Incidents						
	Bulk	General Cargo	Tanker	Tug/ Tank Barge	Pass/ Fish	Tug	Total
Allision	0.23%	0.23%	0.47%	0.23%	1.86%	1.17%	**4.20%**
Collision	0.23%	0.00%	0.23%	0.93%	0.23%	0.00%	**1.63%**
Grounding	0.00%	0.00%	0.47%	0.00%	2.56%	0.47%	**3.50%**
Other, Non-Impact	2.56%	10.72%	13.52%	4.43%	26.57%	15.15%	**72.96%**
Bunker Error	0.47%	0.70%	0.23%	0.70%	3.50%	3.96%	**9.56%**
Transfer Error	0.00%	0.00%	6.06%	2.10%	0.00%	0.00%	**8.16%**
Total	**3.50%**	**11.66%**	**20.98%**	**8.39%**	**34.73%**	**20.75%**	**100.00%**

The percentages of incidents by cause for each incident cause are shown in Table 21. For example, 5.6% of the allisions of VTS vessels involve bulkers. Table 22 shows the percentages of incidents within each vessel type. For example, 64% of tanker incidents involve other, non-impact causes, while only 2% involve allisions. Tables 23 and 24 show the percentages of incidents that occur with VTS vessels by activity (anchored, docked, underway, or maneuvering).

Table 21: VTS Vessel Incidents by Cause 1995 – 2010 (% VTS Incidents within Cause)

Cause	**Percentage of Incidents Within Cause**						
	Bulk	**General Cargo**	**Tanker**	**Tug/ Tank Barge**	**Pass/ Fish**	**Tug**	**Total**
Allision	5.56%	5.56%	11.11%	5.56%	44.44%	27.78%	**100.00%**
Collision	14.29%	0.00%	14.29%	57.14%	14.29%	0.00%	**100.00%**
Grounding	0.00%	0.00%	13.33%	0.00%	73.33%	13.33%	**100.00%**
Other, Non-Impact	3.51%	14.70%	18.53%	6.07%	36.42%	20.77%	**100.00%**
Bunker Error	4.88%	7.32%	2.44%	7.32%	36.59%	41.46%	**100.00%**
Transfer Error	0.00%	0.00%	74.29%	25.71%	0.00%	0.00%	**100.00%**
Total	**3.50%**	**11.66%**	**20.98%**	**8.39%**	**34.73%**	**20.75%**	**100.00%**

Table 22: VTS Vessel Incidents by Cause 1995 – 2010 (% VTS Incidents within Vessel Type)

Cause	**Percentage of Incidents Within Vessel Type**						
	Bulk	**General Cargo**	**Tanker**	**Tug/ Tank Barge**	**Pass/ Fish**	**Tug**	**Total**
Allision	6.67%	2.00%	2.22%	2.78%	5.37%	5.62%	**4.20%**
Collision	6.67%	0.00%	1.11%	11.11%	0.67%	0.00%	**1.63%**
Grounding	0.00%	0.00%	2.22%	0.00%	7.38%	2.25%	**3.50%**
Other, Non-Impact	73.33%	92.00%	64.44%	52.78%	76.51%	73.03%	**72.96%**
Bunker Error	13.33%	6.00%	1.11%	8.33%	10.07%	19.10%	**9.56%**
Transfer Error	0.00%	0.00%	28.89%	25.00%	0.00%	0.00%	**8.16%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 23: VTS Vessel Incidents by Vessel Type and Activity 1995 – 2010

Activity	**Bulk**	**General Cargo**	**Tanker**	**Tug/ Tank Barge**	**Pass/ Fish**	**Tug**	**Total**	**Avg. Per Year**	**Return Years**
Anchored	1	3	6	2	1	4	**17**	1.06	0.94
Docked	6	8	44	23	67	31	**179**	11.19	0.09
Underway	8	33	31	7	15	10	**104**	6.50	0.15
Maneuvering	0	6	9	4	66	44	**129**	8.06	0.12
Total	**15**	**50**	**90**	**36**	**149**	**89**	**429**	**26.81**	**0.04**

Table 24: VTS Vessel Incidents by Activity 1995 – 2010 (% All VTS Incidents)

Activity	**Percentage of All VTS Vessel Incidents**						
	Bulk	**General Cargo**	**Tanker**	**Tug/ Tank Barge**	**Pass/ Fish**	**Tug**	**Total**
Anchored	0.23%	0.70%	1.40%	0.47%	0.23%	0.93%	**3.96%**
Docked	1.40%	1.86%	10.26%	5.36%	15.62%	7.23%	**41.72%**
Underway	1.86%	7.69%	7.23%	1.63%	3.50%	2.33%	**24.24%**
Maneuvering	0.00%	1.40%	2.10%	0.93%	15.38%	10.26%	**30.07%**
Total	**3.50%**	**11.66%**	**20.98%**	**8.39%**	**34.73%**	**20.75%**	**100.00%**

The percentages of incidents by activity for each vessel type are shown in Table 25. For example, 4.5% of the incidents while at dock involve general cargo vessels. Table 26 shows the percentages of incidents within each vessel type. For example, nearly 49% of tanker incidents occur while docked.

Table 25: VTS Vessel Incidents by Activity 1995 – 2010 (% VTS Incidents within Activity)

Activity	Percentage of Incidents within Activity						
	Bulk	General Cargo	Tanker	Tug/ Tank Barge	Pass/ Fish	Tug	Total
Anchored	5.88%	17.65%	35.29%	11.76%	5.88%	23.53%	**100.00%**
Docked	3.35%	4.47%	24.58%	12.85%	37.43%	17.32%	**100.00%**
Underway	7.69%	31.73%	29.81%	6.73%	14.42%	9.62%	**100.00%**
Maneuvering	0.00%	4.65%	6.98%	3.10%	51.16%	34.11%	**100.00%**
Total	**3.50%**	**11.66%**	**20.98%**	**8.39%**	**34.73%**	**20.75%**	**100.00%**

Table 26: VTS Vessel Incidents by Activity 1995 – 2010 (% VTS Incidents within Vessel Type)

Activity	Percentage of Incidents within Vessel Type						
	Bulk	General Cargo	Tanker	Tug/ Tank Barge	Pass/ Fish	Tug	Total
Anchored	6.67%	6.00%	6.67%	5.56%	0.67%	4.49%	**3.96%**
Docked	40.00%	16.00%	48.89%	63.89%	44.97%	34.83%	**41.72%**
Underway	53.33%	66.00%	34.44%	19.44%	10.07%	11.24%	**24.24%**
Maneuvering	0.00%	12.00%	10.00%	11.11%	44.30%	49.44%	**30.07%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Breakdown by Cause and Activity for VTS Vessel Types

Vessel incidents were further broken down by cause and activity for each vessel type within the VTS vessels, as shown in Tables 27 through 32. The percentages are percentages of all incidents *within that vessel type* that occurred during 1995 – 2010. The averages are average incidents per year.

Table 27: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Bulkers

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	1	7%	0.06	0	0%	0.00
Collision	0	0%	0.00	0	0%	0.00	1	7%	0.06	0	0%	0.00
Grounding	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Other	1	7%	0.06	4	27%	0.25	6	40%	0.38	0	0%	0.00
Bunker	0	0%	0.00	2	13%	0.13	0	0%	0.00	0	0%	0.00
Transfer	0	0%	0.00	2	13%	0.13	0	0%	0.00	0	0%	0.00
Total	**1**	**7%**	**0.06**	**6**	**40%**	**0.38**	**8**	**53%**	**0.50**	**0**	**0%**	**0.00**

Table 28: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – General Cargo Vessels

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	0	0%	0.00	1	2%	0.06
Collision	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Grounding	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Other	2	4%	0.13	6	12%	0.38	33	66%	2.06	5	10%	0.31

Table 28: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – General Cargo Vessels

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Bunker	1	2%	0.06	2	4%	0.13	0	0%	0.00	0	0%	0.00
Transfer	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Total	**3**	**6%**	**0.19**	**8**	**16%**	**0.50**	**33**	**66%**	**2.06**	**6**	**12%**	**0.38**

Table 29: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Tankers

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	0	0%	0.00	2	2%	0.13
Collision	0	0%	0.00	0	0%	0.00	1	1%	0.06	0	0%	0.00
Grounding	0	0%	0.00	0	0%	0.00	2	2%	0.13	0	0%	0.00
Other	3	3%	0.19	20	22%	1.25	28	31%	1.75	7	8%	0.44
Bunker	0	0%	0.00	1	1%	0.06	0	0%	0.00	0	0%	0.00
Transfer	3	3%	0.19	23	26%	1.44	0	0%	0.00	0	0%	0.00
Total	**6**	**7%**	**0.38**	**44**	**49%**	**2.75**	**31**	**34%**	**1.94**	**9**	**10%**	**0.56**

Table 30: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Tug and Tank Barges

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	0	0%	0.00	1	3%	0.06
Collision	0	0%	0.00	0	0%	0.00	2	6%	0.13	2	6%	0.13
Grounding	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Other	2	6%	0.13	11	31%	0.69	5	14%	0.31	1	3%	0.06
Bunker	0	0%	0.00	3	9%	0.19	0	0%	0.00	0	0%	0.00
Transfer	0	0%	0.00	9	27%	0.56	0	0%	0.00	0	0%	0.00
Total	**2**	**6%**	**0.13**	**23**	**64%**	**1.44**	**7**	**19%**	**0.44**	**4**	**11%**	**0.25**

Table 31: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Passenger/Fishing Vessels

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	1	1%	0.06	7	5%	0.44
Collision	0	0%	0.00	0	0%	0.00	1	1%	0.06	0	0%	0.00
Grounding	0	0%	0.00	0	0%	0.00	11	7%	0.69	0	0%	0.00
Other	1	1%	0.06	52	35%	3.25	53	36%	3.31	8	5%	0.50
Bunker	0	0%	0.00	15	10%	0.94	0	0%	0.00	0	0%	0.00
Transfer	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Total	**1**	**1%**	**0.06**	**67**	**45%**	**4.19**	**66**	**44%**	**4.13**	**15**	**10%**	**0.10**

Table 32: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Tugs

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	0	0%	0.00	0	0%	0.00	1	1%	0.06	4	4%	0.25
Collision	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Grounding	0	0%	0.00	0	0%	0.00	2	2%	0.13	0	0%	0.00
Other	2	2%	0.13	16	18%	1.00	41	46%	2.56	6	7%	0.38

Table 32: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Tugs

Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Bunker	2	2%	0.13	15	17%	0.94	0	0%	0.00	0	0%	0.00
Transfer	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00
Total	**4**	**4%**	**0.25**	**31**	**35%**	**1.94**	**44**	**49%**	**2.75**	**10**	**11%**	**0.11**

Table 33 summarizes vessel incidents by vessel type, cause, and activity.

Table 33: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity

Vessel Type	Activity	Cause	Avg. Per Year	Return Years
Bulker	**Anchored**	**Allision**	0.00	n/a
Bulker	**Anchored**	**Collision**	0.00	n/a
Bulker	**Anchored**	**Grounding**	0.00	n/a
Bulker	**Anchored**	**Other**	0.06	16.7
Bulker	**Anchored**	**Transfer**	0.00	n/a
Bulker	**Anchored**	**Bunker**	0.00	n/a
Bulker	**Anchored**	**Total**	**0.06**	**16.7**
Bulker	**Docked**	**Allision**	0.00	n/a
Bulker	**Docked**	**Collision**	0.00	n/a
Bulker	**Docked**	**Grounding**	0.00	n/a
Bulker	**Docked**	**Other**	0.25	4.0
Bulker	**Docked**	**Bunker**	0.13	7.7
Bulker	**Docked**	**Transfer**	0.13	7.7
Bulker	**Anchored**	**Total**	**0.38**	**2.6**
Bulker	**Underway**	**Allision**	0.06	16.7
Bulker	**Underway**	**Collision**	0.06	16.7
Bulker	**Underway**	**Grounding**	0.00	n/a
Bulker	**Underway**	**Other**	0.38	2.6
Bulker	**Underway**	**Bunker**	0.00	n/a
Bulker	**Underway**	**Transfer**	0.00	n/a
Bulker	**Anchored**	**Total**	**0.50**	**2.0**
Bulker	**Maneuvering**	**Allision**	0.00	n/a
Bulker	**Maneuvering**	**Collision**	0.00	n/a
Bulker	**Maneuvering**	**Grounding**	0.00	n/a
Bulker	**Maneuvering**	**Other**	0.00	n/a
Bulker	**Maneuvering**	**Bunker**	0.00	n/a
Bulker	**Maneuvering**	**Transfer**	0.00	n/a
Bulker	**Maneuvering**	**Total**	**0.00**	**n/a**
General Cargo	**Anchored**	**Allision**	0.00	n/a
General Cargo	**Anchored**	**Collision**	0.00	n/a
General Cargo	**Anchored**	**Grounding**	0.00	n/a
General Cargo	**Anchored**	**Other**	0.13	7.7
General Cargo	**Anchored**	**Bunker**	0.06	16.7
General Cargo	**Anchored**	**Transfer**	0.00	n/a
General Cargo	**Anchored**	**Total**	**0.19**	**5.3**
General Cargo	**Docked**	**Allision**	0.00	n/a
General Cargo	**Docked**	**Collision**	0.00	n/a
General Cargo	**Docked**	**Grounding**	0.00	n/a
General Cargo	**Docked**	**Other**	0.38	2.6
General Cargo	**Docked**	**Bunker**	0.13	7.7
General Cargo	**Docked**	**Transfer**	0.00	n/a

Table 33: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity

Vessel Type	Activity	Cause	Avg. Per Year	Return Years
General Cargo	Docked	Total	**0.50**	**2.0**
General Cargo	Underway	Allision	0.00	n/a
General Cargo	Underway	Collision	0.00	n/a
General Cargo	Underway	Grounding	0.00	n/a
General Cargo	Underway	Other	2.06	0.5
General Cargo	Underway	Bunker	0.00	n/a
General Cargo	Underway	Transfer	0.00	n/a
General Cargo	Underway	Total	**2.06**	**0.5**
General Cargo	Maneuvering	Allision	0.06	16.7
General Cargo	Maneuvering	Collision	0.00	n/a
General Cargo	Maneuvering	Grounding	0.00	n/a
General Cargo	Maneuvering	Other	0.31	3.2
General Cargo	Maneuvering	Bunker	0.00	n/a
General Cargo	Maneuvering	Transfer	0.00	n/a
General Cargo	Maneuvering	Total	**0.38**	**2.6**
Tanker	Anchored	Allision	0.00	n/a
Tanker	Anchored	Collision	0.00	n/a
Tanker	Anchored	Grounding	0.00	n/a
Tanker	Anchored	Other	0.19	5.3
Tanker	Anchored	Bunker	0.00	n/a
Tanker	Anchored	Transfer	0.19	5.3
Tanker	Anchored	Total	**0.38**	**2.6**
Tanker	Docked	Allision	0.00	n/a
Tanker	Docked	Collision	0.00	n/a
Tanker	Docked	Grounding	0.00	n/a
Tanker	Docked	Other	1.25	0.8
Tanker	Docked	Bunker	0.06	16.7
Tanker	Docked	Transfer	1.44	0.7
Tanker	Docked	Total	**2.75**	**0.4**
Tanker	Underway	Allision	0.00	n/a
Tanker	Underway	Collision	0.06	16.7
Tanker	Underway	Grounding	0.13	7.7
Tanker	Underway	Other	1.75	0.6
Tanker	Underway	Bunker	0.00	n/a
Tanker	Underway	Transfer	0.00	n/a
Tanker	Underway	Total	**1.94**	**0.5**
Tanker	Maneuvering	Allision	0.13	7.7
Tanker	Maneuvering	Collision	0.00	n/a
Tanker	Maneuvering	Grounding	0.00	n/a
Tanker	Maneuvering	Other	0.44	2.3
Tanker	Maneuvering	Bunker	0.00	n/a
Tanker	Maneuvering	Transfer	0.00	n/a
Tanker	Maneuvering	Total	**0.56**	**1.8**
Tug and Tank Barge	Anchored	Allision	0.00	n/a
Tug and Tank Barge	Anchored	Collision	0.00	n/a
Tug and Tank Barge	Anchored	Grounding	0.00	n/a
Tug and Tank Barge	Anchored	Other	0.13	7.7
Tug and Tank Barge	Anchored	Bunker	0.00	n/a
Tug and Tank Barge	Anchored	Transfer	0.00	n/a
Tug and Tank Barge	Anchored	Total	**0.13**	**7.7**
Tug and Tank Barge	Docked	Allision	0.00	n/a

Table 33: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity

Vessel Type	Activity	Cause	Avg. Per Year	Return Years
Tug and Tank Barge	Docked	Collision	0.00	n/a
Tug and Tank Barge	Docked	Grounding	0.00	n/a
Tug and Tank Barge	Docked	Other	0.69	1.4
Tug and Tank Barge	Docked	Bunker	0.19	
Tug and Tank Barge	Docked	Transfer	0.56	1.3
Tug and Tank Barge	Docked	Total	**1.44**	**0.7**
Tug and Tank Barge	Underway	Allision	0.00	n/a
Tug and Tank Barge	Underway	Collision	0.13	7.7
Tug and Tank Barge	Underway	Grounding	0.00	n/a
Tug and Tank Barge	Underway	Other	0.31	3.2
Tug and Tank Barge	Underway	Bunker	0.00	n/a
Tug and Tank Barge	Underway	Transfer	0.00	n/a
Tug and Tank Barge	Underway	Total	**0.44**	2.3
Tug and Tank Barge	Maneuvering	Allision	0.06	16.7
Tug and Tank Barge	Maneuvering	Collision	0.13	7.7
Tug and Tank Barge	Maneuvering	Grounding	0.00	n/a
Tug and Tank Barge	Maneuvering	Other	0.06	16.7
Tug and Tank Barge	Maneuvering	Bunker	0.00	n/a
Tug and Tank Barge	Maneuvering	Transfer	0.00	n/a
Tug and Tank Barge	Maneuvering	Total	**0.25**	**4.0**
Passenger/Fishing	Anchored	Allision	0.00	n/a
Passenger/Fishing	Anchored	Collision	0.00	n/a
Passenger/Fishing	Anchored	Grounding	0.00	n/a
Passenger/Fishing	Anchored	Other	0.06	16.7
Passenger/Fishing	Anchored	Bunker	0.00	n/a
Passenger/Fishing	Anchored	Transfer	0.00	n/a
Passenger/Fishing	Anchored	Total	**0.06**	**16.7**
Passenger/Fishing	Docked	Allision	0.00	n/a
Passenger/Fishing	Docked	Collision	0.00	n/a
Passenger/Fishing	Docked	Grounding	0.00	n/a
Passenger/Fishing	Docked	Other	3.25	0.3
Passenger/Fishing	Docked	Bunker	0.94	1.1
Passenger/Fishing	Docked	Transfer	0.00	n/a
Passenger/Fishing	Docked	Total	**4.19**	**0.2**
Passenger/Fishing	Underway	Allision	0.06	16.7
Passenger/Fishing	Underway	Collision	0.06	16.7
Passenger/Fishing	Underway	Grounding	0.69	1.4
Passenger/Fishing	Underway	Other	3.31	0.3
Passenger/Fishing	Underway	Bunker	0.00	n/a
Passenger/Fishing	Underway	Transfer	0.00	n/a
Passenger/Fishing	Underway	Total	**4.13**	**0.2**
Passenger/Fishing	Maneuvering	Allision	0.44	2.3
Passenger/Fishing	Maneuvering	Collision	0.00	n/a
Passenger/Fishing	Maneuvering	Grounding	0.00	n/a
Passenger/Fishing	Maneuvering	Other	0.50	2.0
Passenger/Fishing	Maneuvering	Bunker	0.00	n/a
Passenger/Fishing	Maneuvering	Transfer	0.00	n/a
Passenger/Fishing	Maneuvering	Total	**0.10**	**10.0**
Tug	Anchored	Allision	0.00	n/a
Tug	Anchored	Collision	0.00	n/a
Tug	Anchored	Grounding	0.00	n/a

Table 33: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity				
Vessel Type	Activity	Cause	Avg. Per Year	Return Years
Tug	**Anchored**	**Other**	0.13	7.7
Tug	**Anchored**	**Bunker**	0.13	7.7
Tug	**Anchored**	**Transfer**	0.00	n/a
Tug	**Anchored**	**Total**	**0.25**	**4.0**
Tug	**Docked**	**Allision**	0.00	n/a
Tug	**Docked**	**Collision**	0.00	n/a
Tug	**Docked**	**Grounding**	0.00	n/a
Tug	**Docked**	**Other**	1.00	1.0
Tug	**Docked**	**Bunker**	0.94	1.1
Tug	**Docked**	**Transfer**	0.00	n/a
Tug	**Docked**	**Total**	**1.94**	**0.5**
Tug	**Underway**	**Allision**	0.06	16.7
Tug	**Underway**	**Collision**	0.00	n/a
Tug	**Underway**	**Grounding**	0.13	7.7
Tug	**Underway**	**Other**	2.56	0.4
Tug	**Underway**	**Bunker**	0.00	n/a
Tug	**Underway**	**Transfer**	0.00	n/a
Tug	**Underway**	**Total**	**2.75**	**0.4**
Tug	**Maneuvering**	**Allision**	0.25	4.0
Tug	**Maneuvering**	**Collision**	0.00	n/a
Tug	**Maneuvering**	**Grounding**	0.00	n/a
Tug	**Maneuvering**	**Other**	0.38	2.6
Tug	**Maneuvering**	**Bunker**	0.00	n/a
Tug	**Maneuvering**	**Transfer**	0.00	n/a
Tug	**Maneuvering**	**Total**	**0.11**	**9.1**
All VTS Vessels	**Anchored**	**Allision**	0.00	n/a
All VTS Vessels	**Anchored**	**Collision**	0.00	n/a
All VTS Vessels	**Anchored**	**Grounding**	0.00	n/a
All VTS Vessels	**Anchored**	**Other**	0.70	1.4
All VTS Vessels	**Anchored**	**Bunker**	0.19	5.3
All VTS Vessels	**Anchored**	**Transfer**	0.00	n/a
All VTS Vessels	**Anchored**	**Total**	**1.07**	**0.9**
All VTS Vessels	**Docked**	**Allision**	0.00	n/a
All VTS Vessels	**Docked**	**Collision**	0.00	n/a
All VTS Vessels	**Docked**	**Grounding**	0.00	n/a
All VTS Vessels	**Docked**	**Other**	6.82	0.1
All VTS Vessels	**Docked**	**Bunker**	2.38	0.4
All VTS Vessels	**Docked**	**Transfer**	2.0	0.5
All VTS Vessels	**Docked**	**Total**	**11.20**	**0.1**
All VTS Vessels	**Underway**	**Allision**	0.19	5.3
All VTS Vessels	**Underway**	**Collision**	0.31	3.2
All VTS Vessels	**Underway**	**Grounding**	0.94	1.1
All VTS Vessels	**Underway**	**Other**	10.38	0.1
All VTS Vessels	**Underway**	**Bunker**	0.00	n/a
All VTS Vessels	**Underway**	**Transfer**	0.00	n/a
All VTS Vessels	**Underway**	**Total**	**11.82**	**0.1**
All VTS Vessels	**Maneuvering**	**Allision**	0.94	1.1
All VTS Vessels	**Maneuvering**	**Collision**	0.13	7.7
All VTS Vessels	**Maneuvering**	**Grounding**	0.00	n/a
All VTS Vessels	**Maneuvering**	**Other**	1.69	0.6
All VTS Vessels	**Maneuvering**	**Bunker**	0.00	n/a

Table 33: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity

Vessel Type	Activity	Cause	Avg. Per Year	Return Years
All VTS Vessels	**Maneuvering**	**Transfer**	0.00	n/a
All VTS Vessels	**Maneuvering**	**Total**	**2.75**	**0.4**

Locations of Incidents by Cause

The locations of VTS vessel incidents by cause are shown in Table 34. Percentages of VTS vessel incidents by subarea are shown in Table 35. Annual incident rates are shown in Table 36.

Table 34: Incidents Involving VTS Vessels by Cause and Subarea 1995 – 2010

Year	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
Allision	0	4	6	4	0	2	2	**18**
Collision	2	2	1	0	0	0	2	**7**
Grounding	8	2	3	1	0	0	1	**15**
Other	42	87	75	45	4	9	51	**313**
Bunker	1	5	12	17	0	0	6	**41**
Transfer	0	3	11	0	0	0	21	**35**
Total	**53**	**103**	**108**	**67**	**4**	**11**	**83**	**429**

Table 35: Percentage of VTS Vessel Incidents by Cause and Subarea 1995 – 2010

Year	% of All VTS Vessel Incidents							
	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
Allision	0.0%	0.9%	1.4%	0.9%	0.0%	0.5%	0.5%	**4.2%**
Collision	0.5%	0.5%	0.2%	0.0%	0.0%	0.0%	0.5%	**1.6%**
Grounding	1.9%	0.5%	0.7%	0.2%	0.0%	0.0%	0.2%	**3.5%**
Other	9.8%	20.3%	17.5%	10.5%	0.9%	2.1%	11.9%	**73.0%**
Bunker	0.2%	1.2%	2.8%	4.0%	0.0%	0.0%	1.4%	**9.6%**
Transfer	0.0%	0.7%	2.6%	0.0%	0.0%	0.0%	4.9%	**8.2%**
Total	**12.4%**	**24.0%**	**25.2%**	**15.6%**	**0.9%**	**2.6%**	**19.3%**	**100.0%**

Table 36: Annual Incidence of VTS Vessel Incidents by Cause and Subarea 1995 – 2010

Year	Annual Number of Incidents by Cause and Subarea							
	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait Boundary Pass	Rosario Strait	Cherry Point	Total
Allision	0.00	0.25	0.38	0.25	0.00	0.13	0.13	**1.13**
Collision	0.13	0.13	0.06	0.00	0.00	0.00	0.13	**0.44**
Grounding	0.50	0.13	0.19	0.06	0.00	0.00	0.06	**0.94**
Other	2.63	5.44	4.69	2.81	0.25	0.56	3.19	**19.56**
Bunker	0.06	0.31	0.75	1.06	0.00	0.00	0.38	**2.56**
Transfer	0.00	0.19	0.69	0.00	0.00	0.00	1.31	**2.19**
Total	**3.31**	**6.44**	**6.75**	**4.19**	**0.25**	**0.69**	**5.19**	**26.81**

Figures 14 through 19 show the locations of incidents within the subareas by incident cause for VTS vessel incidents.

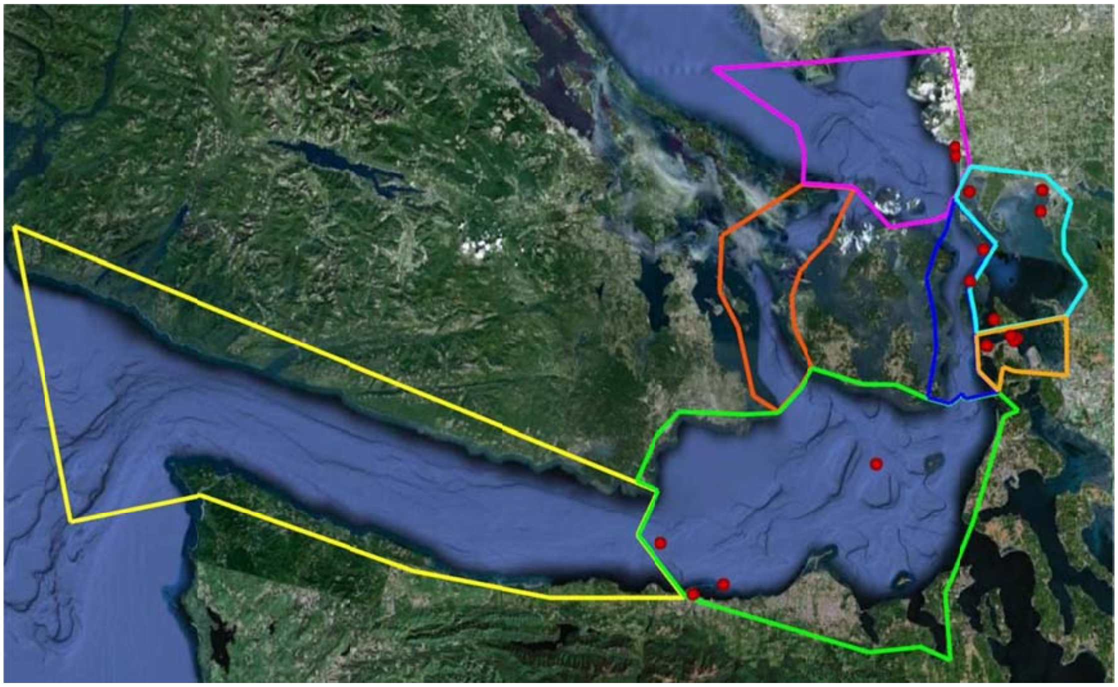

Figure 14: Map of Locations of Allisions for VTS Vessels 1995 – 2010

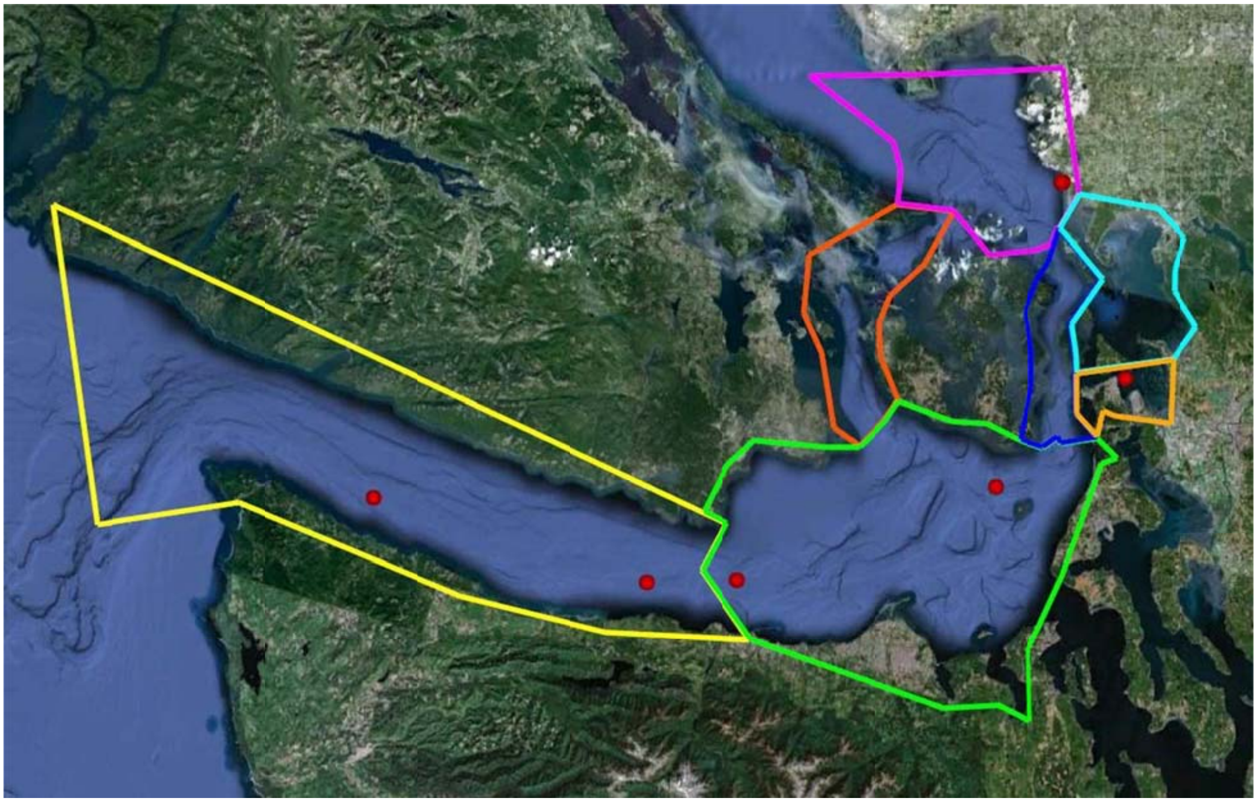

Figure 15: Map of Locations of Collisions for VTS Vessels 1995 – 2010

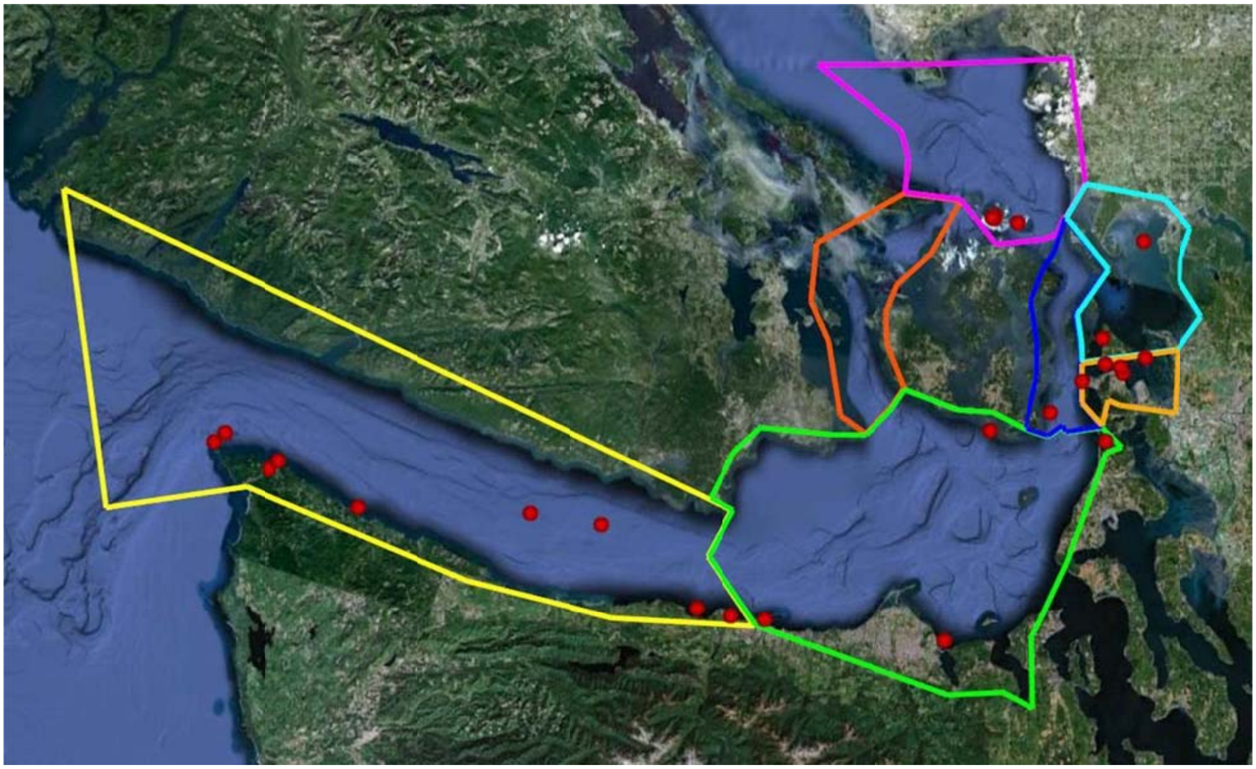

Figure 16: Map of Locations of Groundings for VTS Vessels 1995 – 2010

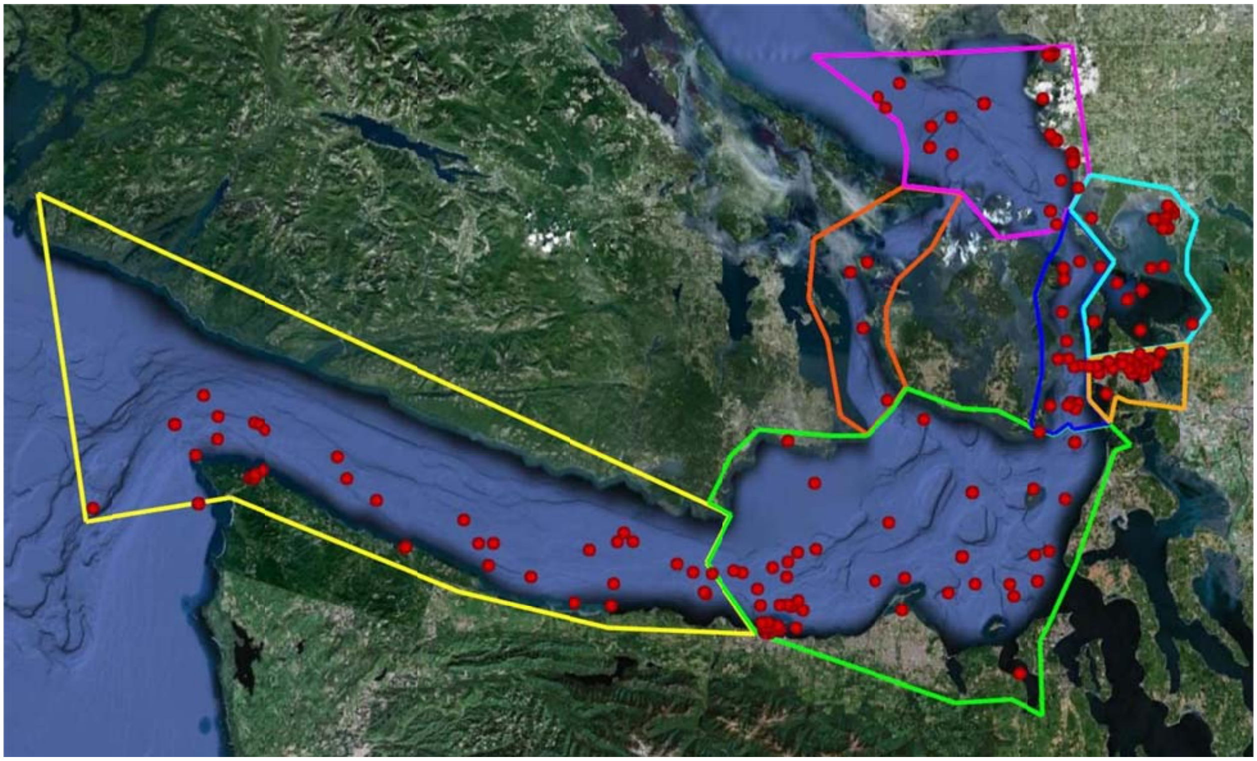

Figure 17: Map of Locations of Other, Non-Impact Incidents for VTS Vessels 1995 – 2010

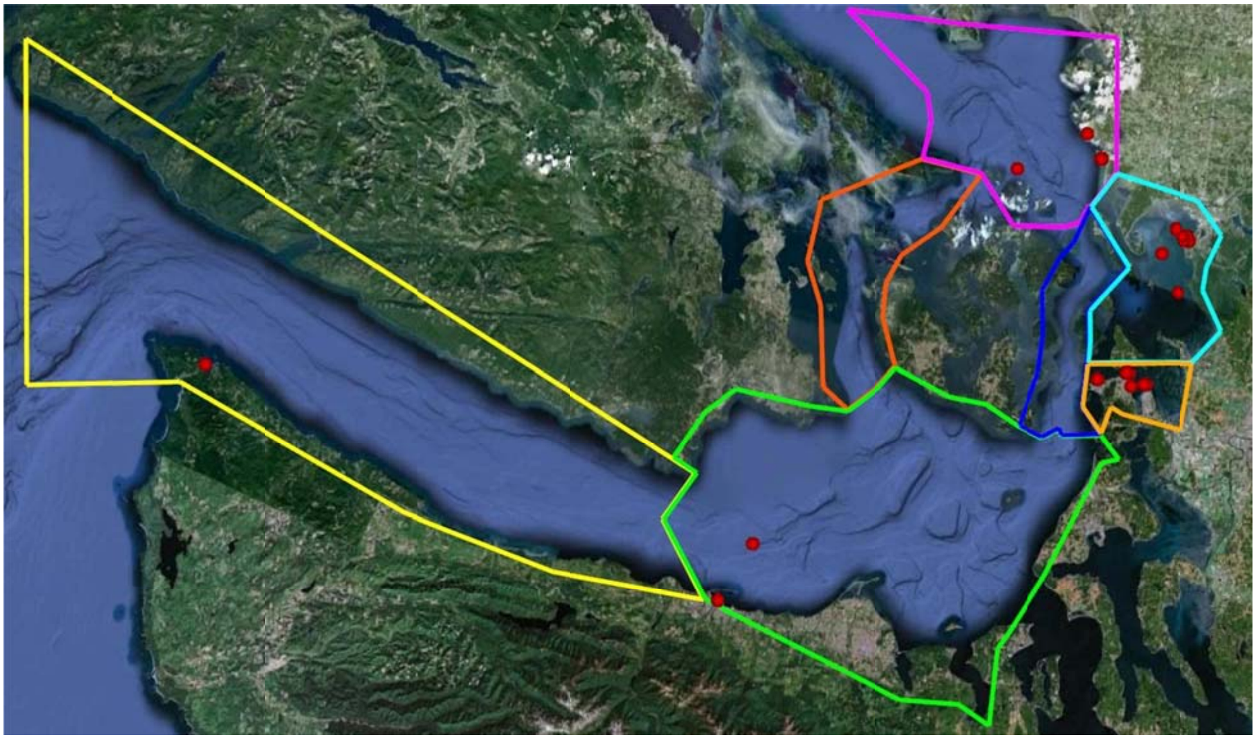

Figure 18: Map of Locations of Bunker Errors for VTS Vessels 1995 – 2010

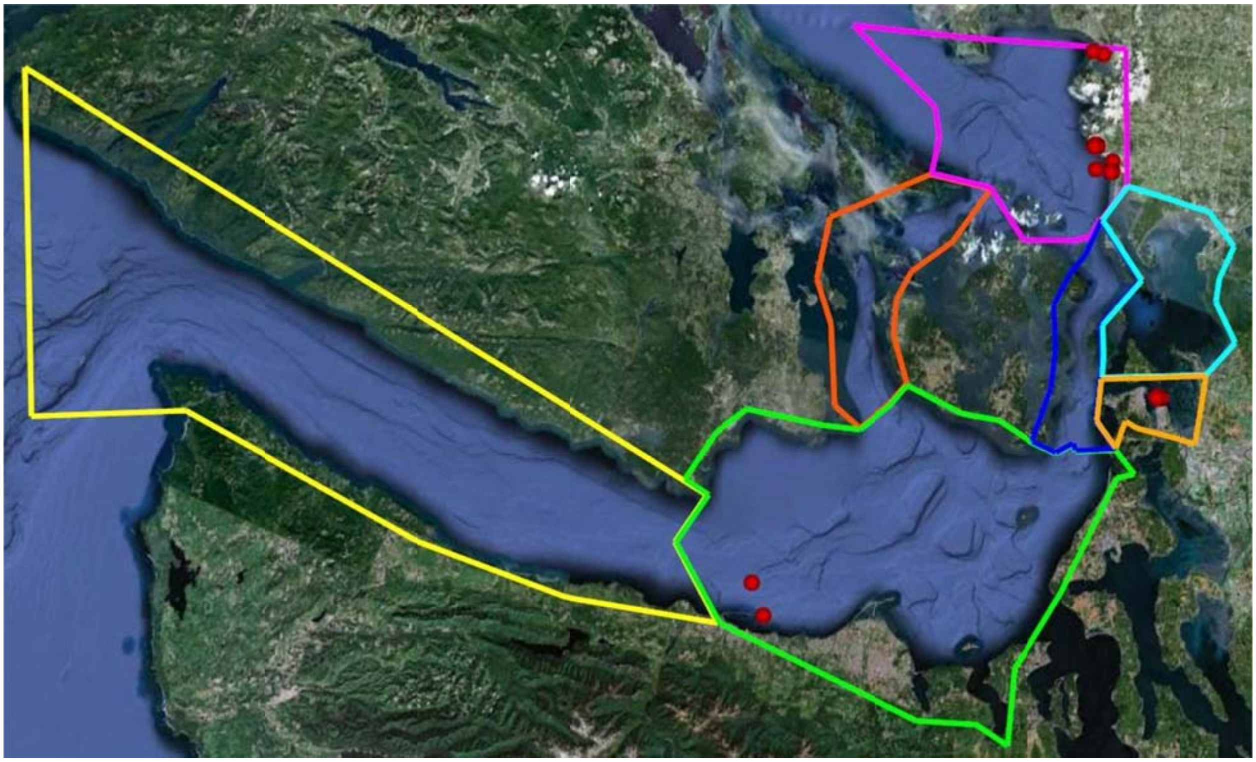

Figure 19: Map of Locations of Transfer Errors for VTS Vessels 1995 – 2010

Figures 20 through 25 show locations of VTS vessel incidents by vessel type and cause.

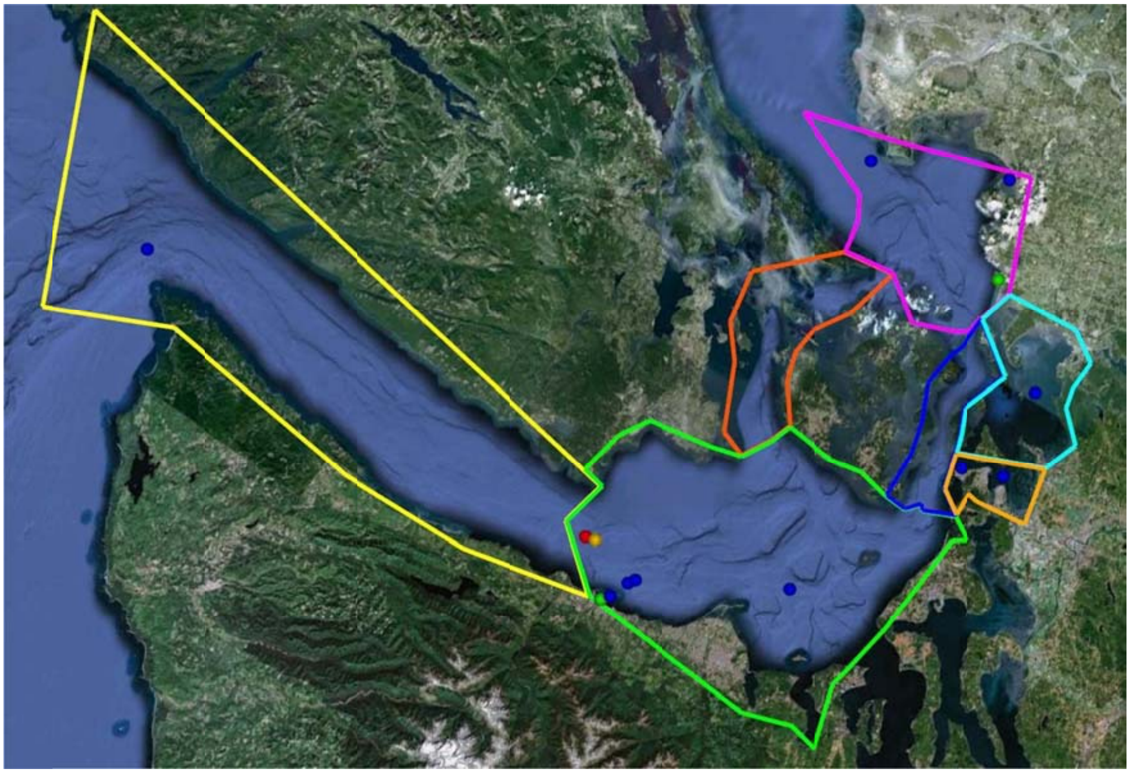

Figure 20: Map of Bulker Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; and blue = other, non-impact incidents.

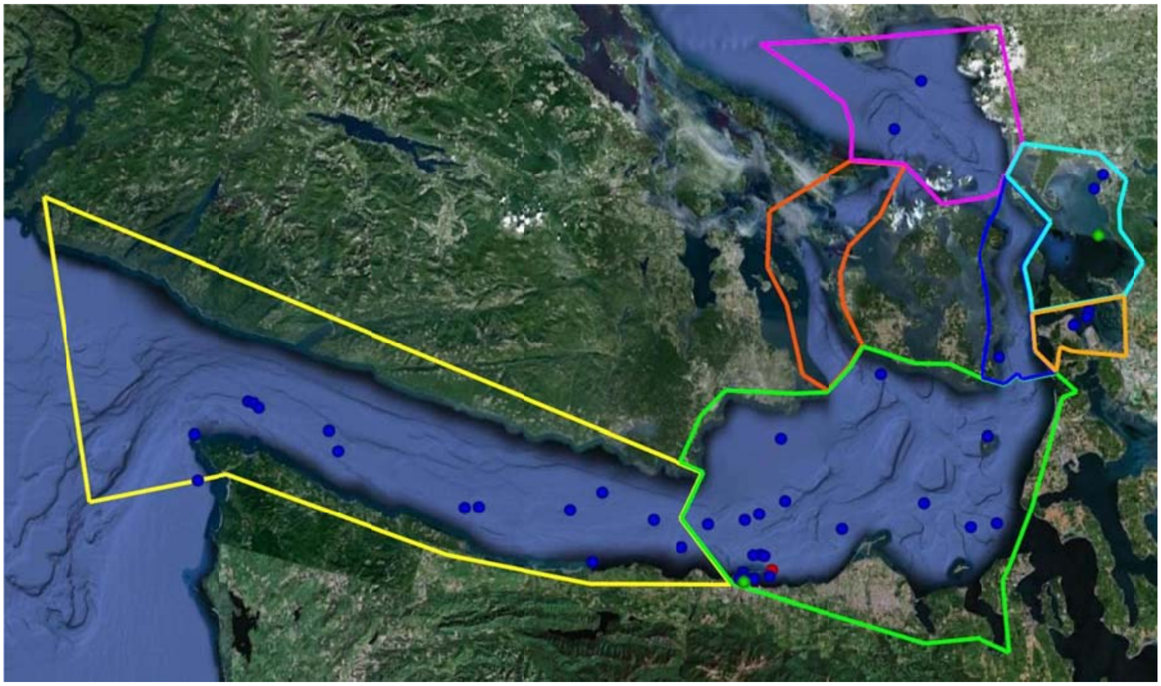

Figure 21: Map of General Cargo Vessel Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; and blue = other, non-impact incidents.

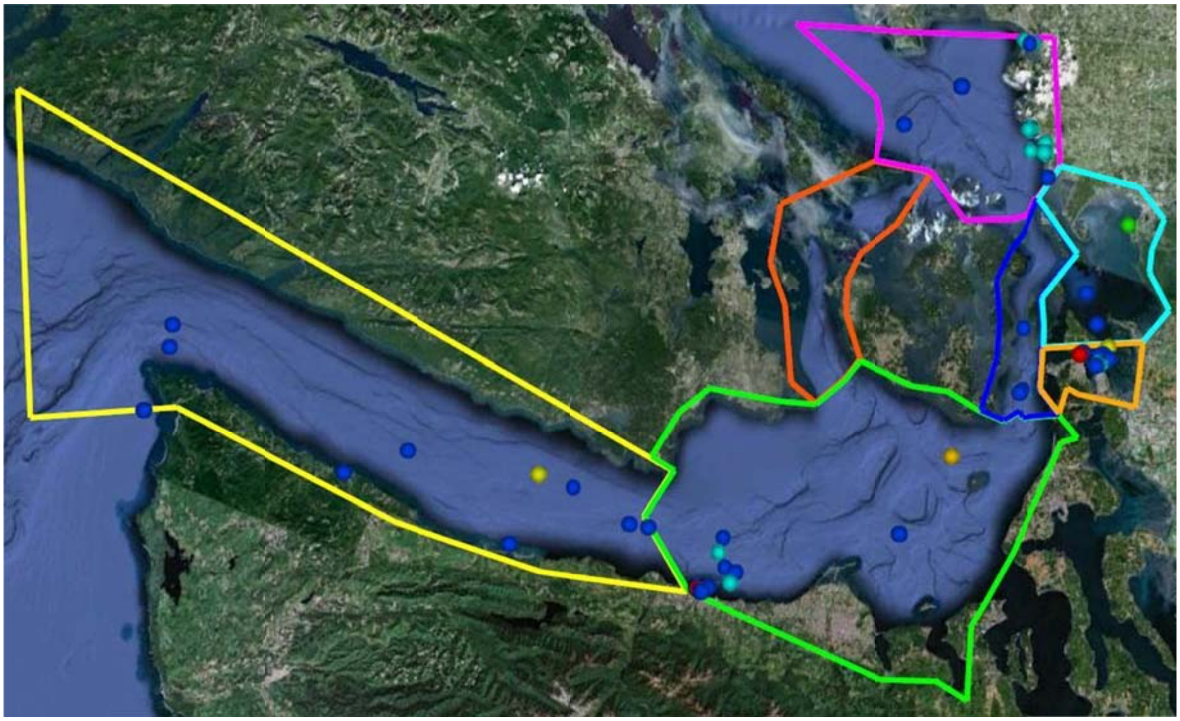

Figure 22: Map of Tanker Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; aqua = cargo transfer errors; and blue = other, non-impact incidents.

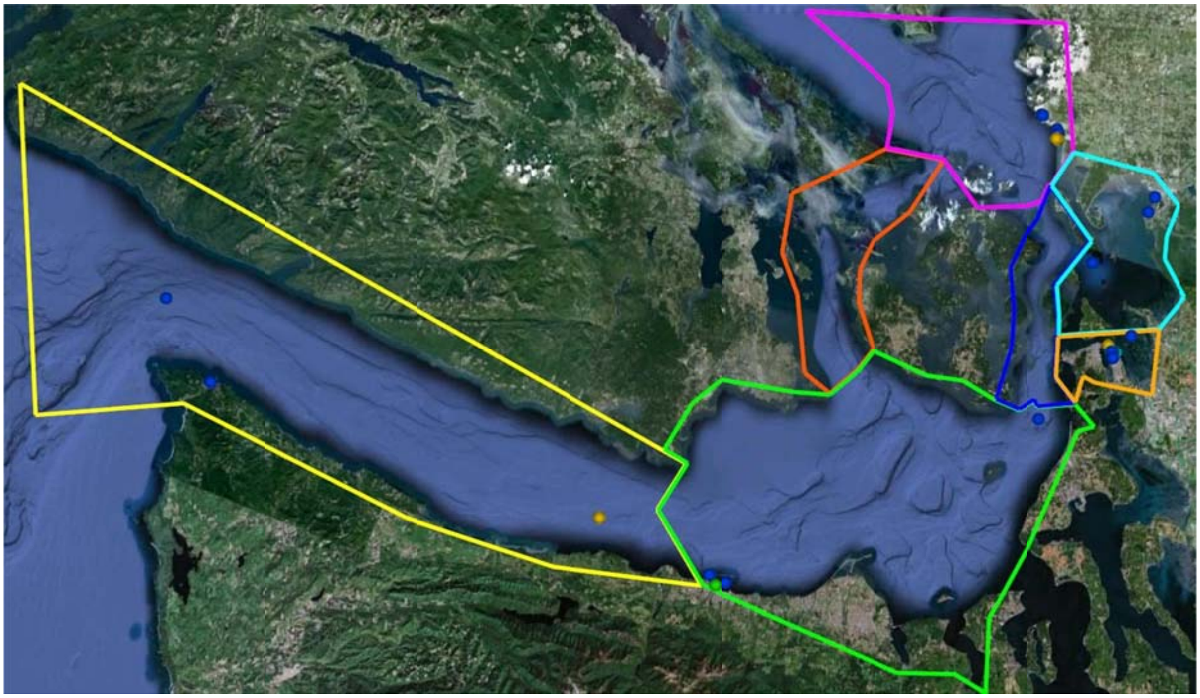

Figure 23: Map of Tug and Tank Barge Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; aqua = cargo transfer errors; and blue = other, non-impact incidents.

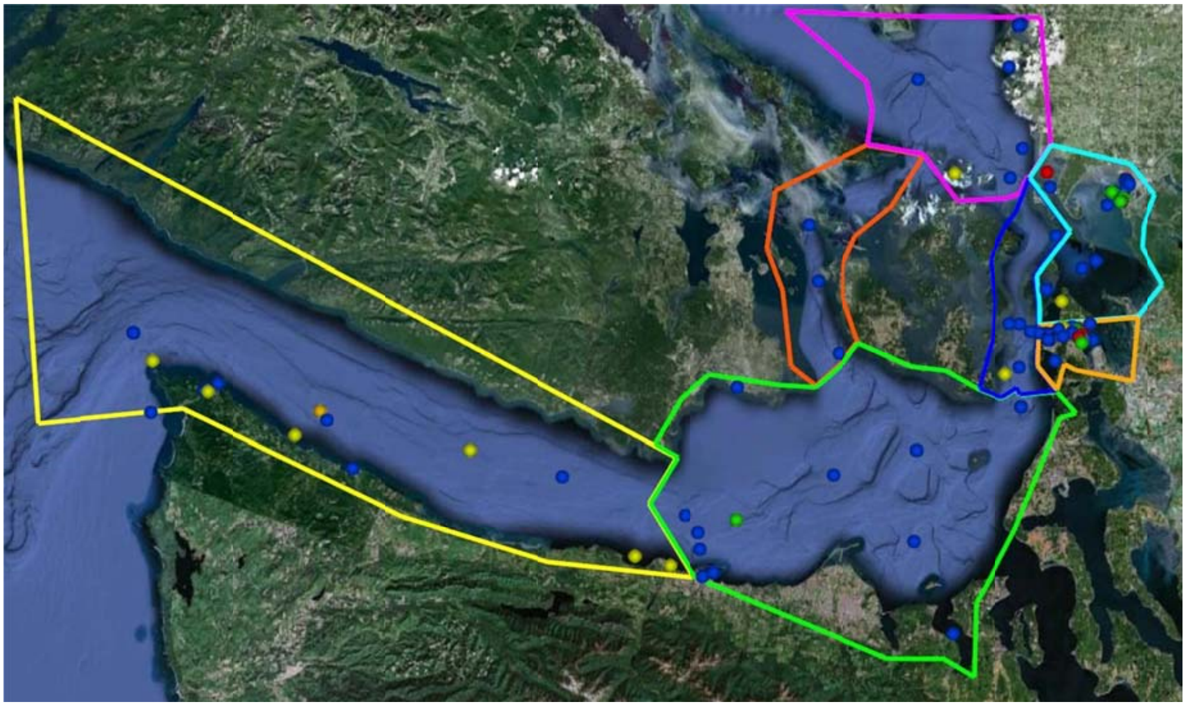

Figure 24: Map of Passenger/Fishing Vessel Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; and blue = other, non-impact incidents.

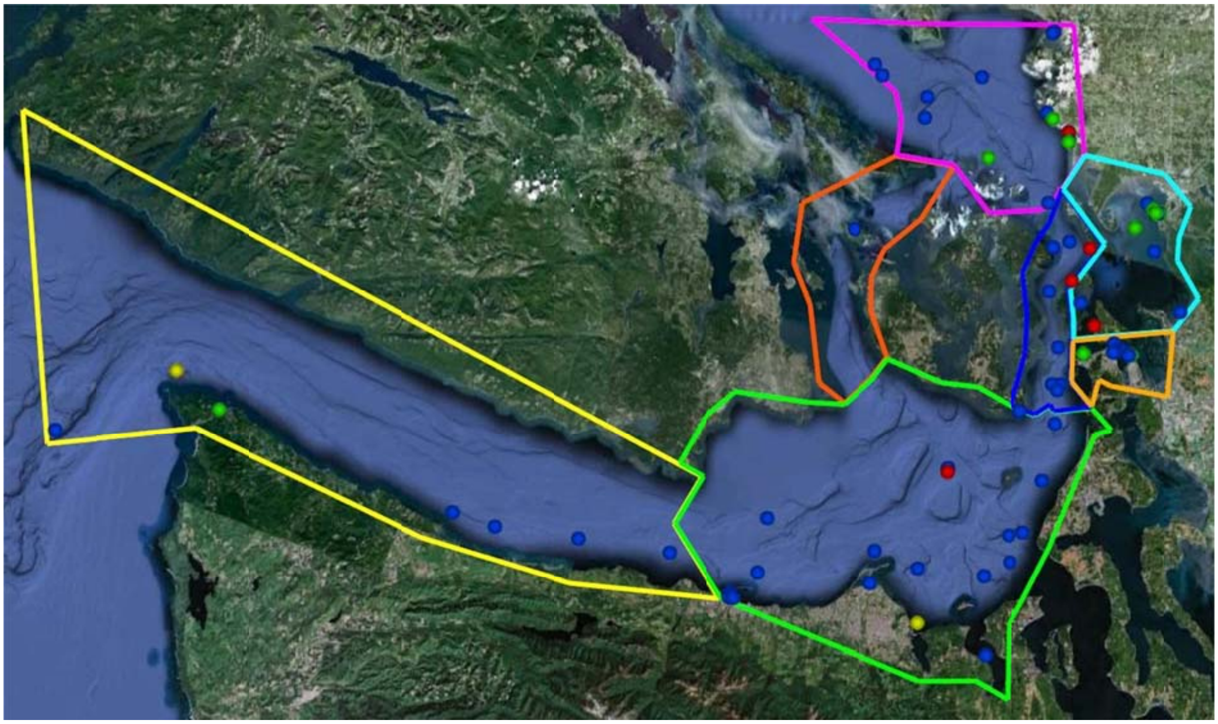

Figure 25: Map of Tug Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Red = allisions; orange = collisions; yellow = groundings; green = bunker errors; and blue = other, non-impact incidents.

Probability of Spillage for VTS Vessel Incidents

When a vessel incident occurs there may or may not be a spill that results. The VTS vessel incidents were analyzed with respect to vessel type and reported cause with respect to the numbers of incidents that resulted in spills. The probability of spillage was calculated as the proportion of incidents that involved spillage of any volume out of all of the incidents for that vessel type and cause as in Table 37. Anecdotally, spills are reported more consistently, than incidents without a spill. Note that if the reporting rate for spills is higher than the reporting rate for incidents without spills, then the calculated probability of spillage would be higher than if all incidents with and without a spill were reported with the same consistency.

Table 37: Probability of Spillage Given Incident for 1995 – 2010 VTS Vessels

Vessel Type	Cause	Incidents with Spill	Incidents with No Spill	Total Incidents	Probability Spillage
Bulker	**Allision**	0	1	**1**	0.00
	Collision	0	1	**1**	0.00
	Grounding	0	0	**0**	-
	Other, Non-Impact	2	9	**11**	0.18
	Bunker Error	1	1	**2**	0.50
	Transfer Error	0	0	**0**	n/a
	All	**3**	**12**	**15**	**0.20**
General Cargo Vessel	**Allision**	0	1	**1**	0.00
	Collision	0	0	**0**	-
	Grounding	0	0	**0**	-
	Other, Non-Impact	11	35	**47**	0.23
	Bunker Error	3	0	**3**	1.00
	Transfer Error	0	0	**0**	n/a
	All	**14**	**36**	**50**	**0.28**
Tug and Tank Barges	**Allision**	0	1	**1**	0.00
	Collision	2	2	**4**	0.50
	Grounding	0	0	**0**	-
	Other, Non-Impact	15	4	**19**	0.79
	Bunker Error	3	0	**0**	1.00
	Transfer Error	7	2	**9**	0.78
	All	**27**	**9**	**36**	**0.75**
Tankers	**Allision**	1	1	**2**	0.50
	Collision	0	1	**1**	0.00
	Grounding	0	2	**2**	0.00
	Other, Non-Impact	16	42	**58**	0.28
	Bunker Error	1	0	**1**	1.00
	Transfer Error	24	2	**26**	0.92
	All	**42**	**48**	**90**	**0.47**
Passenger/Fishing Vessels	**Allision**	0	8	**8**	0.00
	Collision	0	1	**1**	0.00
	Grounding	5	6	**11**	0.45
	Other, Non-Impact	47	67	**114**	0.41
	Bunker Error	4	11	**15**	0.27
	Transfer Error	0	0	**0**	n/a
	All	**56**	**93**	**149**	**0.38**
Tugs	**Allision**	0	5	**5**	0.00
	Collision	0	0	**0**	n/a
	Grounding	1	1	**2**	0.50

Table 37: Probability of Spillage Given Incident for 1995 – 2010 VTS Vessels

Vessel Type	Cause	Incidents with Spill	Incidents with No Spill	Total Incidents	Probability Spillage
	Other, Non-Impact	25	40	**65**	0.38
	Bunker Error	14	3	**17**	0.82
	Transfer Error	0	0	**0**	n/a
	All	**40**	**49**	**89**	**0.45**
All VTS Vessels	**Allision**	1	17	**18**	0.06
	Collision	2	5	**7**	0.29
	Grounding	6	9	**15**	0.40
	Other, Non-Impact	116	197	**313**	0.37
	Bunker Error	33	8	**41**	0.80
	Transfer Error	31	4	**35**	0.89
	All	**189**	**240**	**429**	**0.44**

Key Findings

A total of 1,116 vessel incidents that occurred in the study area during the years 1995 through 2010 were analyzed. The largest percentage (62%) of vessels fell into the “Miscellaneous” category, which included fishing vessels, pleasure craft, workboats, and other vessels that less than 60 feet in length, freight barges of any size, as well as all vessels that may exceed 60 feet for which there are no traffic data available in the traffic study. The vessels for which there are no traffic data included: research vessels, military (public) vessels, passenger vessels other than regularly-scheduled ferries and cruise ships, offshore supply vessels, oil recovery vessels, industrial vessels, anchor handlers, and workboats. The remaining 429 vessel incidents included those involving bulkers (15), general cargo vessels (50), tankers (40 crude tankers and 50 product tankers), “tug and tank barges” (36), tugs (89), and passenger/fishing vessels (149 large fishing vessels, cruise ships, and ferries). Vessels other than those in the Miscellaneous category were called VTS (for Vessel Traffic Study) vessels for the purposes of these analyses.

Six groups of incident causes were analyzed – allisions, collisions, groundings, cargo transfer errors, bunkering errors, and other, non-impact incidents. The activity at the time of the incident – anchored, docked, underway, or maneuvering – were also analyzed. Each vessel incident was analyzed with regard to whether a spill occurred or did not occur.

Incidents were classified into seven geographic subareas - Juan de Fuca West, Juan de Fuca East, Guemes, Saddlebag, Haro Strait-Boundary Pass, Rosario Strait, and Cherry Point.

The key findings of these analyses was the following:

- There was a steady increase in the number of incidents for all vessels over the time period. The increase for the VTS vessels was more gradual. Note that these increases were not adjusted based on any increases in vessel traffic. These increases may reflect a number of factors: increases in vessel traffic, increases in the reporting rates of spills, and/or actual increases in the probabilities of incidents per unit traffic day. The incident rates per vessel traffic days are analyzed in other parts of the study.

For the analyses conducted specifically on the VTS vessels, the following are the key findings:

- Overall, there was an average of nearly 27 incidents per year, or one incident approximately every 0.04 years (every two weeks).
- Of the total incidents, nearly 20 incidents annually were in the other, non-impact category. This category includes: equipment failure, fire, explosion, operator error, structural failure, and incidents with unknown cause.
- Other, non-impact incidents encompassed 73% of all incidents, with 42% of all incidents being “other, non-impact” incidents involving “other” vessels. The next largest category of incidents was transfer errors, which accounted for nearly 18% of incidents. Transfer errors includes both bunker errors and cargo transfer errors.
- For all vessel types, other, non-impact incidents encompassed the largest percentage of incidents.
- For tankers and tug and tank barges the next highest percentage of incidents were attributed to transfer errors.
- Allisions, collisions, and groundings accounted for 4%, 1.6%, and 3.5% of all incidents, respectively.
- Incidents while underway and docked had nearly the same annual incident number, about 11 and 12 incidents annually, respectively. Incidents occurring while anchored or maneuvering accounted for about one and three annual incidents annually, respectively.
- For bulkers, the greatest percentage (40%) of incidents occurred due to other, non-impact causes while underway. The same was true for general cargo vessels with a percentage of 58%, for tankers with a percentage of 30%, and for passenger/fishing vessels with a percentage of 38%.
- Tug and tank barges were most likely to have a transfer incident while docked, which accounted for 33% of tank barge incidents, followed closely by other, non-impact-related incidents at dock, which accounted for 31% of tug and tank barge incidents.
- For allisions, the greatest number occurred with other vessels while maneuvering for an average of less than one incident annually. Collisions were most likely to occur with a tug and tank barge while maneuvering or underway, with one incident occurring about once in four years.
- Groundings occurred about once a year all from vessels while underway.
- Allisions occurred at a rate of just over once a year, with the greatest number occurring in the Guemes subarea.
- Collisions occurred at a rate of about once every two and one-quarter years with an equal number occurring in Juan de Fuca West, Juan de Fuca East, and Cherry Point.
- Groundings occur about oncee a year with the greatest number occurring in Juan de Fuca West.
- Transfer incidents occurred at a rate of nearly five per year with most occurring in Cherry Point followed by Guemes.
- Other, non-impact incidents occurred at a rate of about 20 per year with the highest number occurring in Juan de Fuca East followed by Guemes.

When an incident occurs there is a potential for spillage of oil and/or other cargo. There were no incidents of non-oil cargo being spilled. This is most likely because these incidents have not been tracked nearly as closely as oil spills. Overall, the probability of spillage (i.e., the proportion of incidents that resulted in spillage of any volume, including very small amounts) was 0.44. That means that 44% of incidents resulted in spillage. The highest probability of spillage was with tugs and tank barges for which 75% of incidents resulted in spillage of some amount. The next highest percentage of spillage was for tankers for which 47% of incidents resulted in spillage.

The incidents most likely to result in spillage were cargo transfer errors where 89% of reported incidents with the potential for spillage did result in a spill. Bunker errors resulted in 80% spillage. Groundings, collisions, and allisions resulted in 40%, 29%, and 6% spillage, respectively. Other, non-impact incidents resulted in 37% spillage rates.

The greatest potential spill volume, with regard to the largest worst-case discharge, would be for tankers, which in the study period had two allisions, half of which resulted in some spillage, and one collision and two groundings, none of which resulted in any spillage of oil. This does not mean that a worst-case discharge or larger volume incident could not occur in the future.

Appendix C Vessel Traffic Forecast

Task 4: Future Traffic Forecast

Prepared for

The Glosten Associates and Cardno-Entrix

October 30, 2013

Prepared by

Northern Economics

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Abbreviations

B.C.	British Columbia
BOPD	Barrels of oil per day
DWT	Deadweight Tons
GPT	Gateway Pacific Terminal
MX	Marine Exchange of Puget Sound

Executive Summary

A Vessel Traffic and Risk Assessment Study is being conducted by The Glosten Associates for seven risk analysis cases at the BP Cherry Point facility. Northern Economics Inc. is contributing to the risk assessment by summarizing existing vessel traffic volumes and forecasting future traffic volumes. This memo summarizes Northern Economics, Inc.'s analysis and results.

The goal of Task 4 is to assess the variations in study area vessel activity generated by seven risk analysis cases, as outlined in Table ES-1.

Table ES-1. Risk Analysis Cases

Case	Year	South Wing	North Wing	BP Calls	Traffic Other Than BP
1	2010	Yes	No	Maximum – single wing (335)	Existing
2	2010	Yes	No	2010 actual calls (329)	
3	2010	Yes	Yes	2010 actual calls (329)	
4	2030	Yes	No	Maximum – single wing (335)	General Traffic
5	2030	Yes	Yes	BP "High" forecast (420)	
6	2030	Yes	No	Maximum – single wing (335)	General Traffic plus Cumulative Traffic
7	2030	Yes	Yes	BP "High" forecast (420)	

The seven risk analysis cases require the study team to identify the impact of changes in the number of tankers calling at BP Cherry Point. In order to forecast BP-related traffic and other vessel traffic in the surrounding area, the study team completed the following tasks:

1. Assess BP-related traffic as a proportion of current traffic
2. Forecast baseline[1] traffic
3. Forecast cumulative traffic
4. Forecast BP traffic based on risk scenarios

The study team forecasted the volumes of study area vessel traffic in 2010 (for cases 1–3) and in 2030 (for cases 4–7). The baseline forecast for 2030 is summarized in Table ES-2. The results of the forecast cases are summarized in Figure ES-1 and Figure ES-2. The table and figures show the predicted mean values for traffic volumes.

---

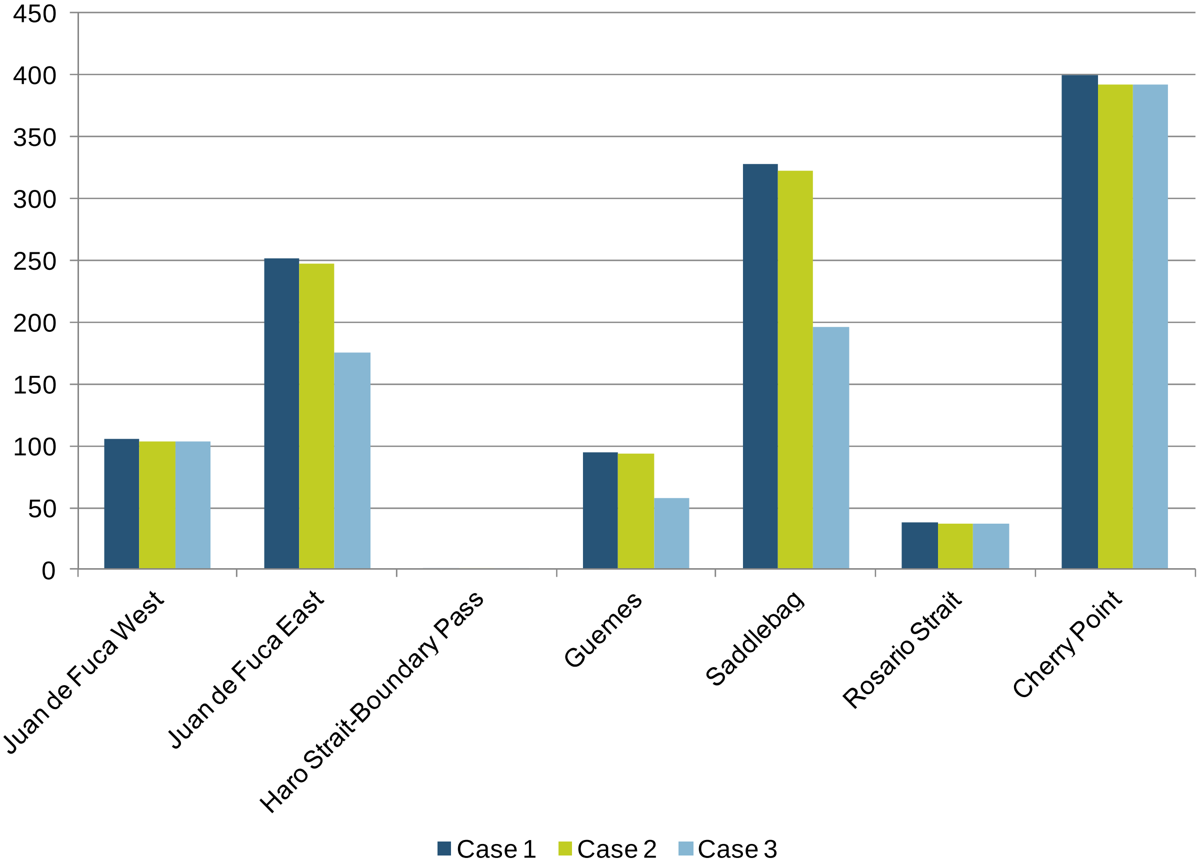
[1] The forecast of baseline traffic refers to the expected change to vessel traffic volumes present in the study area in 2010, including BP-calling traffic; it omits traffic generated by new area projects (such as the Kinder Morgan expansion or Alaska Outer Continental Shelf development), as well as traffic forecasted by BP which is above BST's industry-level economic forecasts.

Table ES-2 . Study Area Baseline Vessel Traffic Volumes, in Vessel Traffic Days (2030)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	263	660	29	529	247	49	472	2,250
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,160	708	260	232	234	14	295	2,902
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,036	477	3,397	2,476	617	2,296	13,069

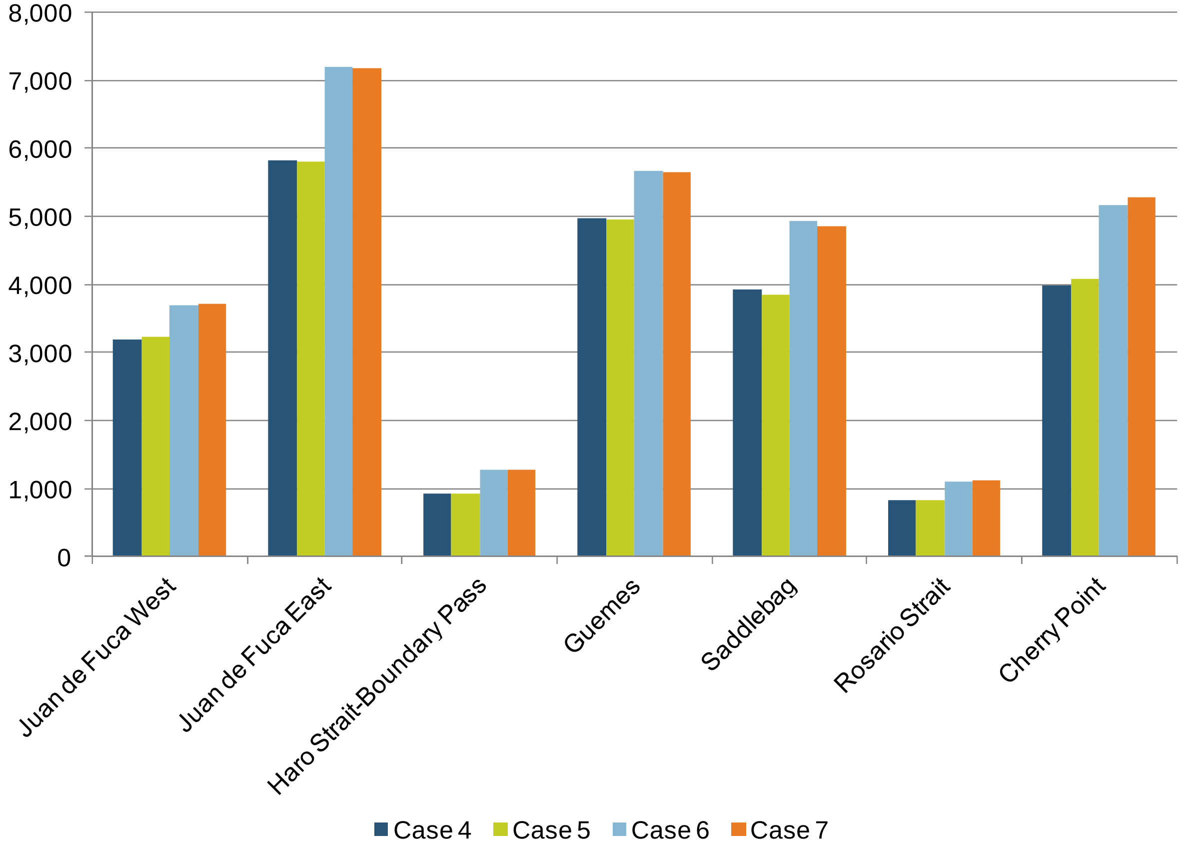
Source: Northern Economics, Inc. 2013

Figure ES-1. Comparison of BP Tanker Time for Cases 1–3



Source: Northern Economics, Inc. 2013

Figure ES-2. Comparison of Total Vessel Time for Cases 4–7



Source: Northern Economics, Inc. 2013

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1 Introduction

The goal of Task 4 is to assess the variations in study area vessel activity generated by seven risk analysis cases, as outlined in Table 1. More specifically, the task will:

> determine future vessel traffic including reasonably foreseeable increases or decreases in vessel traffic along the pathway followed by vessels between Cherry Point and Buoy J including but not limited to vessels calling in British Columbia, and vessels calling at the proposed Gateway Pacific Terminal project, Conoco Phillips Ferndale Refinery (Phillips 66), Alcoa-Intalco Works, and any other reasonably foreseeable future marine terminal facilities in the Cherry Point area. (Glosten 2012)

Table 1. Risk Analysis Cases

Case	Year	South Wing	North Wing	BP Calls	Traffic Other Than BP
1	2010	Yes	No	Maximum – single wing (335)	Existing
2	2010	Yes	No	2010 actual calls (329)	
3	2010	Yes	Yes	2010 actual calls (329)	
4	2030	Yes	No	Maximum – single wing (335)	General Traffic
5	2030	Yes	Yes	BP "High" forecast (420)	
6	2030	Yes	No	Maximum – single wing (335)	General Traffic plus Cumulative Traffic
7	2030	Yes	Yes	BP "High" forecast (420)	

The seven risk analysis cases require the study team to identify the impact of changes in the number of tankers calling at BP Cherry Point. In order to forecast BP-related traffic and other vessel traffic in the surrounding area, the study team completed the following tasks:

1. **Assess BP-related traffic as a proportion of current traffic:** BP Cherry Point tanker and tug traffic represents only a portion of total traffic moving in the study area. Puget Sound tanker and tug traffic is generated by various ports and refineries located in and around the study area including (but not limited to) Shell at March Point, Tesoro in Anacortes, Philips 66 at Ferndale, Kinder Morgan in Vancouver, B.C. and several terminals in south Puget Sound. The first step in forecasting BP-related traffic was to assess what portion of current traffic is attributable to BP activities.
2. **Forecast baseline traffic**: The study team forecasted the volume of study area vessel traffic in 2030, as a projection of existing traffic (baseline)[2]. The forecast includes trends in vessel sizes and economic forecasts of underlying cargo volumes.

---

[2] The study team used commodity-based forecasts to estimate baseline vessel traffic by type in 2030; as forecasted volumes increase or decline for goods such as aluminum, forest products, etc. moved through study area ports, the number of trips made by vessels carrying these goods also shifts.

Forecasted baseline traffic includes some BP activity; however, commodity-based forecasts account for only a portion of the tanker volumes estimated by BP for modeled 2030 scenarios. Baseline forecasts omit the tankers and tugs estimated by BP which are above and beyond those captured by the commodity-based forecasts.

3. **Forecast cumulative traffic:** The study team forecasted the volume of new study area vessel traffic in 2030 that will be generated by foreseeable projects or developments in and around the study area (cumulative traffic).
4. **Forecast BP traffic based on risk scenarios:** Using the baseline traffic forecasts, the cumulative traffic forecasts, and estimates of the proportion of BP traffic included in each forecast, the study team summarized the forecasted traffic generated by each of the seven risk scenarios.

The following sections describe each of the aforementioned steps in greater detail, and outline the results, approach, and data used by the study team.

2 BP Cherry Point Traffic (2010)

In order to forecast the proportion of tanker and tug traffic attributable to BP Cherry Point activities within the Puget Sound, the study team had to first assess what portion of current traffic is attributable to BP Cherry Point. This section first describes what BP-vessel time is, and how it was calculated for the base analysis year (2010).

To determine BP-related vessel time, the study team began with a definition of what constitutes a BP-related activity, and assessed these activities within the most recent data set (2010). In 2010, Marine Exchange of Puget Sound (MX) data show a total of 329 tanker calls at Cherry Point, the majority of which are crude carriers (Table 2).

Table 2. Tanker Calls to BP Cherry Point, 2006–2010

Vessel Type	2006	2007	2008	2009	2010	% of Total
Crude Carriers	165	230	255	212	228	61
Petroleum Product Tankers	187	168	121	126	101	39
Grand Total	352	398	376	338	329	100

Note: Please note that these figures do not include calls by tank barges, which are omitted from the MX data.
Source: Northern Economics using MX 2012.

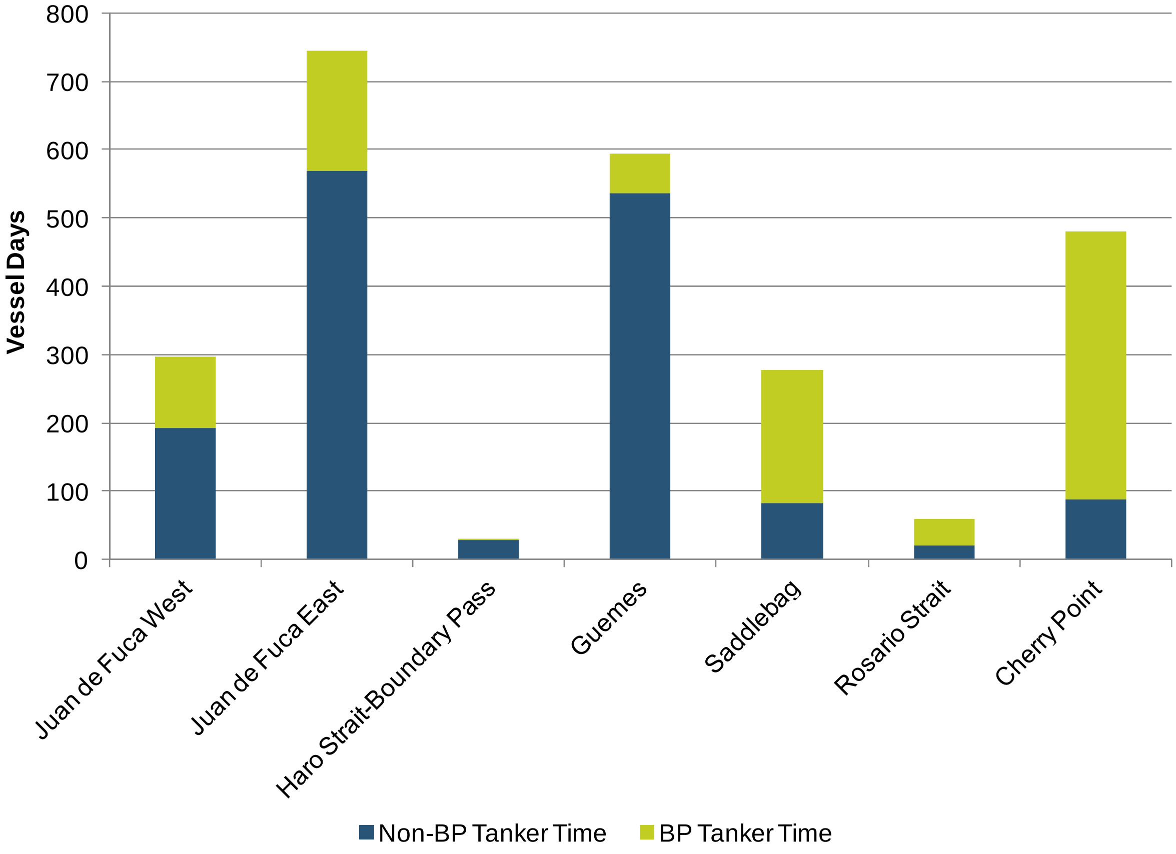
According to our estimates, in 2010 tanker time in the study area amounted to approximately 2,483 days for underway, maneuvering, anchor and at-berth time combined. BP-related tanker time accounted for 962 days, or 39 percent of total tanker time, as shown in Table 3 and Figure 1.

Table 3.BP Tanker and Non-BP Tanker Time by Subarea, in Vessel Traffic Days (2010)

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Non-BP Tanker Time	193	570	29	536	82	22	89	1,521
% of Total	65	76	96	90	29	37	19	61
BP Tanker Time	103	176	1	58	196	37	391	962
% of Total	35	24	4	10	71	63	81	39
Total Tanker Time	296	745	30	594	278	59	480	2,483

Source: Northern Economics using MX 2012.

Figure 1. BP Tanker and Non-BP Tanker Time by Subarea, in Vessel Days (2010)



Source: Northern Economics using MX 2012.

BP-related tug time is comprised of the escorting and maneuvering time associated with BP tanker activities. In contrast to tanker traffic, the MX data do not individually track tug calls within the study area. They do, however, record the number of tugs used by crude carriers and petroleum product tankers when they arrive or depart a port of call. At Cherry Point in 2010, the majority of tankers arriving and departing the facility were accompanied by two Crowley tugs.

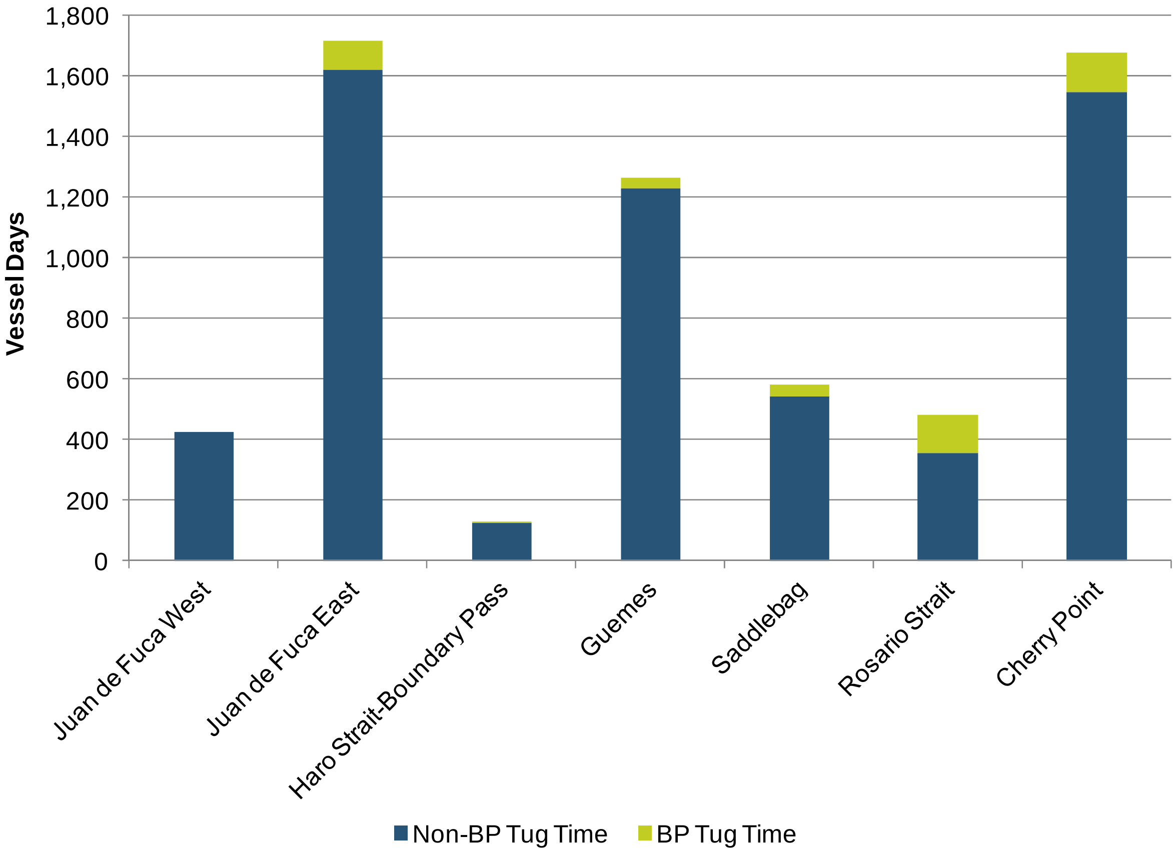
According to our estimates, in 2010 tug time in the study area amounted to approximately 6,272 days for underway, maneuvering, anchor, and at-berth time. BP tug time accounted for 430 days or 7 percent of total tug time, as shown in Table 4 and Figure 2.

Table 4.BP-Tug and Non-BP Tug Time by Subarea, in Vessel Days (2010)

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Non-BP Tug Time	426	1,620	124	1,230	540	357	1,544	5,842
% of Total	100	95	96	97	93	74	92	93
BP Tug Time	0	93	5	35	42	125	131	430
% of Total	0	5	4	3	7	26	8	7
Total Tug Time	426	1,713	129	1,265	582	483	1,674	6,272

Source: Northern Economics using MX 2012.

Figure 2. BP-Tug and Non-BP Tug Time by Subarea, in Vessel Days (2010)



Source: Northern Economics using MX 2012.

In the following sections we discuss our approach to calculating both BP tanker and BP tug time within the study area.

2.1.1 BP Tankers

Definition

For the purpose of this analysis, a BP vessel is defined as a tanker vessel that calls at the BP Cherry Point terminal for the purpose of unloading or loading crude oil or refined product cargos. A BP tanker transit is the movement of a BP vessel en route to or from the BP Cherry Point refinery.

Tanker vessels operating within the study area often call at more than one refinery. To assess the portion of time within the study area that a tanker is considered a BP tanker, the study team imposed further parameters:

- A tanker which enters Puget Sound waters at Cape Flattery and is directly destined for BP Cherry Point is conducting a BP-related transit.
- A tanker which enters Puget Sound waters at Cape Flattery and stops at one or more moorage locations (excluding non-BP refineries) before proceeding to BP Cherry Point is conducting a BP-related transit. All time spent at anchor is included as BP-related time.
- A tanker which calls at a non-BP refinery within Puget Sound waters conducts a BP-related transit only when the non-BP refinery has been departed and the vessel is en route to BP-Cherry Point. Time spent transiting to non-BP refineries is not considered BP-related time (even if the tanker subsequently calls at BP-Cherry Point). Time spent travelling from non-BP refineries en route to BP-Cherry point is considered BP-related time.
    - Non-BP refineries include Phillips 66, Shell's March Point refinery, Tesoro's Anacortes refinery and the U.S. Oil refinery in Tacoma, WA.
- BP tankers cease to be BP vessels upon arrival at their next moorage location after calling at the BP Cherry Point refinery.
    - The only instance in which a tanker continues to be a BP vessel at its next moorage location within the study area is when calling at an interim anchorage from which the vessel returns to Cherry Point. For example, if a vessel calls at the BP Cherry Point dock, travels to the Cherry Point anchorage, and returns to the BP Cherry Point dock, all time associated with the move to anchor is considered BP time.
    - If a BP tanker departs BP Cherry Point and does not stop again within the study area, all in-study-area time spent on this transit is considered BP related.

Methodology

The MX data record trips within the study area as a series of origin and destination pairs using "last port", "port", and "next port". A sample vessel entry is shown in Table 5.

Table 5. Sample MX Data Entry

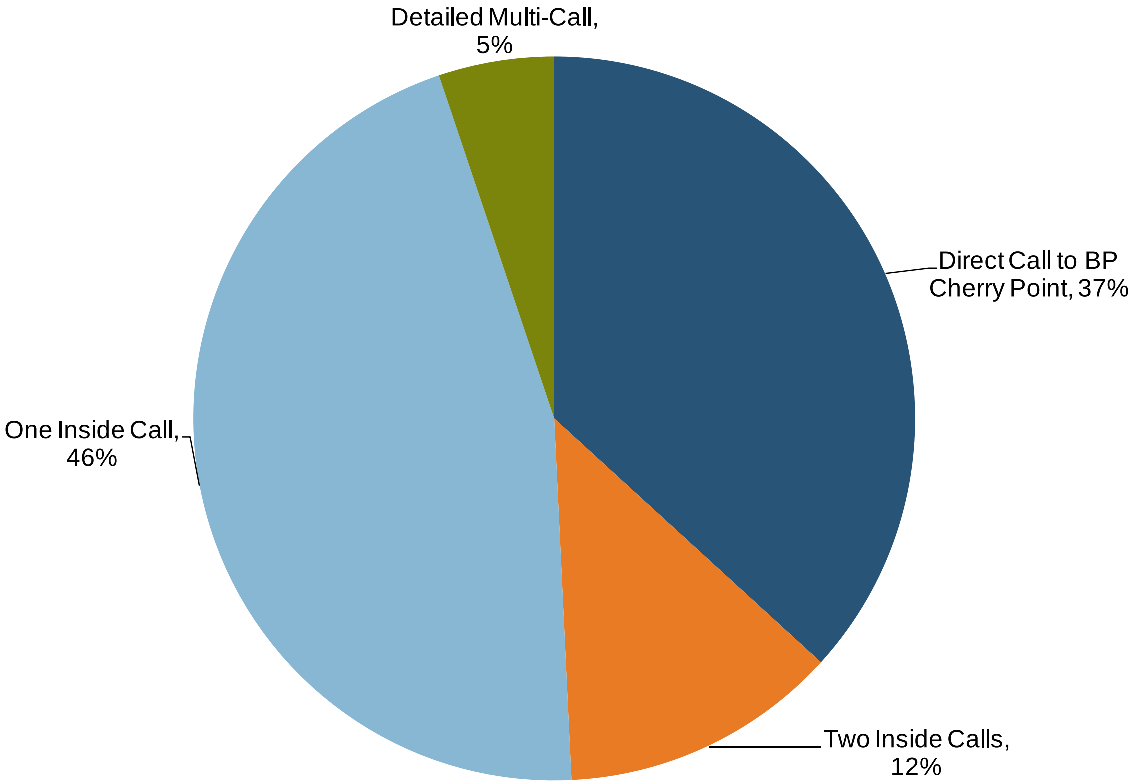
Year	VESSEL NAME	TANK TYPE	LAST PORT	PORT	NEXT PORT
2010	BRITISH OAK (T)	CRUDE CARRIER	LONG BEACH	VENDOVI ISLAND	CHERRY POINT

Source: Puget Sound Marine Exchange, 2012

The vast majority of trips to BP Cherry Point—and the associated transit time—are captured within the three-move window provided by each data entry.

In 2010 there were 329 calls at BP Cherry Point recorded within the MX data. The ports associated with these moves were categorized as being either inside or outside of Puget Sound. As shown in Figure 3, 37 percent of calls were direct to BP Cherry Point from origins outside of the study area. Approximately 46 percent of vessels made one stop within the study area before calling at BP. The remaining 17 percent made at least two calls within the study area before calling at BP Cherry Point.

Figure 3. Transit Patterns to BP Cherry point



Source: Northern Economics, 2013 using MX 2012

Of the 17 percent of vessels which made at least two calls within the study area, most included a move which prevented previous moves from being BP-related. For example, a vessel which called at Vendovi Island, Ferndale, and then BP Cherry Point is only considered a BP-related vessel for the last portion of the transit (from Ferndale to Cherry Point). This prevented the study team from having to determine the routing to Vendovi Island, as by definition, the move to Vendovi Island is considered non-BP related within the parameters of this study. Of the 58 transits with at least two inside Puget Sound calls, BP-related transit time was derived for 41 transits without having to link previous records. Only 17 of the total 329 moves (5 percent) required the study team to manually trace a vessel transit back for more than one record (or more than two moves).[3]

In 2010 the study team estimates that BP-related tanker time within the study area amounted to approximately 962 traffic days, or about 2.9 days per vessel (Table 6). The majority of underway time is spent in Juan de Fuca West, which is the longest of the study subareas. At-anchor time in Juan de Fuca East, Guemes Channel, and Saddlebag is explained by vessels anchoring at Port Angeles, Anacortes (sometimes referred to as the March Point anchorage) and Vendovi Island, respectively. All at-dock time attributable to BP activities takes place at the BP facility in Cherry Point.

Table 6. BP-Related Tanker Activity in Vessel Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Underway	103	64	1	3	6	37	23	237
Maneuvering	0	7	0	3	6	0	21	37
At-Anchor	0	105	0	52	184	0	1	342
At-Dock	0	0	0	0	0	0	345	345
Total	**103**	**176**	**1**	**58**	**196**	**37**	**391**	**962**

Source: Puget Sound Marine Exchange, 2012

Overall, about one-third of the time in the study area is spent at anchor; another one-third is spent at berth at Cherry Point, and the remaining third is spent underway or maneuvering in the study area (Figure 4).

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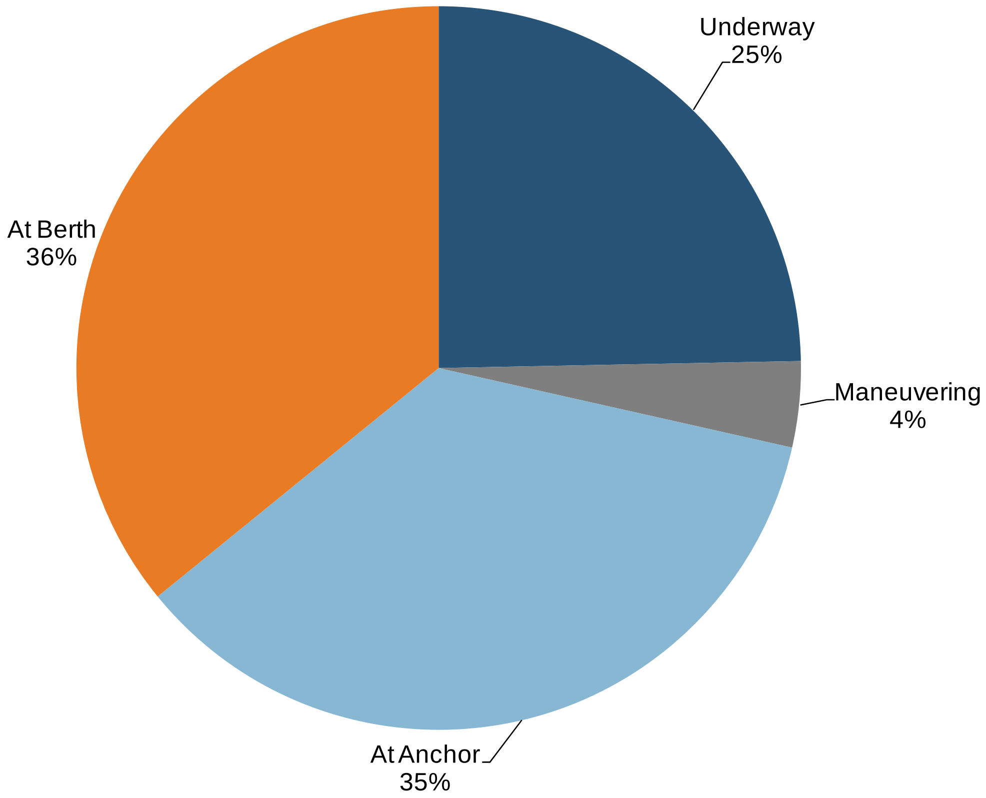
[3] Linking separate entries within the MX database is difficult due to the variable nature of transits. For example, a single vessel trip into the study area may have two, three, or four associated entries (representing between three and five origin-destination pairs). Consequently, tracing a vessel's movement pattern required a case-by-case tracking of individual transits.

Figure 4. BP-Tanker Time by Activity Type, 2010



Source: Northern Economics, 2013 using MX 2012

2.1.2 BP Tug Traffic

Definition

Tugs associated with BP tanker activity are divided into two groups: escort tugs and assist tugs. These tugs have only two BP-related activity types, transiting and maneuvering. The definition of BP tug time is further outlined in the bullets below:

- BP Tugs are considered to be on a BP-related transit when escorting BP tankers to or from the BP Cherry Point facility.
- BP Tugs are considered to be on a BP-related transit when going to or coming from Cherry Point for the purpose of assisting a tanker to or from the BP Cherry Point dock.
- Under normal conditions[4] tugs are not required to remain with a tanker vessel at anchor.
- Tugs at anchor or at berth are, for the purpose of this analysis, considered free agents available for other work. Consequently there is no at-anchor or at-berth BP tug time.
- Unloaded tankers departing the study area do not require an escort tug.

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[4] Poor weather conditions may warrant use of a tug while a tanker is at anchor

- Escort tugs will meet tanker vessels at buoy "R"—or east of a line extending from Discovery Island Light south to New Dungeness Light. Tankers operating within the study area are escorted by at least two escort vessels in those navigable waters east of a line connecting New Dungeness Light with Discovery Island Light and all points in the Puget Sound area north and south of these lights[5].
- The time spent assisting a tanker to or from the BP Cherry Point dock is considered BP tug maneuvering time. Generally for docking/undocking, two tugs are used.[6] In Puget Sound there are only two tug companies which escort BP Cherry Point tanker vessels: Crowley and Foss (Figure 5). These companies each station tugs in close proximity to Cherry Point; Crowley stations tugs at the town dock in Anacortes, while Foss stations tugs in Bellingham. The majority of tugs escorting or assisting BP-Cherry Point tankers are expected to come from either of these two locations. The exception is moves from South Puget Sound (Seattle, Manchester or Tacoma) to the study area, when a south Puget Sound tug would be engaged due to closer proximity.

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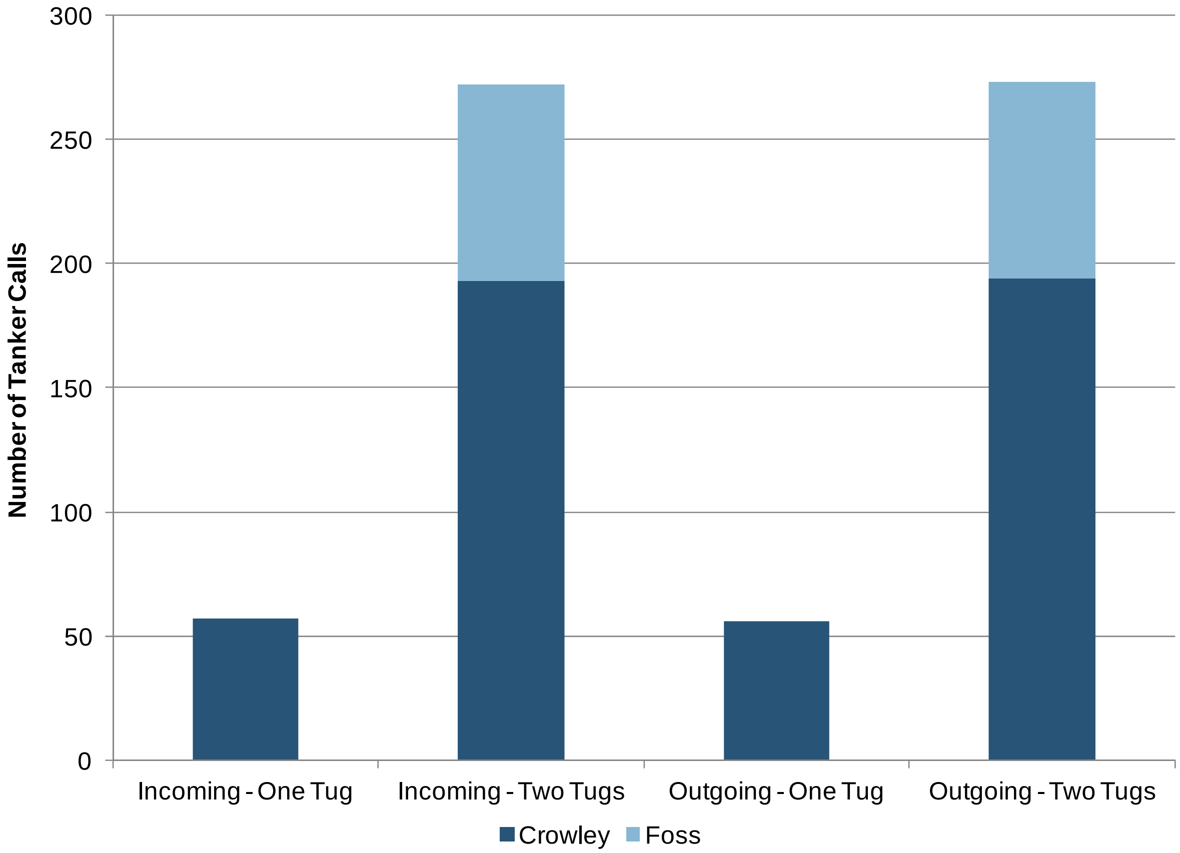
[5] 33 CFR 168.40 and 33 CFR 168.50

[6] Under normal circumstances the aggregate horsepower of the tugs has to be >5% of the DWT of the tanker. Two tugs are generally used unless environmental factors require an additional tug mid-ships on the tanker, a circumstance that would be, for the most part, rare as the tugs stationed in the area are large conventional or tractors >7,000 hp. (i.e. Hunter, Garth Foss, Lindsay Foss).

Figure 5. Cherry Point Tug Assists, 2010



Source: Northern Economics using MX 2012.

Methodology

Using the tanker routings referenced in Section 2.1.1, the study team mapped in accompanying tug movements. Tugs will depart from their homeport to meet vessels at Buoy R for escorting, and are expected to return to their homeports once the tanker vessel is at dock or anchor. BP tug transiting time consists of three general activities: the time transiting to Buoy R to begin an escort, the time spent escorting a tanker, and the time from Cherry Point to the tugs' homeport upon docking or undocking from Cherry Point. No other BP tug transiting time has been incorporated into the analysis.

As noted in the BP tug definition, only tankers coming into the study area from South Puget Sound are expected to have escort tankers from South Puget Sound. These tugs both enter and exit the study area via Admiralty Inlet. All remaining escort and assist tugs are assumed to come from Anacortes or Bellingham[7].

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[7] In 2010, MX data show that 250, or 76 percent, of the tanker calls to BP Cherry Point were escorted by Crowley tugs (Anacortes), and that 79, or twenty-four percent, were escorted by Foss tugs (Bellingham). We hold this proportion constant when estimating future BP-tug vessel traffic days by subarea.

Tug maneuvering time is estimated at between an hour and an hour and a half for a tanker vessel arriving at Cherry Point, and at fifteen to thirty minutes for a tanker vessel departing Cherry Point.[8]

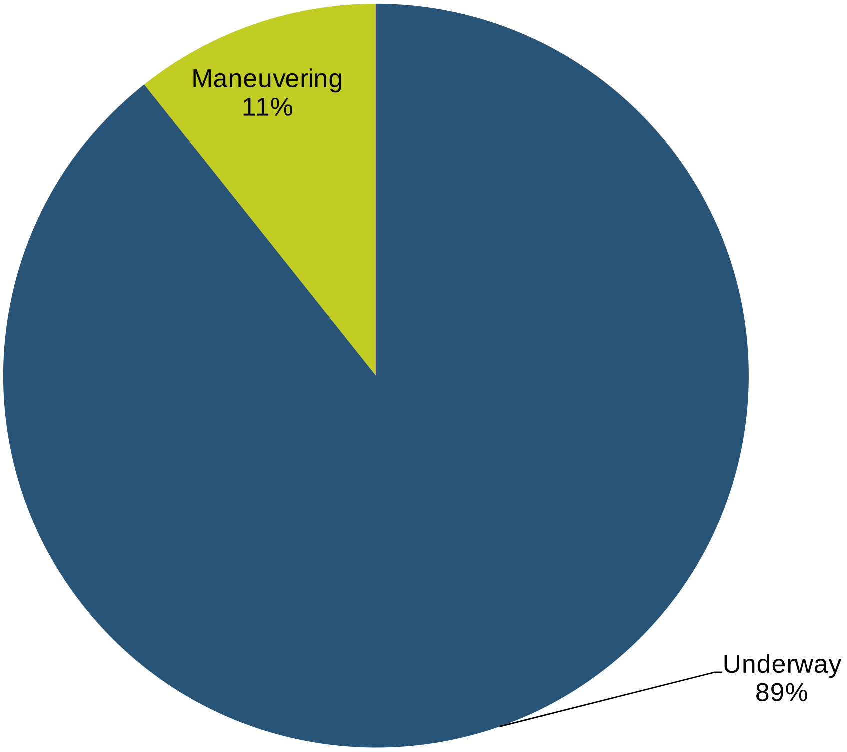
In 2010 the study team estimates that BP-related tug time within the study area amounted to 430 traffic days (Table 7 and Figure 4). The majority of BP tug time is spent in the Cherry Point subarea, maneuvering tankers to and from the BP dock.

Table 7. BP-Related Tug Activity in Vessel Days, 2010

Activity Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Underway	0	93	5	35	42	125	85	384
Maneuvering	0	0	0	0	0	0	46	46
At Anchor	0	0	0	0	0	0	0	0
At Berth	0	0	0	0	0	0	0	0
Total	0	93	5	35	42	125	131	430

Source: Puget Sound Marine Exchange, 2012

Figure 6. BP-Tug Time by Activity Type, 2010



Source: Northern Economics using MX 2012

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[8] This distribution is mapped into our @RISK simulation

3 Baseline Traffic Forecasting

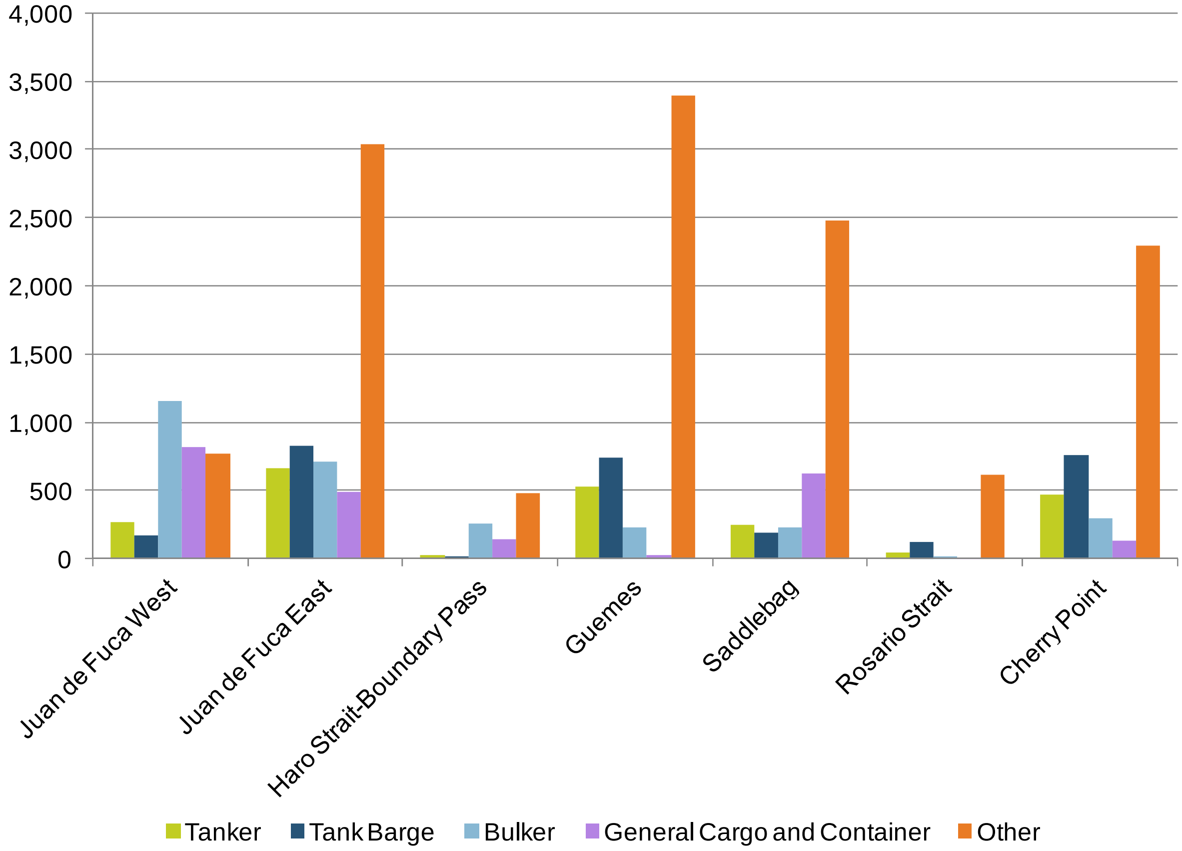
The study team forecasted the volume of study area vessel traffic in 2030, both as a projection of existing traffic (baseline) and with new developments incorporated (cumulative). The results of the baseline forecast are summarized in Table 8 and Figure 7. All traffic volume forecasts shown in this report are based on the predicted mean values for assumptions (see Section 5). This section discusses the methodology used to produce the baseline traffic forecast and forecast results for each vessel type.

Table 8. Study Area Baseline Vessel Traffic Volumes, in Vessel Days (2030)

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	263	660	29	529	247	49	472	2,250
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,160	708	260	232	234	14	295	2,902
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,036	477	3,397	2,476	617	2,296	13,069

Source: Northern Economics, Inc. 2013

Figure 7. Study Area Baseline Vessel Traffic Volumes, in Vessel Days (2030)



Source: Northern Economics, Inc. 2013

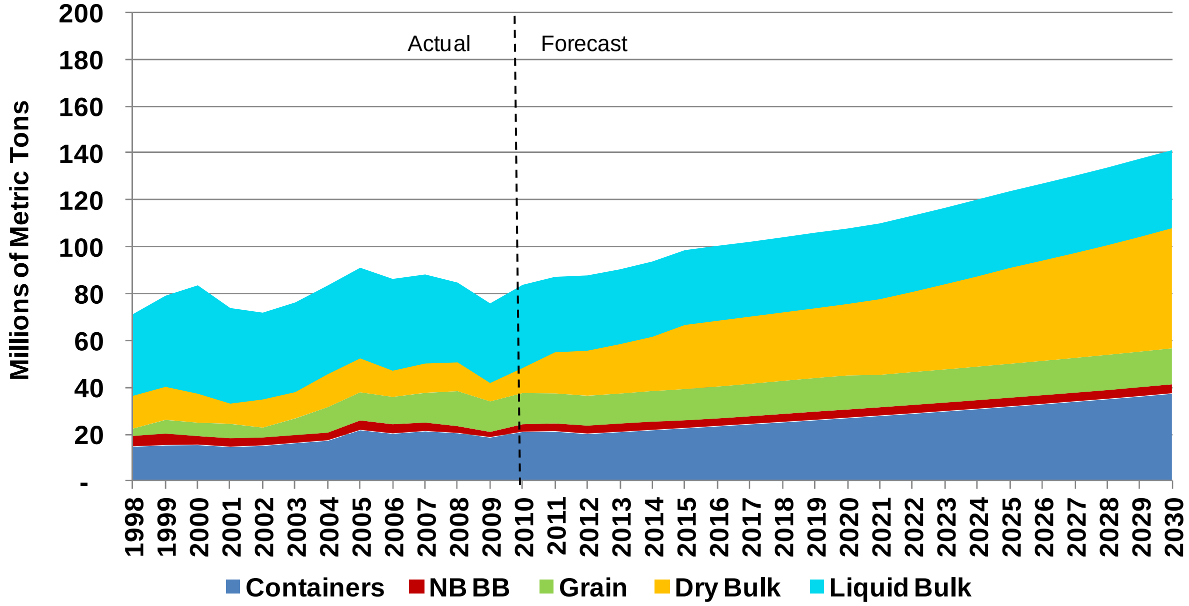
3.1 Methodology

The study team's baseline vessel traffic forecast relies heavily upon a commodity-based economic forecast generated by BST Associates, as well as historic trends and patterns of vessel behavior. The Washington Public Ports Association, in partnership with the Washington State Department of Transportation, periodically funds a marine cargo forecast and performance assessments of the state's marine port transportation system.

> These reports are used as planning tools within the port community and related industries. They also alert state and local policymakers, as well as the public, to potential opportunities and constraints. Previous versions of this study have been conservative or close to accurate across all cargo types. Container volumes for 2007, for instance, were within 3% to 4% of the 1995, 1999, and 2004 forecasts – an impressive degree of accuracy by almost any standard. (BST 2009)

The study team used both the 2009 Marine Cargo Forecast and the 2011 Update as the basis for our estimates of vessel traffic in the study area in 2030 (Figure 8).

Figure 8. Puget Sound and Washington Coast Moderate Forecast



Note: NB=Neobulk; BB = Breakbulk
Source: BST 2011

To derive a relationship between commodity volumes and vessel trips, the study team used historic data. Combining historic commodity volumes[9] with average annual vessel size, the number of unique vessel trips within the study area,[10] and an adjustment for carrying capacity, the study team generated a formula which estimates the number of unique trips into the study area using BST commodity volumes. For example, the study team compared the annual volumes of grain exported from Washington State between 2006 and 2010 to the total number of unique grain bulker trips into the study area, and the average Deadweight Tons (DWT) of these bulkers over that same period. We then generalized the relationship between the three variables to derive a formula which would estimate number of grain bulker trips into the study area using the total volume of BST-forecasted grain exports.

It should be noted that trends in vessel size are accounted for in our analysis. As shown in Figure 9, the study team accounted for overall trends in average vessel size. As vessel size increases, the trips necessary to transport equivalent commodity volumes decreases. The opposite is true for vessel types, which may be decreasing in size.

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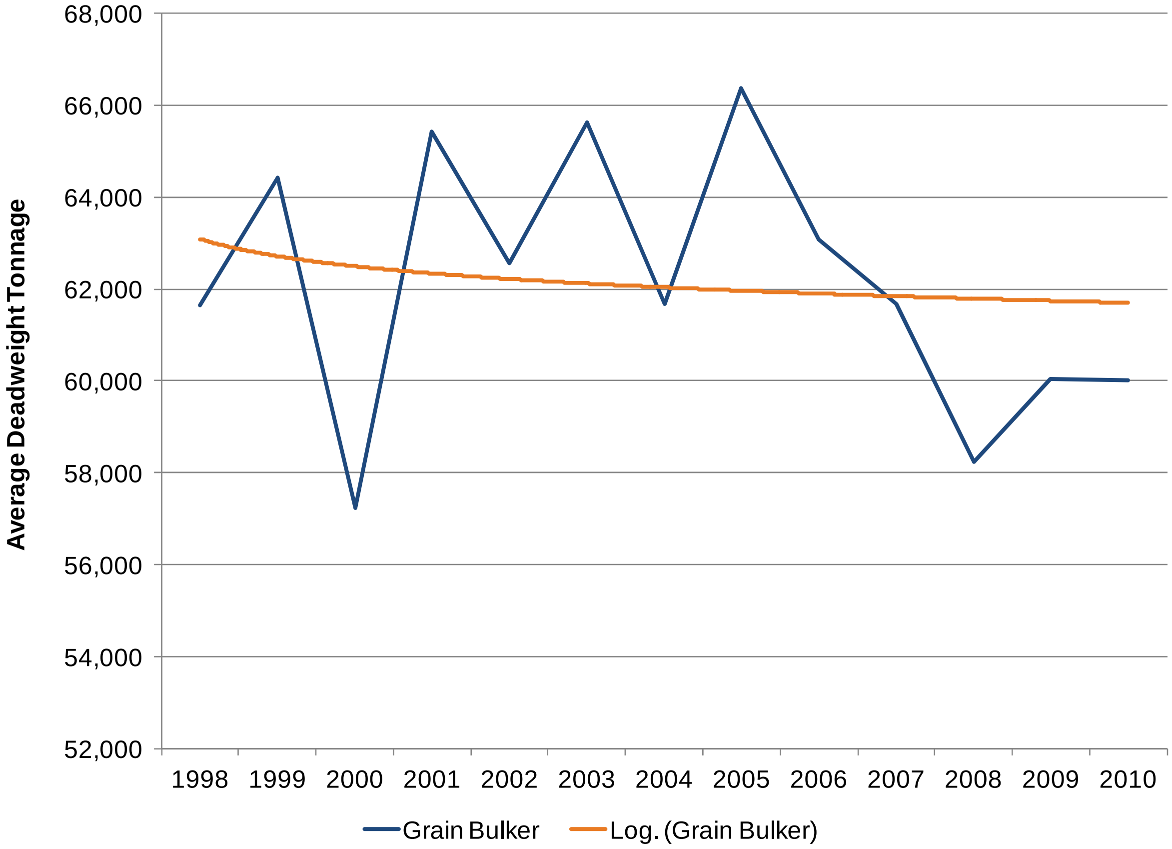
[9] Actual commodity volumes from 1998–2008 were published in the 2009 Marine Cargo Forecast

[10] Both available from the MX data

Figure 9. Grain Bulker Average DWT, 1998-2010



Source: Northern Economics, Inc. 2013 using MX 2012

The study team compared our estimates to the actual MX data to check the accuracy of this approach. Table 9 summarizes the results for Grain Bulkers; the equation for grain bulker trips generates estimates within a 15 percent average of actual trips. The standard deviation of our results is 8 percent.

Table 9. Actual to Estimated Trip Comparison, Grain Bulkers (2006-2010)

	Year				
Vessel Type	**2006**	**2007**	**2008**	**2009**	**2010**
Actual Trips	241	224	295	255	243
Forecasted Trips	246	274	342	289	295
Difference	5	50	47	34	52
Ratio (BST/MX)	102%	123%	116%	113%	121%

Source: Northern Economics, Inc. 2013 using MX 2012

The only vessel types for which the MX data were not used to forecast are 'other vessels.' We discuss each of these in more detail in the following sections.

Tugs

There is no single commodity forecasted by BST which would suffice as an indicator for future tug traffic volumes. Tugs, which are used for berth assists, escorting, and towing, act as support vessels for regional industries. Generally speaking, as total vessel activity grows, so does the need for tug services. The study team forecasted increases in tug transits proportional to total growth in study area vessel activity.[11]

Ferry Component of Passenger Vessels

Ferry transit data show that between 1995 and 2010, underway and at-dock time remained within a 30-day window each year. That is to say, of the 15 years included in our data, ferry vessel traffic days ranged from a high of 2,650 to a low of 2,620. The study team held ferry traffic days constant at 2010 levels for the 2030 forecast.

Fishing Vessels

Fishing vessel transits are forecasted using historic trends. Between 1995 and 2010, the number of active fishing vessels in the study area dropped significantly. The study team forecasts a continued, although slower, decline in fishing vessel transits.

Canadian Forecast

Vessels calling at Port Metro Vancouver were forecasted using historic traffic patterns. The study team projected forward the historic trends seen for each vessel and activity type, and mapped this activity into our baseline forecast.

3.2 Results

The following sections discuss the baseline forecast results for each vessel type by activity and subarea.

3.2.1 Tankers

Tanker traffic in the study area is primarily driven by the movement of liquid bulk cargos, including crude oil and petroleum products. According to BST, liquid bulk commodity volumes are expected to increase slightly between 2010 and 2030 (Figure 10).

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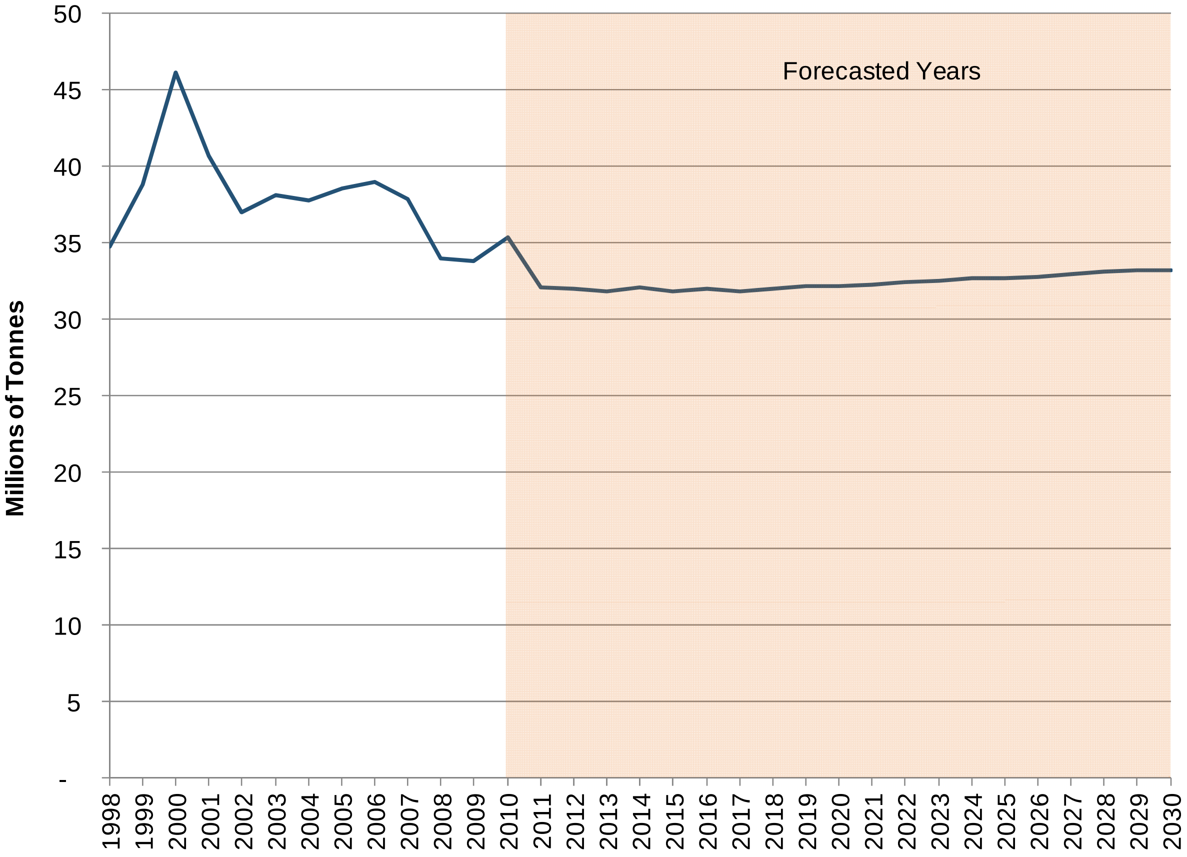
[11] Non-BP tug activity is calculated by subtracting BP-related tug activity from total tug activity.

Figure 10. Liquid Bulk Commodity Volumes, 1998-2030



Source: BST Associates 2011

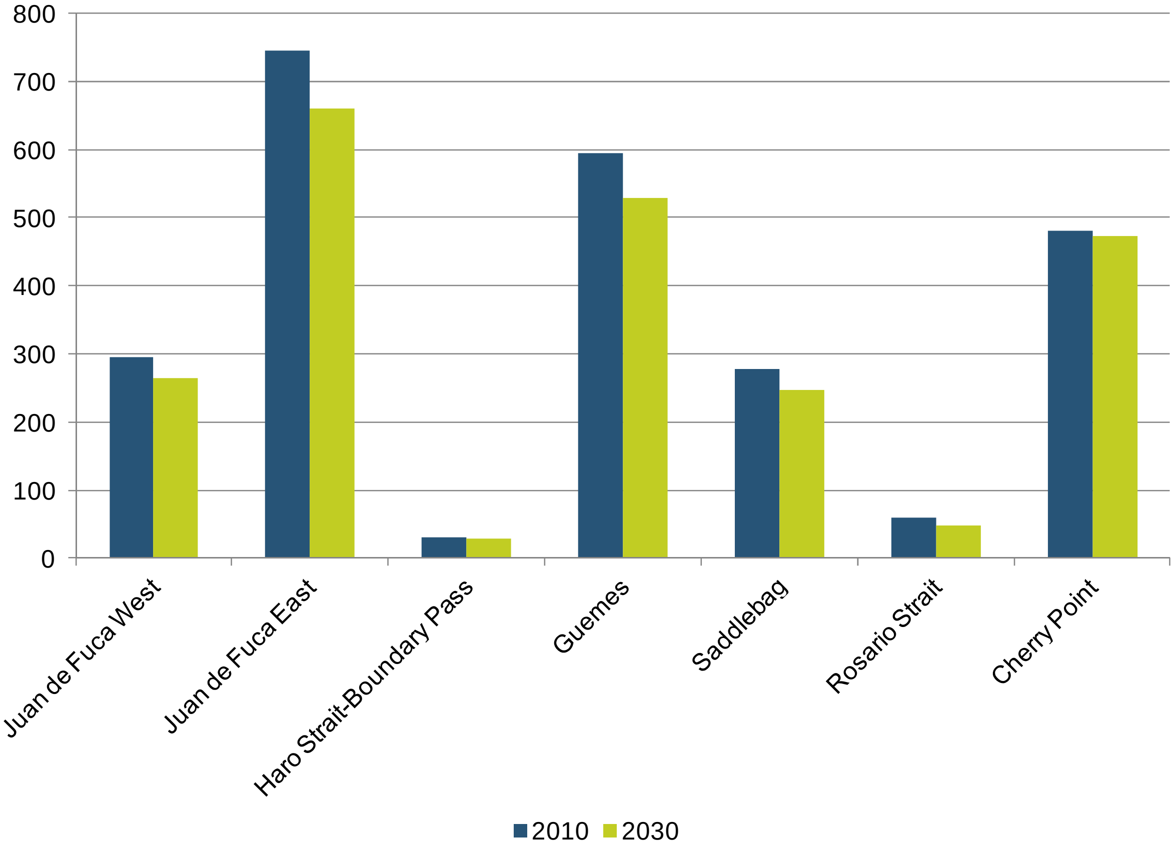
However, this slight increase is countered by a forecasted increase in average tanker size, which lowers the overall number of transits necessary to move cargo volumes. The result is a slight decrease in tanker traffic days by subarea, as shown in Table 10 and Figure 11.

Table 10. Current and Forecasted Baseline Tanker Days by Subarea (2030)

Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
2010	296	745	30	594	278	59	480
2030	263	660	29	529	247	49	472
Difference	-33	-85	-1	-65	-31	-10	-8

Source: Northern Economics, Inc. 2013

Figure 11. Current and Forecasted Baseline Tankers, in Vessel Days (2010 and 2030)



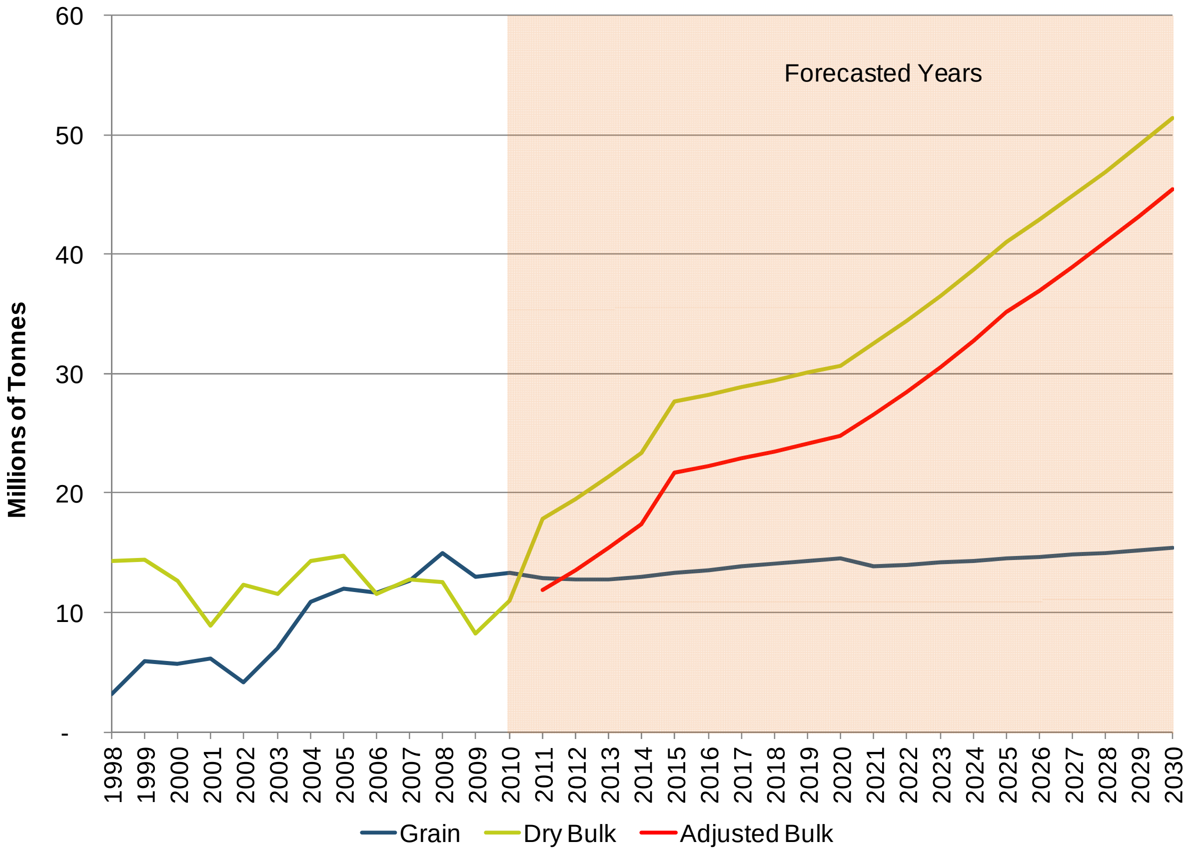
Source: Northern Economics, Inc. 2013

3.2.2 Bulkers

BST commodity volume forecasts for dry bulk and grain were used to forecast baseline bulker traffic volumes (Figure 12). BST's 2011 forecast anticipates a sharp rise in dry bulk volumes between 2010 and 2011. The increase was primarily due to projected growth in exports of U.S. coal through Roberts Bank, B.C.

According to data received from Port Metro Vancouver (which includes Robert's Bank cargo volumes), bulker transits did not increase at the rate forecasted by BST. The study team adjusted down the forecasted dry bulk cargo volumes to account for this discrepancy. The red 'adjusted bulk' volumes shown in Figure 12 were used to forecast bulker vessel volumes.

Figure 12. Grain and Dry Bulk Commodity Volumes, 1998-2030



Source: Northern Economics, Inc. 2013 and BST Associates 2011

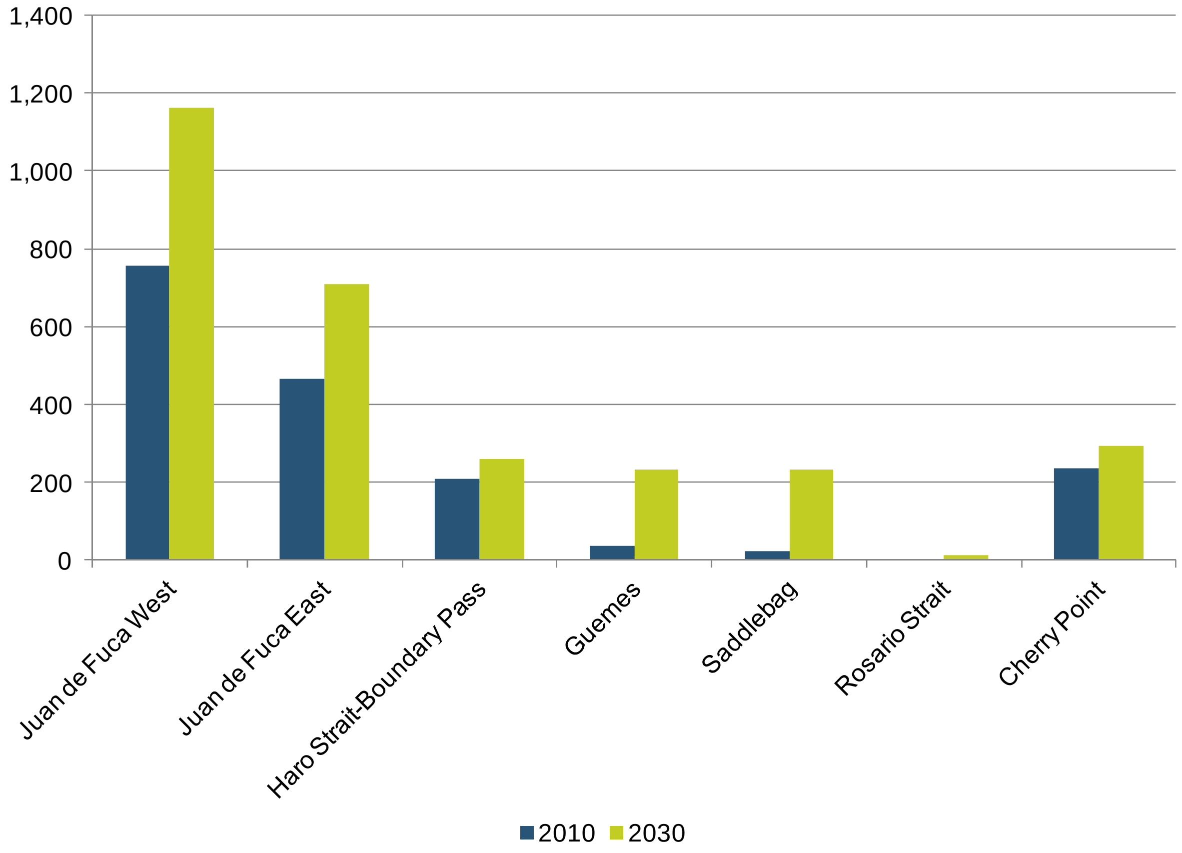
The results of our baseline bulker forecast are summarized in Table 11 and Figure 13. Current trends are expected to continue, with increasing traffic days in all subareas where current bulker activity takes place.

Table 11. Current and Forecasted Baseline Bulkers, in Vessel Days (2010 and 2030)

Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
2010	756	464	209	35	22	2	238
2030	1,160	708	260	232	234	14	295
Difference	404	243	51	197	212	12	57

Source: Northern Economics, Inc. 2013

Figure 13. Current and Forecasted Baseline Bulkers, in Vessel Days (2010 and 2030)

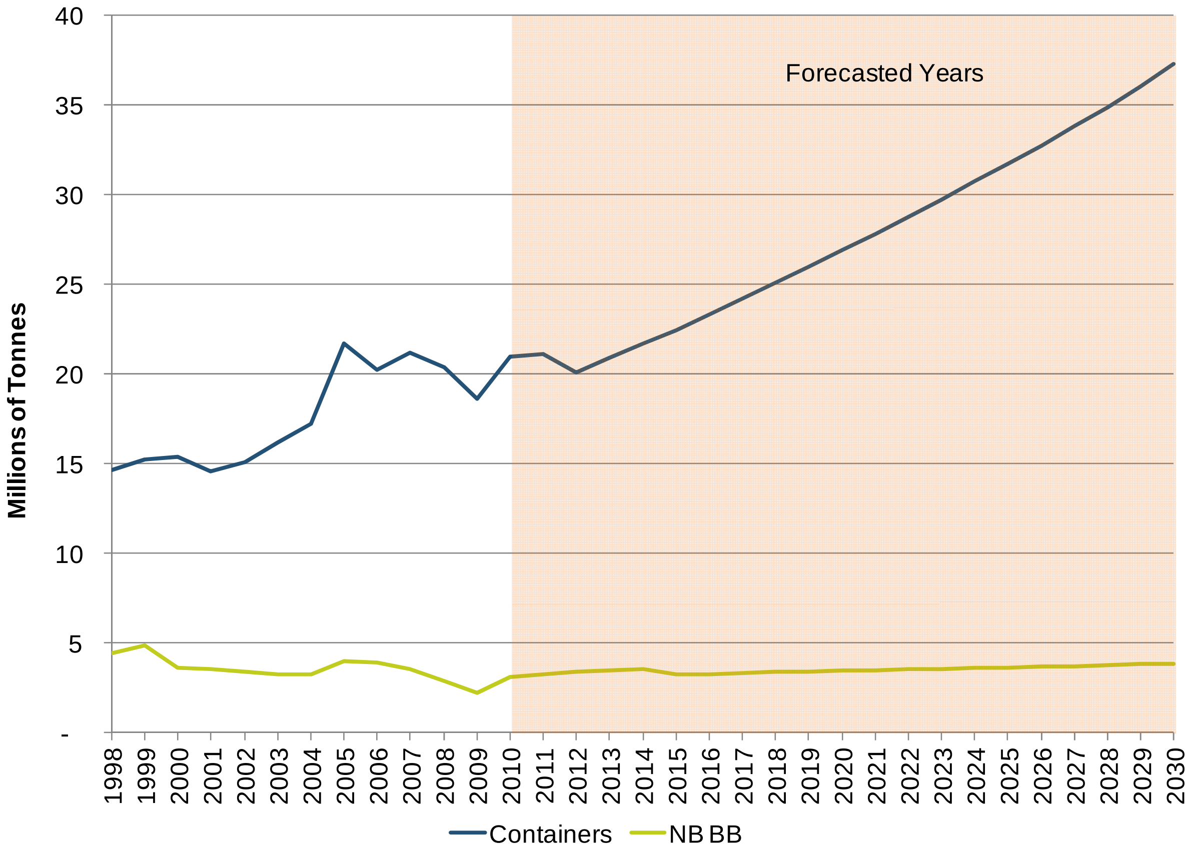


Source: Northern Economics, Inc. 2013

3.2.3 Cargo Ships

The study team forecasted cargo ship traffic using container, neo bulk and break bulk commodity volumes. Containerized cargo often travels on liner vessels and can be anything from food products to sneakers; as long as it moves in a 20, 40, 45, or 53-foot container, it is considered containerized cargo. Neo bulk is a type of general cargo which is usually pre-packaged or bundled, such as lumber, scrap iron, or waste paper. Break bulk cargo is similar to neo bulk, but is not in a form which can be bundled. Examples of break bulk cargo include construction equipment, large electrical equipment such as commercial generators, yachts, etc.

Figure 14. Container and Neo Bulk/Break Bulk Commodity Volumes, 1998-2030



Note: NB BB=neo bulk/break bulk
Source: BST Associates 2011

While neo bulk and break bulk volumes are forecasted to remain level, container volumes are expected to increase sharply between 2010 and 2030, causing the increase in traffic days shown in Table 12 and Figure 15.

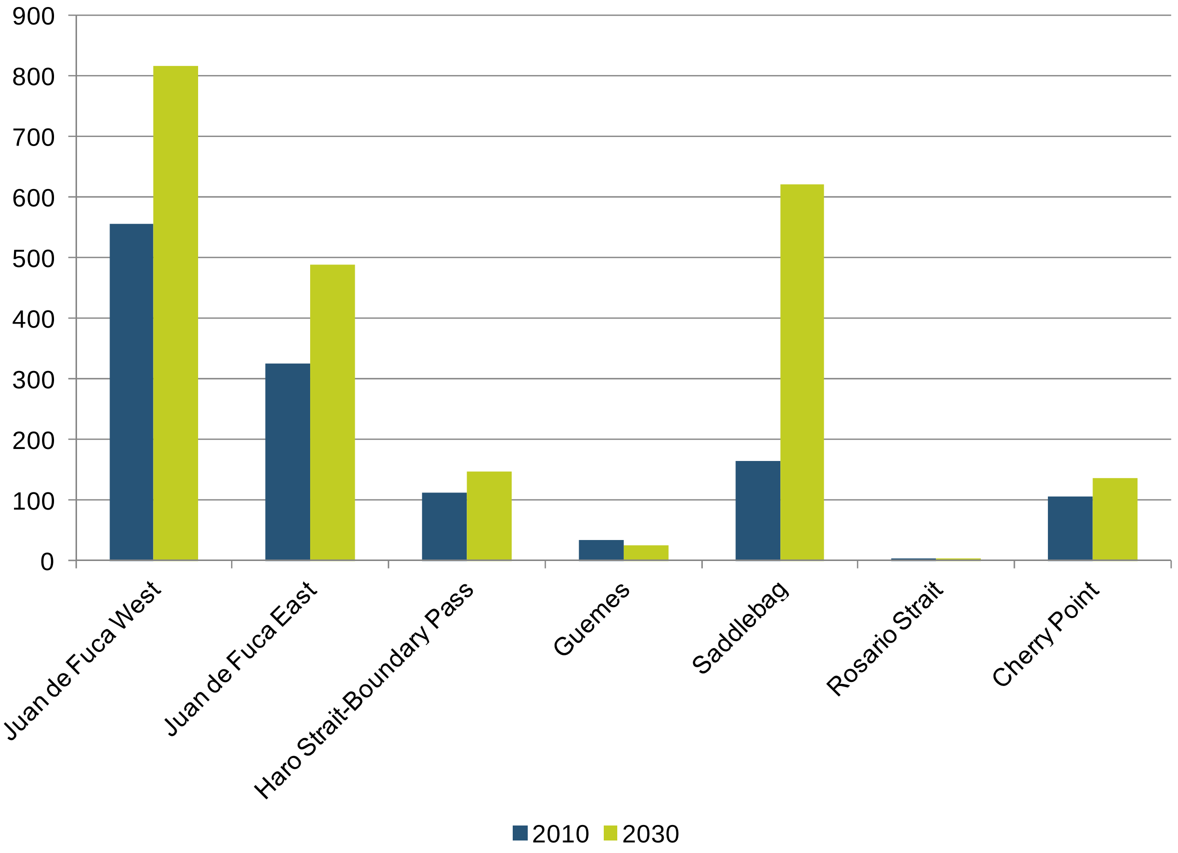
Table 12. Current and Forecasted Baseline Cargo Ships, in Vessel Days (2010 and 2030)

Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
2010	556	325	112	33	165	3	106
2030	816	488	147	25	621	4	137
Difference	260	163	35	-8	456	2	31

Source: Northern Economics, Inc. 2013

Few cargo vessels call in the study area; most transit through the study area en route to South Puget Sound or to Vancouver, B.C. Figure 15 summarizes the subareas in which vessel day increases are expected. The subareas with the largest changes are Juan de Fuca West and Juan de Fuca East, both of which are transited en route to either Seattle/Tacoma or Vancouver, B.C.

Figure 15. Current and Forecasted Baseline Cargo Ships, in Vessel Days (2010 and 2030)



Source: Northern Economics, Inc. 2013

3.2.4 Tank Barges

Tank barge transits are forecasted using the historic transits reported by the Washington State Department of Ecology. Similar to tanker forecasts, the study team used the pattern of growth expected for liquid bulk volumes to project forward the tank barge numbers (Figure 10). Very little change is expected between 2010 and 2030 tank barge volumes (Table 13 and Figure 16).

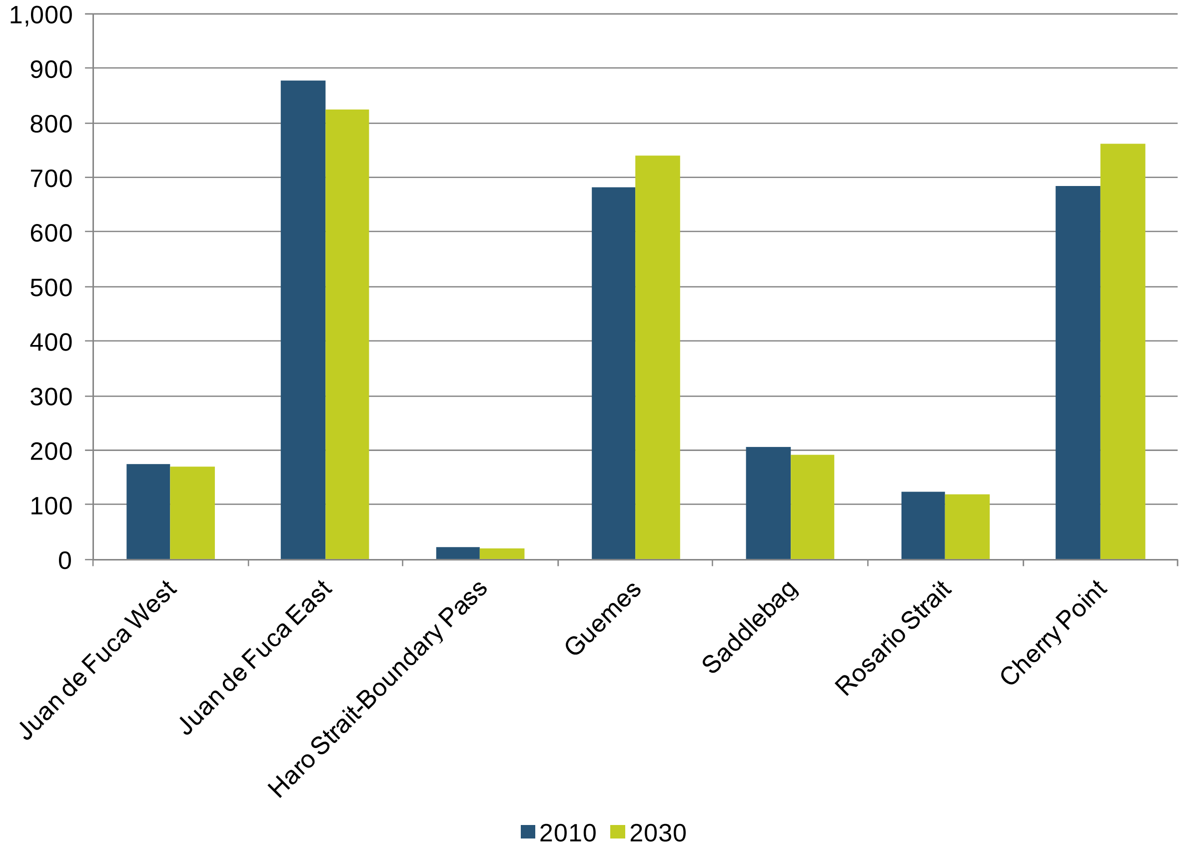
Table 13. Tank Barge Traffic in Vessel Days, Current and Forecasted (2010 and 2030)

Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
2010	175	877	21	682	206	124	685
2030	170	825	20	739	191	120	762
Difference	-5	-52	-2	57	-16	-4	76

Source: Northern Economics, Inc. 2013

Figure 16 summarizes the small shifts in tank barge volumes expected over the course of the study period. Vessel days are expected to drop slightly from 2010 levels (in line with the BST commodity forecast), then stay relatively constant.

Figure 16. Tank Barge Traffic, Current and Forecasted (2010and 2030)



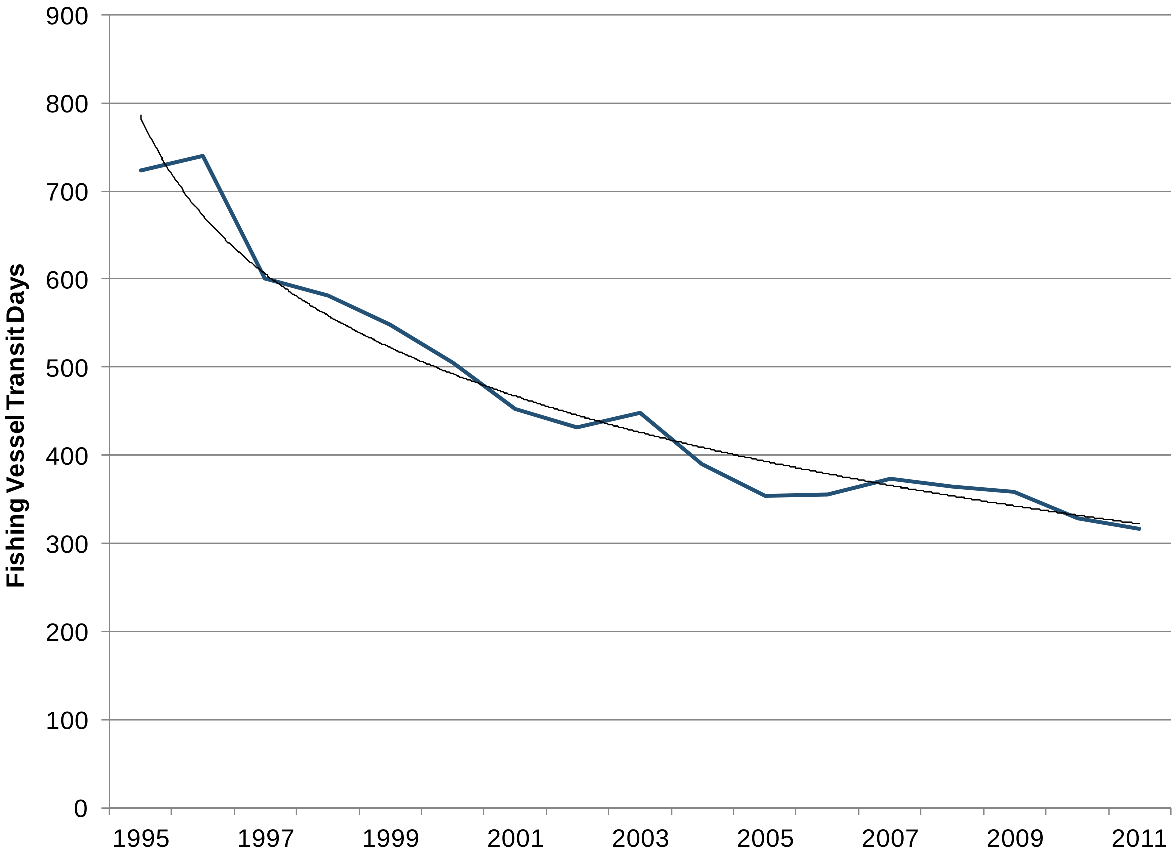
Source: Northern Economics, Inc. 2013

3.2.5 Other Vessels

Tugs, passenger vessels, and fishing vessels are collectively expected to spend the most time in the study area in both 2010 and 2030. It should be noted:

1. Study area tug volumes are forecasted using total traffic volumes. As the number of non-tug traffic days spent in the subarea increases, so do the expected number of tug days.
2. A continued decline in the number of large fishing vessel transits through the Strait of Juan de Fuca is expected. This drop accounts for the reduction in 2030 'other' vessel traffic days in Saddlebag (Table 14). The forecasted pattern of fishing vessel transits is summarized in Figure 17.

Figure 17. Study Area Fishing Vessel Transit Days (1995-2011)



Source: Northern Economics, Inc. 2013

3. Passenger vessel transits will increase. While ferry transits are expected to stay the same, forecasted cruise vessel transits will increase between 2010 and 2030. It is worth noting, however, that cruise vessel transits in 2030 are expected to be near historic highs seen in the mid to late 1990s.

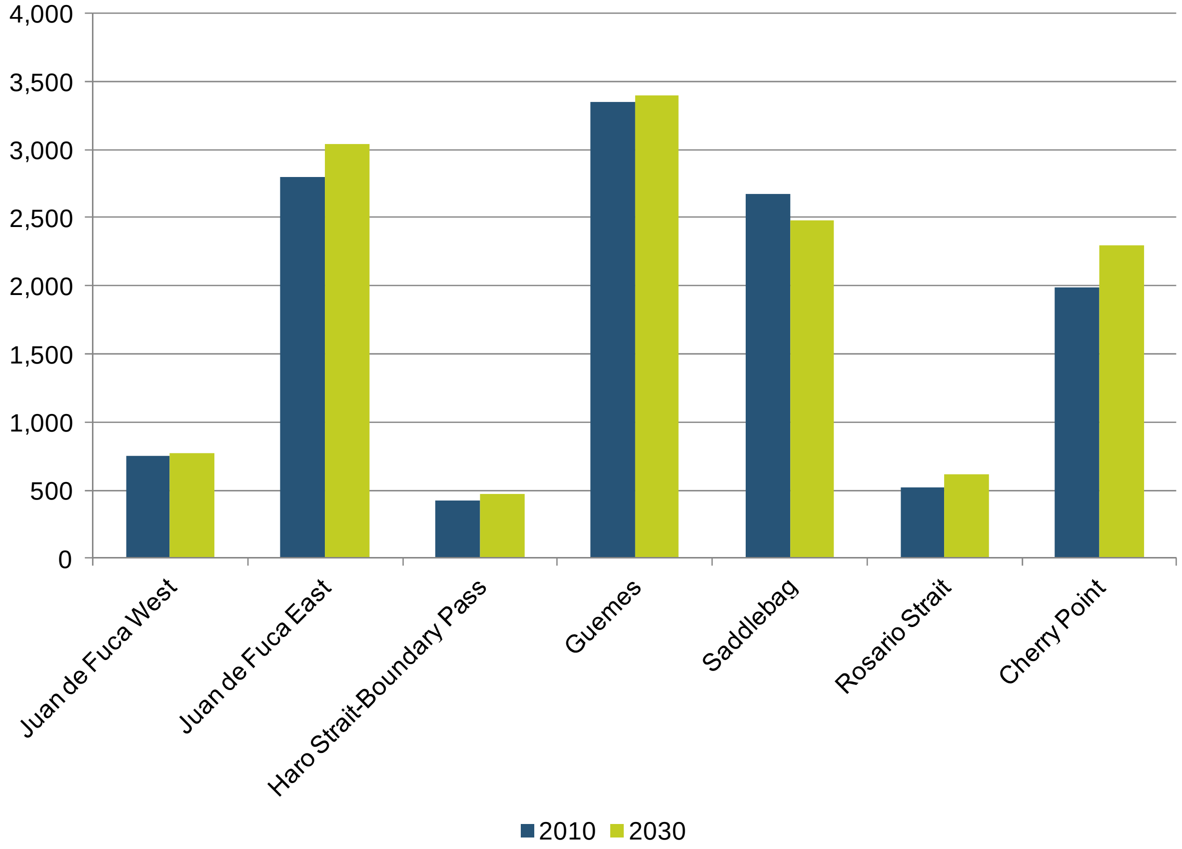
Forecasted 'other' vessel traffic days are summarized in Table 14 and Figure 18.

Table 14. Other Vessel Traffic in Vessel Days, Current and Forecasted (2010 and 2030)

Year	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
2010	747	2,797	422	3,346	2,676	516	1,989
2030	771	3,036	477	3,397	2,476	617	2,296
Difference	23	239	54	50	-200	101	306

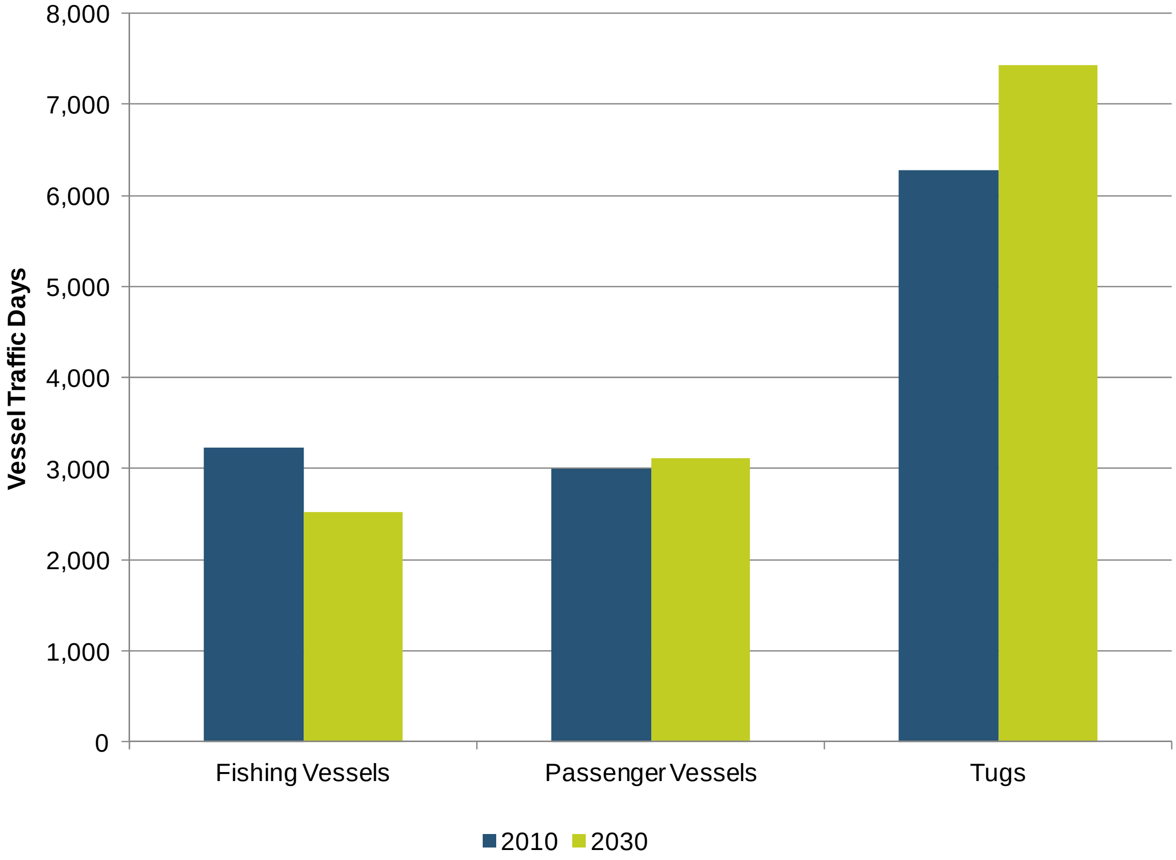
Source: Northern Economics, Inc. 2013

Figure 18. Other Vessel Traffic, Current and Forecasted (2010 and 2030)



Source: Northern Economics, Inc. 2013

Figure 19. Other Vessel Traffic by Type, Current and Forecasted (2010 and 2030)



Source: Northern Economics, Inc. 2013

4 Cumulative Traffic Forecast

At the outset of the vessel traffic study, the Northern Economics project team conducted interviews with project stakeholders to assess regional activity that could change historic vessel traffic volumes or patterns. The study team conducted interviews with local ports, shipping companies, refineries, and small boat harbors. During these interviews it became apparent that several potential events could significantly change the projected tanker and tug vessel traffic volumes used in our analysis. These events include:

1. New oil production from the Alaska Outer Continental Shelf (OCS) beginning in 2024;
2. Shale oil production from the Alaska North Slope with substantial volumes online by 2016;
3. Expansion of Kinder Morgan's Transmountain pipeline to export oil to Asia; construction will begin in 2016 and increased tanker traffic is incorporated into the 2030 estimates;
4. Construction of the Gateway Pacific Terminal (GPT) will increase study area bulker vessel volumes and is incorporated into the 2030 estimates.

These events would generate increases well beyond the incremental increases expected from traditional forecasting methods as they would not be reflected in regressions of historic trends. The vessel traffic associated with these projects, coupled with the previously described baseline traffic forecast, are collectively referred to as the cumulative traffic forecast for the purpose of this analysis.

While not definite, OCS production, shale oil production, Kinder Morgan's expansion and construction of GPT are considered reasonably foreseeable by the study team, and all four were factored into our cumulative traffic forecast. The specific assumptions regarding cumulative traffic are summarized in Table 15[12].

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[12] The transportation forecast does not account for volumes of crude by rail as the study team believes that crude transport by rail (i.e. the volumes from North Dakota) will depend on future oil price spreads. The cost to transport crude from North Dakota to Puget Sound is about $10 per barrel (RBN Energy LLC, 2013); as of late June 2013, the spread between Brent and Bakken was less than $10.00. Our forecast assumes that the spreads remain narrow and do not cover the cost of rail transport.

Table 15. Cumulative Forecast Assumptions

Year	Case
2030	• Alaska OCS production on line with an assumed 300,000 barrels of oil per day (BOPD) or about 1 additional tanker every 3.25 days or 112 additional tankers in 2030 • Other Alaska oil production declines by about 141,000 BOPD from 2012 levels or about 1 tanker every 7 days resulting in about 52 fewer tanker calls • Oil shale production has increased to 190,000 BOPD or about 1 additional tanker every 5 days or 73 additional tankers in 2030 • Kinder Morgan at 348 additional tankers per year (Forecasted volume is 34 tankers per month, but 5 are already calling, so there will be an increase of 29 per month). ***Net effect:*** Total additions are 533, less reductions from Other Alaska production of 52, for a net of 481compared to 2010 levels. Washington refineries are not expected to be able to handle this entire increase; while the additional tankers from Alaska will displace all foreign tankers (11) and some Canadian crude, it is estimated that 53 of the annual tankers will be routed to California refineries rather than Washington State. The maximum number of additional tankers is 428 (533-(52+53)).

Source: Northern Economics Inc., 2013

4.1 Outer Continental Shelf Production

As oil production in the existing fields of the Alaska North Slope continues to decline, many companies have started looking towards the development of the Alaska OCS. The Alaska OCS under the Beaufort and Chukchi Seas is believed to contain a large undiscovered amount of oil and natural gas. It has been estimated that this area contains 27 billion barrels of oil and 122 trillion cubic feet of natural gas, which is greater than both the Atlantic and Pacific OCS current estimates combined. Since 2005 the federal government has held several Alaska OCS lease sales and approximately 30 exploration wells have been drilled in the Beaufort Sea and five in the Chukchi Sea (American Petroleum Institute 2011).

4.2 Shale Oil Production

The waning output from the Prudhoe Bay oil fields has also sparked increased exploration into extracting oil from the source rocks on the North Slope to produce shale oil. The State of Alaska has leased more than half a million acres of its land to exploration companies for further development. A U.S. Geological Survey report released in February 2012 assessing the North Slope's shale rock resources estimated that up to 2 billion barrels of oil and 80 trillion cubic feet of gas are technically recoverable in the region (Eilperin 2012).

4.3 Kinder Morgan Tankers and Tugs

Kinder Morgan has operated a Puget Sound pipeline system that ships Canadian crude oil via the Transmountain pipeline from British Columbia to refineries in Anacortes, Cherry Point and Ferndale since 1956. Kinder Morgan has proposed expanding their Alberta-to-Metro Vancouver pipeline from Edmonton to Burnaby, increasing the pipeline's capacity for crude oil by 550,000 barrels a day (Hamilton 2012). This expansion is forecasted to be operational in 2017 and the majority of the addition oil throughput is expected to be shipped to Asian markets out of Port Metro Vancouver.

By 2030 both Alaska OCS and oil shale production will be on line, increasing the number of tankers calling at refineries within the study area. In addition, an increased number of tankers calling at the Canadian Kinder Morgan terminal will increase vessel traffic in Juan de Fuca West, Juan de Fuca East, Haro Strait and Cherry Point.

4.4 GPT Vessel Traffic

Pacific International Terminals, Inc. proposes to construct and operate GPT at Cherry Point Washington. GPT is planned to be a multimodal, deep water terminal intended to support the import and export of dry bulk commodities mainly to Asian and other international markets. The proposed terminal will include a deep-draft wharf with access trestle, dry bulk materials handling and storage facilities, and rail transportation access. GPT is projected to be operational starting in 2016 and operating at full capacity by 2026; cumulative vessel traffic forecasts for 2030 hold GPT 2026 volumes constant.

GPT traffic includes both bulkers and tugs assisting bulkers with docking and undocking maneuvers. GPT development will be completed in four operational phases as dictated by the growth in capacity of the terminal. Commodities would be moved by oceangoing vessel to and from the Terminal. Approximately 221 vessels (144 Panamax vessels and 77 Capesize vessels) are expected to call at GPT per year during Phase 1 operations. At full operational capacity, approximately 487 vessels per year are expected to call at GPT (Table 16).

Table 16. Vessels per Year by Vessel Class and Operations Phase

			Capesize/yr		Panamax/yr		
Operational Phase	Approximate Year (estimated)	Total Nominal Maximum Terminal Capacity (mtpa)	Serving East Loop	Serving West Loop	Serving East Loop	Serving West Loop	Total
1	2016	25	77	0	144	0	221
2	2017	31	77	31	144	59	311
3	2021	45	122	31	229	59	441
4	2026	54	138	31	259	59	487

Note: mtpa – millions of metric tons per year
Source: Pacific International Terminals, 2011

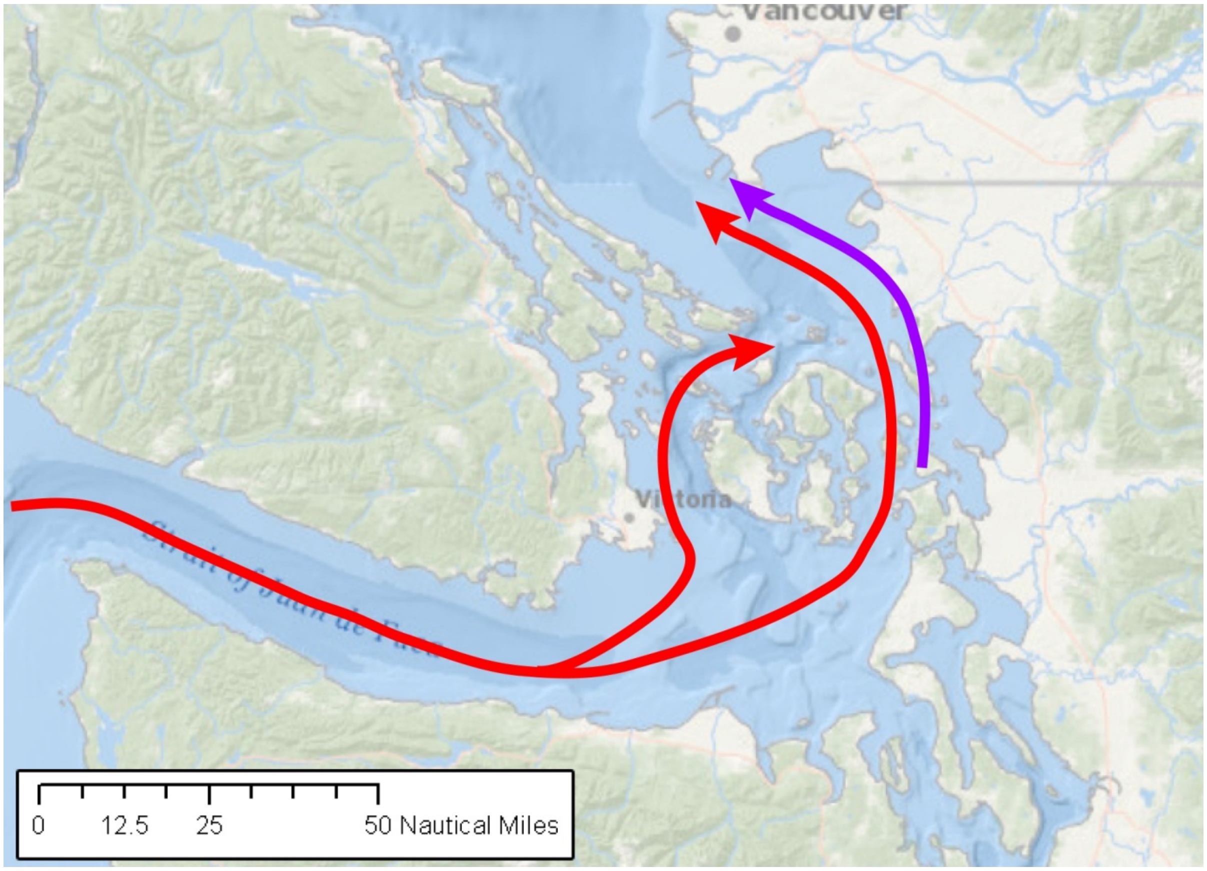
The study team mapped GPT vessel activity into the model for the year 2030 (after full build-out). Based on current vessel traffic patterns and bulker activity, the study team used the following transit pattern:

1. Bulker vessels calling at GPT will originate from outside the study area;
2. GPT bulkers will transit into and out of the study area using the Strait of Juan de Fuca; these vessels will transit Juan de Fuca West, Juan de Fuca East, either Haro or Rosario Strait. In 2030, 85 percent will use Rosario Strait, and 15 percent will use Haro Strait.
3. GPT bulkers will travel between 12 and 13 knots, in line with the bulker speeds currently seen in the study area;

4. Bulker vessels currently make 2.6 transits (or moves) per unique entry into the study area. Two of these moves are accounted for by arrival at and departure from dock. Additional moves are accounted for by anchorage activity. The study team expects GPT-bound tankers to also make 2.6 transits per unique trip into the study area;
5. GPT bulker anchorage time is distributed to four subareas based on current patterns of use. GPT bulkers are expected to spend 28 percent of their anchorage time in Juan de Fuca East, 17 percent in Guemes Channel, 49 percent in Saddlebag and 6 percent at Cherry Point;
6. GPT bulkers are expected to take 2.25 hours to maneuver to anchor, and 2 hours to maneuver to berth. This time is referred to as 'maneuvering time' and is included with 'transit time' to form 'total time underway'.
7. Each bulker call at GPT will require an assist tug. Assist tugs will homeport in Anacortes, and are expected to travel through the study subareas of Guemes Channel, Saddlebag, Rosario Strait and Cherry Point when travelling to and from GPT;
8. For each bulker call at GPT, there are two assist tug transits (back and forth from Anacortes to Cherry Point).

The movements described are illustrated in Figure 20.

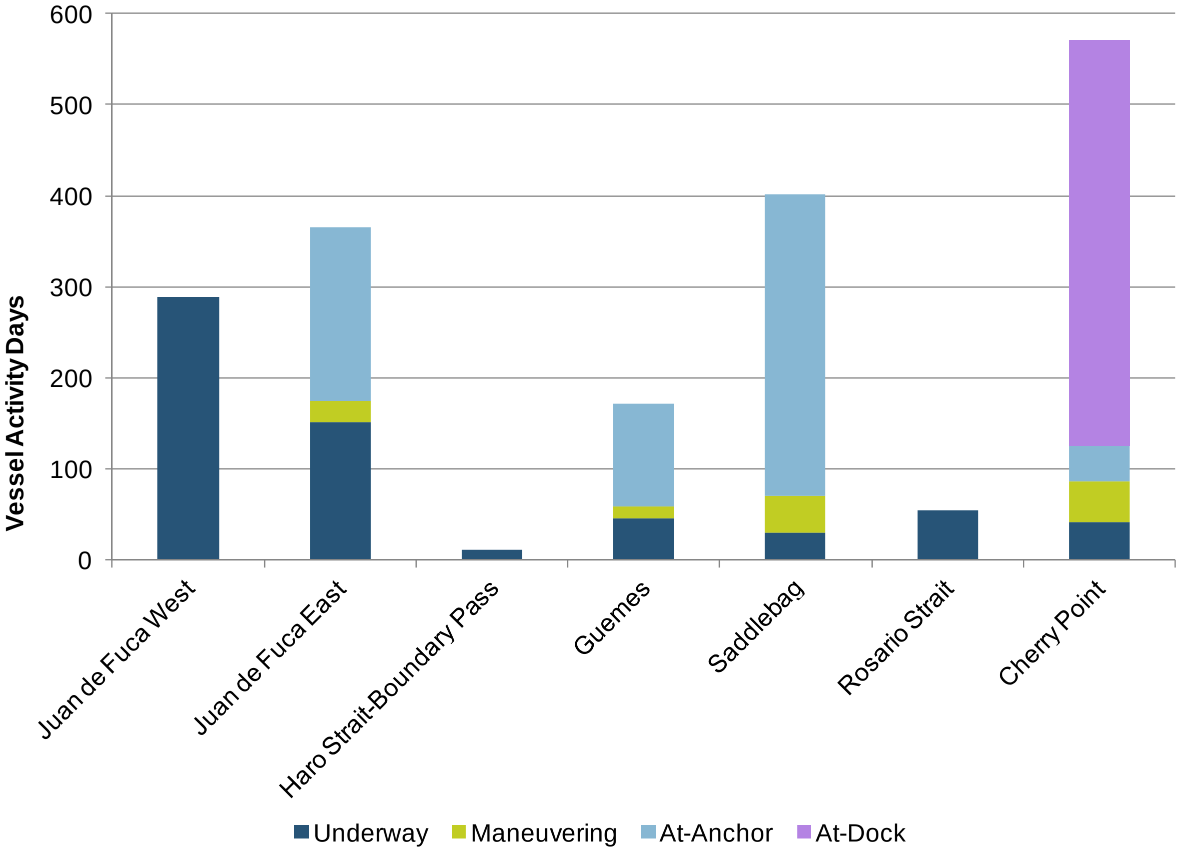
Figure 20. GPT Bulker and Tug Transit Patterns



Note: red arrows are GPT-bulkers. Purple arrow is GPT-bound assist tugs
Source: Northern Economics, Inc. 2013

By 2030 GPT bulker days are forecasted at 1,860. The additional vessel calls will mean additional transit time in each of the subareas, as well as added time at berth in Cherry Point. Time at anchor will decrease due to the availability of two docks at GPT (Figure 21).

Figure 21. GPT Bulker Days by Activity Type and Subarea, 2030



Source: Northern Economics, Inc. 2013

5 Building in Uncertainty

Forecasting is, by nature, an inexact science. While the study team forecasted vessel traffic volumes and patterns based on known data, there is inherent uncertainly in predicting the future. For example, export volumes of petroleum products from the study region could be higher or lower than forecasted by BST. Deviation from BST's economic forecast would skew resulting vessel traffic estimates.

To encompass such uncertainty, the study team built variation into the model using Palisade Corporation's @RISK software. @RISK allows the study team to map in a range of values for specific variables, which in turn generate a range of probable outcomes for vessel traffic. Key areas modeled using @RISK were the commodity growth rates used for the economic forecast, trip-to-transit ratios for future traffic flows, cruise vessel trips and tug maneuvering and at-berth time.

This report uses the most-likely vessel traffic days as a basis for its analysis; however it is worth noting that the values used for the downstream risk analysis are actually ranges of values.

Economic Forecast

Each of the commodity forecasts developed by BST Associates and used in the model included annual commodity volumes for 2011 through 2030, grouped into periods of similar growth (five-year compound average growth rates). For the purpose of this study, the team modeled the five-year growth rates using normal distributions, with BST's five-year growth rates used as the mean values. The team used the standard deviation of the annual growth rates for each period as a basis for the standard deviations of the normal distributions.

Trip-to-Transit Ratios

For each unique vessel that enters the study area, a range of transits can be made depending on the vessel's routing (whether it goes to anchor, makes multiple calls, etc.) The average trip-to-transit ratio was calculated by vessel type for each year from 2006 to 2010.[13] To accommodate the range of trip-to-transits possible for any given vessel type, the study team used a triangular distribution to incorporate a high, low and most likely value. The low and high limits of the distribution were set at the minimum and maximum values seen within the data set; the most likely value was set at the average.

Cruise Vessel Trips

The base analysis modeled trends in cruise ship traffic to develop a forecast.[14] The study team developed low and high estimates for cruise ship traffic and used a triangular distribution to evaluate the uncertainty in cruise ship traffic between those limits, with the base trend as the most likely trip count.

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[13] The years for which the MX data were available.

[14] Cruise vessels are the only passenger vessel type for which an @RISK forecast distribution was developed as ferry traffic days are held constant at 2010 levels.

Tug Maneuvering and At-Berth Time

Tug maneuvering time was expected to range from 0.25 to 1.5 days. For the purpose of modeling, the study team used a uniform distribution to represent this uncertainty, with 0.25 days and 1.5 days as the lower and upper limits, respectively.

Tug at-berth time was expected to range from 0.5 to 2 days. For the purpose of modeling, the study team used a uniform distribution to represent this uncertainty, with 0.5 days and 2 days as the lower and upper limits, respectively.

6 BP Scenario Results

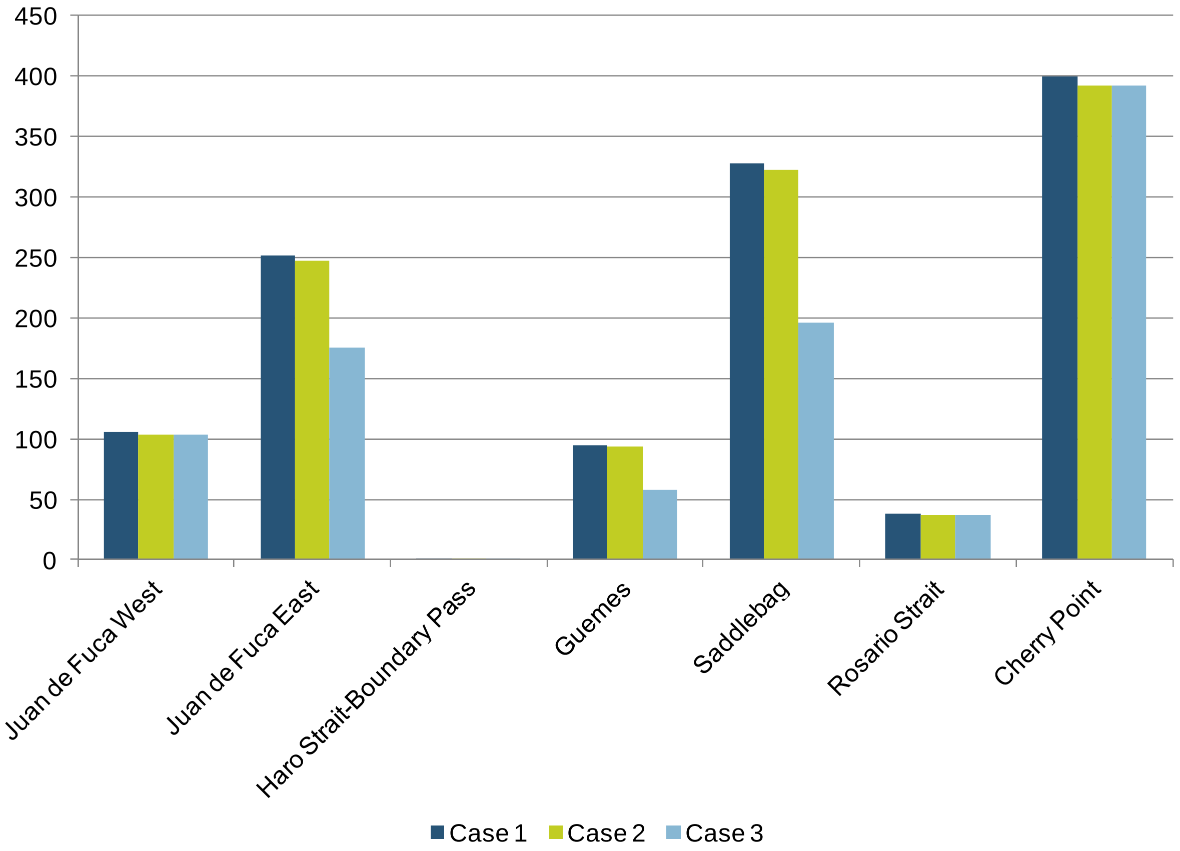
The work described in previous sections of this report was combined to generate estimates of the traffic impact of the seven BP risk scenarios shown in Table 17.

Table 17. Risk Analysis Cases

Case	Year	South Wing	North Wing	BP Calls	Traffic Other Than BP
1	2010	Yes	No	Maximum – single wing (335)	Existing
2	2010	Yes	No	2010 actual calls (329)	
3	2010	Yes	Yes	2010 actual calls (329)	
4	2030	Yes	No	Maximum – single wing (335)	General Traffic
5	2030	Yes	Yes	BP "High" forecast (420)	
6	2030	Yes	No	Maximum – single wing (335)	General Traffic plus Cumulative Traffic
7	2030	Yes	Yes	BP "High" forecast (420)	

For Cases 1 through 3, the non-BP traffic volumes for 2010 do not change; the scenario variability derives from variations to BP-specific vessel calls and berth availability. Consequently the presentation of results for these cases focus on the differences among BP tanker and BP tug times.

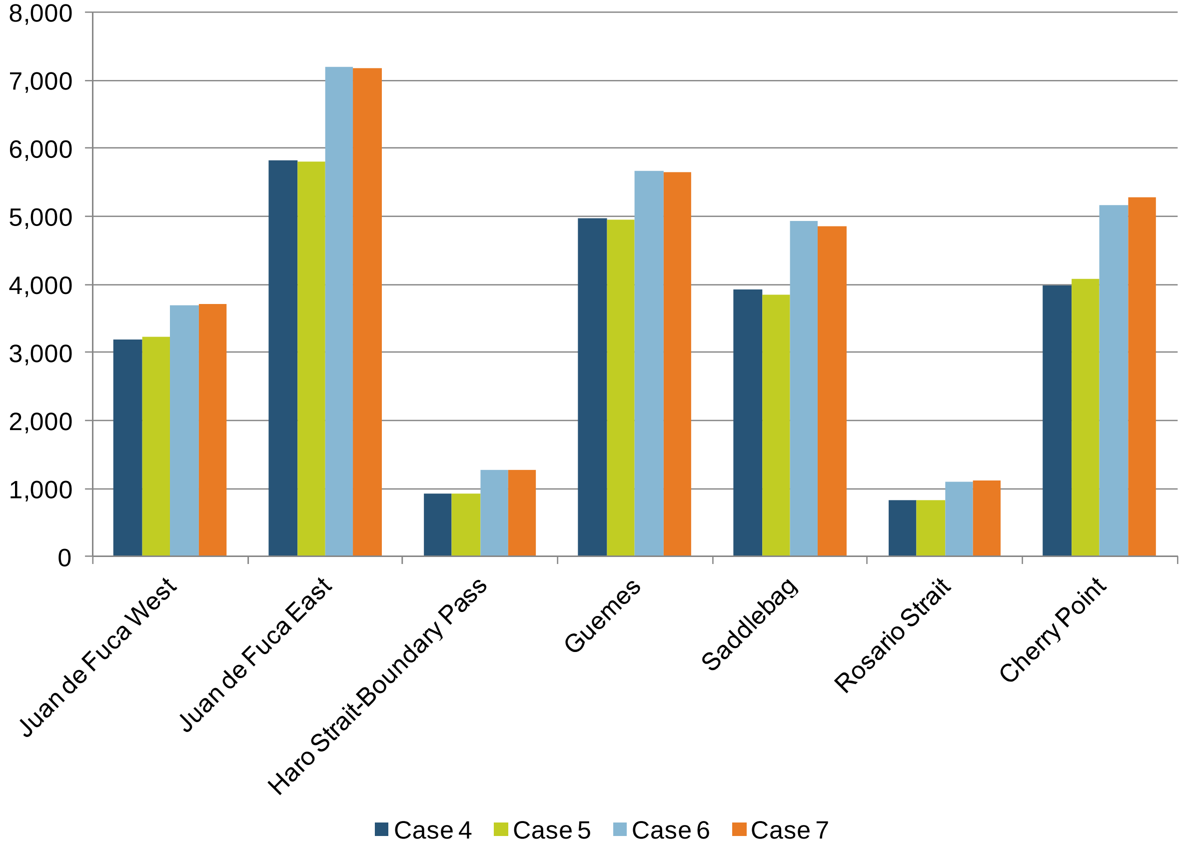
Figure 22. Comparison of BP Tanker Time for Cases 1–3



Source: Northern Economics, Inc. 2013

For Cases 4 through 7, variability exists in both the number of vessels calling at BP Cherry Point and the non-BP traffic volumes. To facilitate comparison among these cases, we focus on total traffic volumes and present our results as total traffic days by subarea and vessel type.

Figure 23. Comparison of Total Vessel Time for Cases 4–7



Source: Northern Economics, Inc. 2013

Case 1: 2010 Single Wing Maximum

Risk analysis Case 1 summarizes the 2010 vessel day impact of 335 tanker vessel calls (the maximum number which can be accommodated with one berth) at BP Cherry Point in 2010. This is an additional six vessels above the 329 that MX data show actually called at the facility in 2010. In addition, the case assumes that only one wing is open (south wing). The impact of the single wing is highlighted in the at-anchor traffic days; with only a single berth available, tanker vessels are expected to have to wait at anchor before a dock space is available. The at-anchor time generated by this scenario, when compared to Scenario 3 (329 calls with two berths available), shows BP-tankers with 245 additional at-anchor days. This additional at-anchor time is concentrated in Juan de Fuca East, Guemes Channel, and Saddlebag subareas.

Table 18. Case 1 BP-Related Tanker Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait - Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	105	65	1	3	6	38	24
Maneuvering	0	7	0	3	6	0	22
At-Anchor	0	179	0	89	316	0	3
At-Dock	0	0	0	0	0	0	351
Total	105	252	1	95	328	38	399

Source: Northern Economics, Inc. 2013

Table 19. Case 1 BP-Related Tug Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	0	95	5	35	42	128	86
Maneuvering	0	0	0	0	0	0	47
At-Anchor	0	0	0	0	0	0	0
At-Dock	0	0	0	0	0	0	0
Total	0	95	5	35	42	128	133

Source: Northern Economics, Inc. 2013

Table 20. Case 1 Total Vessel Activity in Vessel Traffic Days, 2010

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	298	822	30	631	409	60	482	2,733
Tank Barge	175	877	21	682	206	124	685	2,771
Bulker	756	464	209	35	22	2	238	1,726
Cargo	556	325	112	33	165	3	106	1,300
Other	747	2,797	422	3,346	2,676	516	1,989	12,494

Source: Northern Economics, Inc. 2013

Case 2: 2010 Single Wing Actual Calls

Risk analysis Case 2 summarizes the vessel day impact of 329 tanker vessel calls at BP Cherry Point in 2010. While the total number of vessel calls equals those that actually called at the facility in 2010, the case assumes that only one wing is open (south wing). As with case one, the impact of the single wing is highlighted in the at-anchor traffic days; with only a single berth available, tanker vessels are expected to have to wait longer at anchor before a dock space is available.

Table 21. Case 2 BP-Related Tanker Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	103	64	1	3	6	37	23
Maneuvering	0	7	0	3	6	0	21
At-Anchor	0	176	0	87	310	0	3
At-Dock	0	0	0	0	0	0	345
Total	103	247	1	93	322	37	392

Source: Northern Economics, Inc. 2013

Table 22. Case 2 BP-Related Tug Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	0	93	5	35	42	125	85
Maneuvering	0	0	0	0	0	0	46
At-Anchor	0	0	0	0	0	0	0
At-Dock	0	0	0	0	0	0	0
Total	0	93	5	35	42	125	131

Source: Northern Economics, Inc. 2013

Table 23. Case 2 Total Vessel Activity in Vessel Traffic Days, 2010

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	296	817	30	630	404	59	481	2,716
Tank Barge	175	877	21	682	206	124	685	2,771
Bulker	756	464	209	35	22	2	238	1,726
Cargo	556	325	112	33	165	3	106	1,300
Other	747	2,797	422	3,346	2,676	516	1,989	12,494

Source: Northern Economics, Inc. 2013

Case 3: 2010 Double Wing Actuals

Risk analysis Case 3 is identical to the actual vessel calls at Cherry Point in 2010. The scenario summarizes the vessel day impact of 329 tanker vessel calls at BP Cherry Point, and assumes that both wings (north and south) are open. This scenario is the one which emulates the actual vessel traffic that moved in 2010.

Table 24. Case 3 BP-Related Tanker Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	103	64	1	3	6	37	23
Maneuvering	0	7	0	3	6	0	21
At-Anchor	0	105	0	52	184	0	1
At-Dock	0	0	0	0	0	0	345
Total	103	176	1	58	196	37	391

Source: Puget Sound Marine Exchange, 2012

Table 25. Case 3 BP-Related Tug Activity in Vessel Traffic Days, 2010

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	0	93	5	35	42	125	85
Maneuvering	0	0	0	0	0	0	46
At-Anchor	0	0	0	0	0	0	0
At-Dock	0	0	0	0	0	0	0
Total	0	93	5	35	42	125	131

Source: Puget Sound Marine Exchange, 2012

Table 26. Case 3 Total Vessel Activity in Vessel Traffic Days, 2010

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	296	745	30	594	278	59	480	2,483
Tank Barge	175	877	21	682	206	124	685	2,771
Bulker	756	464	209	35	22	2	238	1,726
Cargo	556	325	112	33	165	3	106	1,300
Other	747	2,797	422	3,346	2,676	516	1,989	12,494

Source: Northern Economics, Inc. 2013

Case 4: 2030 Single Wing Maximum; General Traffic

Risk analysis Case 4 summarizes the 2030 vessel day impact of 335 tanker vessel calls (the maximum number of which can be accommodated with one berth) at BP Cherry Point in 2030, same as Case 1. The case assumes that only one wing is open (south wing). In addition, the scenario assumes only a general or baseline traffic increase for non-BP vessels. Case 4 forecast General Traffic is the same for Cases 5 – 7.

Table 27. Case 4 Total Vessel Activity in Vessel Traffic Days, 2030

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	281	759	29	572	401	54	480	2,577
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,160	708	260	232	234	14	295	2,902
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,048	477	3,401	2,481	634	2,313	13,125

Source: Northern Economics, Inc. 2013

Case 5: 2030 BP High Forecast; General Traffic

Risk analysis Case 5 summarizes the 2030 vessel day impact of 420 tanker vessel calls at BP Cherry Point in 2030. The case assumes that both wings are open, and incorporates only a general or baseline traffic increase for non-BP vessels. Case 5 is the same forecasted general traffic as Case 4.

Table 28. Case 5 BP-Related Tanker Activity in Vessel Days, 2030

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	142	86	1	4	7	50	28
Maneuvering	0	11	0	3	8	0	30
At-Anchor	0	134	0	66	235	0	2
At-Dock	0	0	0	0	0	0	441
Total	142	231	1	73	250	50	501

Source: Northern Economics, Inc. 2013

Table 29. Case 5 BP-Related Tug Activity in Vessel Days, 2030

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Transiting	0	119	6	44	53	160	108
Maneuvering	0	0	0	0	0	0	59
At-Anchor	0	0	0	0	0	0	0
At-Dock	0	0	0	0	0	0	0
Total	0	119	6	44	53	160	167

Source: Northern Economics, Inc. 2013

Table 30. Case 5 Total Vessel Activity in Vessel Traffic Days, 2030

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	314	736	29	550	323	66	581	2,600
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,160	708	260	232	234	14	295	2,902
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,048	477	3,401	2,481	634	2,313	13,125

Source: Northern Economics, Inc. 2013

Case 6: 2030 Single Wing Maximum; Cumulative Traffic

Risk analysis Case 6 summarizes the 2030 vessel day impact of 335 tanker vessel calls (the maximum number of which can be accommodated with one berth) at BP Cherry Point in 2030, same as Cases 1 and 4. The case assumes that only one wing is open (south wing). Case 6 is the same forecasted general traffic as Case 4. In contrast to Case 4, the scenario assumes a cumulative traffic increase for non-BP vessels.

Table 31. Case 6 Total Vessel Activity in Vessel Traffic Days, 2030

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	484	1,382	83	746	535	72	604	3,907
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,448	1,073	271	404	635	68	865	4,765
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,423	758	3,748	2,951	837	2,803	15,290

Source: Northern Economics, Inc. 2013

Case 7: 2030 BP High Forecast; Cumulative Traffic

Risk analysis Case 7 summarizes the 2030 vessel day impact of 420 tanker vessel calls at BP Cherry Point in 2030, same as Case 5. The case assumes that both wings are open. Case 7 is the same forecasted general traffic as Case 4, and (in contrast to Case 5) incorporates a cumulative vessel traffic forecast.

Table 32. Case 7 Total Vessel Activity in Vessel Traffic Days, 2030

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	518	1,359	83	724	457	84	705	3,931
Tank Barge	170	825	20	739	191	120	762	2,826
Bulker	1,448	1,073	271	404	635	68	865	4,765
Cargo	816	488	147	25	621	4	137	2,239
Other	771	3,423	758	3,748	2,951	837	2,803	15,290

Source: Northern Economics, Inc. 2013

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Appendix D Incident and Spill Volume Model

BP Cherry Point Vessel Traffic Analysis Study

Characterization of Casualty Consequences

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1 October 2013

ENVIRONMENTAL RESEARCH CONSULTING

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Purpose

The purpose of this report is to provide necessary data and algorithms for the development of the Monte Carlo traffic risk modeling effort associated with the BP Cherry Point Vessel Traffic Analysis Study.

Terminology

Nomenclature

- **Actual bunker fuel load:** the physical capacity of the vessel's bunker fuels reduced to 70% as that is the largest actual amount of bunker fuel typically carried on a vessel in actual practice.[1]
- **Actual oil cargo load:** the physical capacity of the vessel's cargo tanks reduced to 98% (or 93.6% of deadweight tonnage) as that is the largest actual amount of oil cargo typically carried on a vessel.
- **Allision:** an incident in which a moving object strikes a stationary object (e.g., when a vessel strikes a pier or another vessel that is anchored or docked).
- **BPCP VTA Vessels:** vessels for which there are sufficient traffic data and that are therefore included in the analysis of vessel traffic risk.
- **Bunker hull type:** the type of hull (single or double) on the bunker fuel tanks of a general cargo vessel, bulk carrier, or tanker.
- **Bunker:** includes all types of bunker fuel (Bunker A, Bunker B, Bunker C, No. 6 fuel oil, intermediate fuel oil – IFO), as well as diesel fuel (No. 2 fuel oil), and marine gas oil.
- **Bunkering:** the transfer of bunker fuels from one vessel to another or from a stationary facility (storage tank) to a vessel.
- **Cargo hull type:** the type of hull (single or double) on the cargo tanks of a tanker or tank barge
- **Collision:** an incident in which two moving vessels strike each other.
- **Crude tanker:** a tank ship (tanker) that is between 67,000 and 125,000 DWT[2] and usually carries crude oil rather than refined products.
- **Cumulative probability[3]:** the probability that a value (e.g., oil outflow of a certain percentage) will be less than or equal to that value. For example, if the cumulative probability of an oil outflow of 80% of the oil cargo is 95%, it means that there is a 95% chance that an oil outflow will be of 80% oil cargo or less. There is only a 5% chance that the oil outflow percentage will be larger. This is similar to the term "percentile". The 95th percentile spill is that spill volume for which there is only a 5% chance that the spill will be larger.
- **Dry cargo:** bulk commodities carried by bulk carriers, including coal, grain, sand, stone, etc.
- **Deadweight tonnage (DWT)**: the weight (in long tons[4]) that a vessel can carry, including oil (or other) cargo, bunker fuel, stored water, ballast (when not cargo-laden), crew, and miscellaneous

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[1] The derivation of this adjustment is described later in this report.

[2] The vessel size description for crude tankers is based on industry descriptions of crude tankers, as the lower limit, and the regulatory load line limit of tanker size in Puget Sound, as the upper limit.

[3] This is distinct from an alternative use of this term in statistical practice which means the probability of multiple events occurring at the same time.

[4] 1 short ton = 2,000 pounds (lbs); 1 long ton = 2,240 lbs; 1 metric ton (tonne) = 2,205 lbs; 1 long ton = 1.016 metric ton (tonne).

minor contributors to weight. On an oil tanker, 97.5% of DWT is available for oil cargo, 2% for bunker fuel, and 0.5% for stored water.

- **Impact accident:** an incident involving a collision, allision, or grounding.
- **Incident:** an occurrence with a vessel that leads to the potential for spillage of oil or dry cargo or actual spillage.
- **Oil transfer:** any movement of oil cargo and/or bunkers from one vessel to another or from a stationary facility (storage tank) to a vessel.
- **Other Vessels:** this category includes only BPCP VTA vessels not included in the other categories of tanker, bulker, tank barge, or general cargo – cruise ships, regularly-scheduled ferries, tugboats (tugboats and towboats), and fishing vessels of 60 feet or larger.
- **Other, Non-Impact Error:** the category of vessel incidents that excludes impact accidents (allisions, collisions, and groundings) and transfer errors, but includes a variety of other causes, such as equipment failures, operations errors, structural failures, sinking, mechanical failures, intentional discharges, unintended discharges and leakages, and unknown causes.
- **Outflow percentage:** the percentage of the adjusted cargo or bunker capacity on board the vessel that will be released or spilled with a particular incident.
- **Product tanker:** a tank ship (tanker) that is between 22,000 and 67,000 DWT and usually, but not necessarily, carries refined products rather than crude oil. Articulated tank barges (ATBs) and integrated tank barges (ITBs) are included in the "product tanker" size category.
- **R^2:** the coefficient of determination is a value between 0 and 1 that describes how closely a regression curve (derived equation) fits the data. Based on the proportion of data variability that is accounted for in the statistical model (derived equation), a high R^2 means that the equation fits well and will more accurately predict future outcomes.
- **Spill volume:** the amount of spillage (for oil, this is in gallons; for dry cargo, this can be in cubic feet or a weight measurement).
- **Tankers:** tankers are tank ships that carry oil (crude or refined product) as cargo, including integrated tug barges (ITBs) and articulated tug barges (ATBs).
- **Tank Barge**: a barge carrying oil cargo that may or may not be attached to a tug (towboat or tugboat) at the time of the incident. The analytical results apply only to the tank barge (oil spillage, probabilities) and not to the tug. Tugs are separately accounted for under the category "Other Vessel."

Equation Variables

Table A: Equation Variables

Variable	Description	Potential Values
P(x)	Probability of event x	CS, cargo spillage BS, bunker spillage CH_x, cargo hull type BH_x, bunker hull type SV_x, spill volume O_x, outflow
CS	Cargo spillage	-
BS	Bunker spillage	-

Table A: Equation Variables

Variable	Description	Potential Values
Vx	Vessel of type x	Values for x: t, tanker pt, product tanker ct, crude tanker tb, tank barge b, bulk carrier g, general cargo o, other vessel
y	Year	y = 1 for year 2010, *y* = 2 for year 2011, … , *y* = 21 for year 2030
I_x	Incident with cause x	Values for x: c, collision a, allision g, grounding cag, all impact accidents combined o, other, non-impact t, transfer error ot, all non-impact incidents combined
CH_x	Cargo hull type	Values for x: d, double hull s, single hull
BH_x	Bunker hull type	Values for x: d, double hull s, single hull
DWT	Deadweight tonnage	-
GRT	Gross registered tonnage	-
Length	Vessel length (ft)	-
K_x	Vessel capacity (actual load)	Values for x: o, oil cargo b, bunker fuel
SV_x	Spill volume	Values for x: o, oil cargo b, bunker fuel
O_x	Outflow percentage[5]	Values for x: o, oil cargo b, bunker fuel
t	Metric ton (tonne)	-

Calculations for the Probability of Spillage

The probability of spillage is the probability that given an incident there will be a spill of any volume (from very small to very large). This probability does not indicate the volume of spillage, which is calculated in a separate step. The probability of cargo spillage is related to the variables of vessel type, incident cause, and hull type. Since the probability of hull type will change over time, it will be necessary to incorporate a year-dependent probability of hull type for both oil cargo spillage and bunker spillage.

Probability of Oil Cargo Spillage

The relevant variables for determining the probability of oil cargo spillage, *P(CS)*, are shown in Table 1. Oil cargo spillage can only occur from tank vessels – tankers and tank barges.

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[5] Percentage of vessel adjusted capacity.

Table 1: Variables for Probability of Oil Cargo Spillage

Variable	Values
Vessel Type, V_x	Product Tanker, V_{pt}
	Crude Tanker, V_{ct}
	Tank Barge, V_{tb}
Cargo Hull, CH[6]	Single Hull, CH_s
	Double Hull, CH_d
Incident Cause, I_x	Allision, I_a
	Collision, I_c
	Grounding, I_g
	Other, Non-Impact, I_o
	Transfer Error, I_t

The spill probabilities for each vessel/incident cause/hull combination are shown in Table 2. The probabilities of spillage in this table for collisions, allisions, and groundings are derived from outflow models on tankers and tank barges that were developed by naval architects and engineers working on behalf of the International Maritime Organization (IMO)[7] to estimate the probability of spillage given various types of vessel accidents, as well as a more recent study that conducted regression analyses on US Coast Guard vessel casualty data to investigate the effect of double-hulls on spillage rates.[8] The spillage rates for other, non-impact errors and transfer errors are derived from data in National Research Council (NRC) studies and studies conducted by ERC for the US Army Corps of Engineers.[9]

Table 2: Cargo Spill Probabilities for Tankers and Tank Barges[10]

Vessel Type	Incident Cause	Hull[11]	Cargo Spill Probability in Incident, $P(CS)$
Product Tanker (V_{pt})	**Collision (I_c)**	**Single (CH_s)**	0.68
		Double (CH_d)	0.15
	Allision (I_a)	**Single (CH_s)**	0.68
		Double (CH_d)	0.15
	Grounding (I_g)	**Single (CH_s)**	0.91
		Double (CH_d)	0.18
	Other, Non-Impact Error (I_o)	**Single (CH_s)**	0.40
		Double (CH_d)	0.40
	Transfer Error (I_t)	**Single (CH_s)**	0.92
		Double (CH_d)	0.92
Crude Tanker (V_{ct})	**Collision (I_c)**	**Single (CH_s)**	0.81
		Double (CH_d)	0.19
	Allision (I_a)	**Single (CH_s)**	0.81
		Double (CH_d)	0.19
	Grounding (I_g)	**Single (CH_s)**	0.93
		Double (CH_d)	0.20
	Other, Non-Impact Error (I_o)	**Single (CH_s)**	0.40
		Double (CH_d)	0.40
	Transfer Error (I_t)	**Single (CH_s)**	0.92
		Double (CH_d)	0.92

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[6] Single or double hull on cargo tanks for tankers (tank ships) and tank barges. Note that articulated tank barges (ATBs) and integrated tank barges (ITBs) are considered tankers.

[7] Rawson 1998; NRC 1998; NRC 2001; IMO 1995.

[8] Yip *et al.* 2011b.

[9] NRC 1998; NRC 2001; Etkin *et al.* 2002.

[10] Based on Yip *et al.* 2011b; Rawson 1998; NRC 1998; NRC 2001; IMO 1995; Etkin *et al.* 2002.

[11] For tank vessels, hull refers to cargo hull. For all other vessels hull refers to bunker tank hull.

Table 2: Cargo Spill Probabilities for Tankers and Tank Barges[10]

Vessel Type	Incident Cause	Hull[11]	Cargo Spill Probability in Incident, $P(CS)$
Tank Barge (V_{tb})[12]	**Collision (I_c)**	**Single (CH_s)**	0.76
		Double (CH_d)	0.13
	Allision (I_a)	**Single (CH_s)**	0.76
		Double (CH_d)	0.13
	Grounding (I_g)	**Single (CH_s)**	0.76
		Double (CH_d)	0.22
	Other, Non-Impact Error (I_o)	**Single (CH_s)**	0.40
		Double (CH_d)	0.40
	Transfer Error (I_t)	**Single (CH_s)**	0.92
		Double (CH_d)	0.92

The probabilities of a tanker or tank barge having a single or double cargo hull are show in Table 3.

Table 3: Probabilities of Cargo Hull Types for Tankers and Tank Barges by Year

Years (y)	Double Hull, $P(CHd)$	Single Hull, $P(CHs)$
2010 (y = 1)	0.87	0.13
2011 (y = 2)	0.90	0.10
2012 (y = 3)	0.93	0.07
2013 (y = 4)	0.96	0.04
2014 (y = 5)	0.99	0.01
2015 (y = 6)	1.00	0.00
2016 (y = 7)	1.00	0.00
2017 (y = 8)	1.00	0.00
2018 (y = 9)	1.00	0.00
2019 (y = 10)	1.00	0.00
2020 (y = 11)	1.00	0.00
2021 (y = 12)	1.00	0.00
2022 (y = 13)	1.00	0.00
2023 (y = 14)	1.00	0.00
2024 (y = 15)	1.00	0.00
2025 (y = 16)	1.00	0.00
2026 (y = 17)	1.00	0.00
2027 (y = 18)	1.00	0.00
2028 (y = 16)	1.00	0.00
2029 (y = 17)	1.00	0.00
2030 (y = 18)	1.00	0.00

Probability of Bunker Spillage, *P(BS)*

The relevant variables for determining the probability of bunker[14] spillage, *P(BS)*, are shown in Table 4. A "transfer error" of bunker fuel is also called a "bunkering error."

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[12] Note that for the category "Tank Barge", the incident rate relates only to the tank barges themselves, which may or may not occur while there is a tug (towboat or tugboat) associated with tank barge. Incidents involving tugs are included under Other Vessels. In those cases, the tug (towboat or tugboat) may be operating independently or have a tank barge or other barge attached to it.

[14] The term "bunker" is used for all fuel types – Bunker A, Bunker B, Bunker C, Intermediate Fuel Oil (IFO), diesel (No. 2 fuel), gasoline, etc.

Table 4: Variables for Probability of Bunker Spillage for All BPCP VTA Vessels

Variable	Values
Vessel Type, V_x	Tanker, V_t
	Tank Barge, V_{tb}
	Bulk, Vb
	General Cargo, V_g
	Other, V_o
Bunker Hull, BH[15]	Single Hull, BH_s
	Double Hull, BH_d
Incident Cause, I_x	Allision, I_a
	Collision, I_c
	Grounding, I_g
	Other, Non-Impact, I_o
	Transfer Error, I_t

The probabilities of bunker spillage by vessel type, cause, and hull type are shown in Table 5.

The hull configuration for bunker tanks is also independent of the hull configuration of the cargo tanks. That is, there can be a double-hull on the cargo tanks and only a single-hull on the bunker tanks. The schedules for implementation of double-hulls on cargo and bunker tank are different (see Tables 3 and 6). The probabilities in Table 5 are based on bunker tank outflow modeling conducted for IMO[16] and studies conducted on US oil spills.[17]

Tankers, bulk carriers, and general cargo vessels have been assigned the same bunker spill probabilities as the previous analyses conducted on bunker spillage probabilities do not differentiate between different vessel types. For the vessels in the “other vessels” category, there is no difference between spillage probabilities in double and single hulled tanks. These vessels are not covered under the regulations that will mandate double hulls on bunker tanks. There will therefore be no difference in double and single hulls for these vessels.

Table 5: Bunker Spill Probabilities for All BPCP VTA Vessels[18]

Vessel Type	Incident Cause	Hull	Bunker Spill Probability
Tankers (V_t)[19]	**Collision (I_c)**	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Allision (I_a)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Grounding (I_g)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Other, Non-Impact Error (I_o)	**Single (BH_s)**	0.20
		Double (BH_d)	0.20
	Transfer Error (I_t)	**Single (BH_s)**	0.92
		Double (BH_d)	0.92

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[15] Single- or double hull on bunker tanks for all vessels including tankers, except for tank barges, which do not have bunker tanks.

[16] Michel and Winslow 1999, 2000; Barone *et al.* 2007.

[17] Etkin and Michel 2003; Herbert Engineering *et al.* 2003.

[18] Based on Etkin and Michel 2003; Michel and Winslow 1999, 2000; Barone *et al.* 2007; Herbert Engineering *et al.* 2003; Barone *et al.* 2007.

[19] Product and crude tankers are treated as a combined category only as there are no differences in bunker spillage probabilities between the two vessel sub-categories.

Table 5: Bunker Spill Probabilities for All BPCP VTA Vessels[18]

Vessel Type	Incident Cause	Hull	Bunker Spill Probability
Tank Barge (V_{tb})[20]	**Collision (I_c)**	**Single (BH_s)**	0.00
		Double (BH_d)	0.00
	Allision (I_a)	**Single (BH_s)**	0.00
		Double (BH_d)	0.00
	Grounding (I_g)	**Single (BH_s)**	0.00
		Double (BH_d)	0.00
	Other, Non-Impact Error (I_o)	**Single (BH_s)**	0.00
		Double (BH_d)	0.00
	Transfer Error (I_t)	**Single (BH_s)**	0.92
		Double (BH_d)	0.92
Bulk Carriers (V_b)	**Collision (I_c)**	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Allision (I_a)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Grounding (I_g)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Other, Non-Impact Error (I_o)	**Single (BH_s)**	0.20
		Double (BH_d)	0.20
	Transfer Error (I_t)	**Single (BH_s)**	0.92
		Double (BH_d)	0.92
General Cargo Vessels (V_g)	**Collision (I_c)**	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Allision (I_a)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Grounding (I_g)	**Single (BH_s)**	0.05
		Double (BH_d)	0.02
	Other, Non-Impact Error (I_o)	**Single (BH_s)**	0.20
		Double (BH_d)	0.20
	Transfer Error (I_t)	**Single (BH_s)**	0.92
		Double (BH_d)	0.92
Other Vessels[21] **(V_o)**	**Collision (I_c)**	**Single (BH_s)**	0.05
		Double (BH_d)	0.05
	Allision (I_a)	**Single (BH_s)**	0.05
		Double (BH_d)	0.05
	Grounding (I_g)	**Single (BH_s)**	0.05
		Double (BH_d)	0.05
	Other, Non-Impact Error (I_o)	**Single (BH_s)**	0.20
		Double (BH_d)	0.20
	Transfer Error (I_t)	**Single (BH_s)**	0.92
		Double (BH_d)	0.92

The probabilities of vessels in Table 5 having a single or double hull are show in Table 6. The exceptions are tank barges, which do not have bunker tanks,[22] and vessels in the Other Vessels category, which will not likely have double hulls within the study period through 2030.

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[20] Note that since tank barges do not carry bunker fuel, the probability for bunker fuel spillage is zero. The probability for the tug (towboat or tugboat) towing the tank barge is separately handled in the Other Vessel category.

[21] Includes only BPCP VTA vessels not in other categories of tanker, bulk, tank barge, or general cargo.

[22] This is referring only to the tank barge and not its associated tug.

Table 6: Application of Double-Hulls for Bunker Tank Percentages to Future Projections

Years (y)	Probability of Double Hull (BH_d)	Probability of Single Hull (BH_s)
2010 ($y = 1$)	0.05	0.95
2011 ($y = 2$)	0.09	0.91
2012 ($y = 3$)	0.14	0.86
2013 ($y = 4$)	0.18	0.82
2014 ($y = 5$)	0.23	0.77
2015 ($y = 6$)	0.27	0.73
2016 ($y = 7$)	0.32	0.68
2017 ($y = 8$)	0.36	0.64
2018 ($y = 9$)	0.41	0.59
2019 ($y = 10$)	0.45	0.55
2020 ($y = 11$)	0.50	0.50
2021 ($y = 12$)	0.54	0.46
2022 ($y = 13$)	0.59	0.41
2023 ($y = 14$)	0.63	0.37
2024 ($y = 15$)	0.68	0.32
2025 ($y = 16$)	0.72	0.28
2026 ($y = 17$)	0.75	0.25
2027 ($y = 18$)	0.79	0.21
2028 ($y = 19$)	0.83	0.17
2029 ($y = 20$)	0.87	0.13
2030 ($y = 21$)	0.91	0.09

Special Issue of Tanker Bunker and/or Cargo Spillage

For tankers only, the spill of oil cargo is a separate event from the spillage of bunker fuel. There are separate probabilities that a bunker spill will occur with an impact and that cargo spill will occur with an impact. They are independent events. For all incident causes, there is a higher probability of oil cargo spillage than for bunker spillage. Transfer errors are treated differently, as there are two separate events for bunkering operations and cargo transfer operations.

Calculations for Vessel Oil Capacity

Since the spillage or outflow is determined as a percentage of the amount of oil on board the vessel as a function of its volumetric capacity (either for oil cargo or bunker fuel), the capacity of each vessel in the system must be estimated based on vessel type and size, typically deadweight tonnage (DWT).

Approaches to Estimating Oil Cargo Capacity for Tankers

In general, there is a distinction between the vessel's true capacity, i.e., the volumetric capacity of its cargo tanks and the actual amount of oil that is on board a "fully-laden" tanker in practice.

Two professors on shipping practices, Niko Wijnolst, Chairman of the European Network of Maritime Clusters, and Tor Wergeland stated in their textbook on shipping[25] that, in practice, loading rates for crude oil carriers vary from 80% to 97% of the deadweight tonnage (DWT) for a "fully laden" tanker. The authors state that utilization in practice hardly exceeds 95%, but could be as low as 65%. (Note that this is a "fully laden" tanker not one that has off-loaded a portion of its cargo at one port and proceeds to

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[25] Wijnolst and Wergeland 1997.

the next with less than the original amount.) In two significant dynamic collision risk modeling studies, the figure of 91% is utilized.[26]

For outflow modeling purposes, IMO uses 98% of volumetric capacity of the cargo tanks.[27] The calculations for outflow are based on these values. In official records of a vessel's cargo capacity (e.g., Clarkson Register, Lloyds Register, American Bureau of Shipping) the "cargo capacity" of a tanker is reported as 98% of the volumetric capacity of its cargo tanks.

Professors Wijnolst and Wergeland[28] write that, typically, 2.5% of the deadweight tonnage of a vessel is used for storage of water and bunker oil, with bunker oil assumed to be about 2%. [29] This would mean then that if one was using 95% deadweight tonnage maximum loading value,[30] 2.5% could be subtracted for the bunker fuel and oil, giving a high value of 92.5% DWT that is actually oil cargo. Note also that even if one is using the 98% full tank, when one is calculating the amount of oil on board the vessel from its DWT, one has to subtract 2.5% of the DWT for bunker fuel and stored water.

Development of Formula for Actual Amount of Oil on "Fully Laden" Tanker

As a practical matter, for the Monte Carlo simulation and other aspects of the current study, the oil on board of tankers, which represents the worst-case discharge potential for the vessels, must be derived as a function of some measure of vessel size. Deadweight tonnage is the most appropriate measure of vessel size for these purposes.

Deadweight tonnage (DWT) of a tanker is the total weight that a vessel can carry. This includes the oil cargo, bunker fuels, stored water, ballast (when the vessel is in ballast rather than laden), and miscellaneous other smaller loads, including the crew. On an oil tanker, clearly the vast majority of DWT is taken up by the oil cargo when the tanker is laden. Using the rule of thumb of Wijnolst and Wergeland (1997) that 2% of DWT is bunker fuel, and 0.5% of DWT is stored water, this leaves 97.5% of DWT for oil cargo alone. The actual percentage may be somewhat less depending the contribution of the other minor factors of crew and miscellaneous loads.[31]

The remaining 97.5% DWT is then the theoretical maximum capacity of the tanker for oil cargo. This can then be further broken down depending on the assumption of capacity. This would need to be applied to any formulae or algorithms that are working directly with the capacity of tanks rather DWT.

If one begins with the assumption of 98% full cargo tanks,[32] this needs to be converted to a percentage of DWT as in Equations 1 – 3 to estimate the actual cargo load:

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[26] Eide *et al.* 2007; Behrens *et al.* 2003.

[27] National Research Council 1998, 2001.

[28] Wijnolst and Wergeland 1997.

[29] This also bears out in analyses of known bunker capacities and deadweight tonnages as in Etkin and Michel 2003.

[30] Based on Eide *et al.* 2007 and Behrens *et al.* 2003.

[31] It is assumed that this is less than 0.5% since it is not even mentioned in the calculations of Wijnolst and Wergeland (1997) and others (Behrens *et al.* 2003; Eide *et al.* 2007).

[32] National Research Council 1998, 2001.

$$K_o(long - tons) = 0.98 \cdot 0.975 \cdot DWT$$
$$K_o(tonnes) = 0.971 \cdot DWT$$
$$K_o(gallons) = 285.4 \cdot DWT$$
[1, 2, 3]

The regulatory basis for limiting the maximum amount of oil cargo transported through Puget Sound is based on a limit of 125,000 DWT as per federal regulations[33], that is by the tanker's tonnage.

Bunker Capacity (K_b) for Tankers and General Cargo Vessels

Again, for oil outflow modeling purposes only, IMO uses 98% of volumetric capacity as the maximum assumed bunker load on a vessel.[39] In actual practice, however, the expert advice has been that bunker tanks are never more than 70% full in practice. [40]

The recommended formulae for estimating bunker capacity for BPCP study vessels are Equations 4 and 5. These formulae were derived from regressions of known bunker volumes (corrected to 70%) for the vessel types – tankers and general cargo vessels. The Glosten Associates has developed its own equation for the purpose of estimating bunker capacity in bulker vessels as the regression developed from bulker vessels in the incident data did not include vessels of a capacity above 44,000 DWT.

$$K_b(V_t) = 5.086 DWT + 106{,}924$$
$$R^2 = 0.958$$
$$K_b(V_g) = 27.545 DWT - 64{,}922$$
$$R^2 = 0.930$$
[4, 5]

Where $K_b(V_t)$ = bunker tank capacity of tankers (in gallons) adjusted for 70% capacity[41]
$K_b(V_g)$ = bunker tank capacity of general cargo vessels[42] (in gallons)
DWT = deadweight tonnage

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[33] 33 CFR (Code of Federal Register) §165.1303b
[39] Barone *et al.* 2007; Michel and Winslow 1999, 2000.
[40] This is the value that was used in the US Army Corps study (Etkin and Michel 2003), as well as studies for Puget Sound (Etkin 2001; Etkin *et al.* 2009; French-McCay *et al.* 2008) and other parts of the US (Etkin 2003, 2003). ERC has not seen any other mention of the actual percentage of bunker tank capacity that is filled with bunker fuel. These assumptions were applied to all of the aforementioned studies on the Puget Sound (Etkin 2001; Etkin *et al.* 2009; French-McCay *et al.* 2008; Etkin *et al.* 2005; French-McCay *et al.* 2005, 2006a, 2006b, 2006c, 2006d), as well as US-wide studies (Etkin 2002, 2003).
[41] In other studies conducted by ERC with Herbert Engineering, Inc., adjustments were made to bunker tank capacity as it is common practice that bunker tanks are rarely filled to more than 70% capacity even when "full" (Etkin and Michel 2003).
[42] Based on data available for container ships.

Calculation of Spill Volume Probability Distributions – Oil Cargo

If a spill of oil cargo does occur, it will involve a volume (from very small to very large) based on the type of vessel, including hull type, and the accident cause. Based on historical data, a distribution of probabilities is assigned to the spill volumes. Generally, smaller spills are more common and very large spills are rare.

Oil Cargo Spill Volume Distributions

The relevant variables for determining the probability distributions of oil cargo spillage volume, *P(Svc)*, are shown in Table 7. Oil cargo spillage can only occur from tank vessels – tankers and tank barges. The probabilities of cargo hull type for tankers and tank barges by year were shown in Table 3.

Table 7: Variables for Probability Distributions of Oil Cargo Spillage Volume

Variable	Values
Vessel Type, V_x	Tanker, V_t
	Tank Barge, V_{tb}
Cargo Hull, CH_x[43]	Single Hull, CH_s
	Double Hull, CH_d
Incident Cause, I_x	Allision, I_a
	Collision, I_c
	Grounding, I_g
	Other, Non-Impact, I_o
	Transfer Error, I_t

Cargo oil spill volume is the percentage outflow of the cargo (O_o) times the oil cargo capacity (*Ko*), as in Equation 6.

$$SV_O = O_O \times K_O \quad [6]$$

Oil Cargo Outflow Probability for Tankers in Impact Accidents

Oil outflow probabilities differ somewhat by hull type for tankers. The probability distribution of percentage of outflow for *double-hull* tankers involved in impact accidents is as shown in Table 8. The probability distribution of percentage of outflow for single-hull tankers involved in impact accidents is as shown in Table 9. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[44] which was in turn, adjusted to derive the same probability density function of spill volumes based on 98% of volumetric cargo capacity rather than the original known cargo amounts as per Equation 3. The approach was verified by existing oil outflow models developed for IMO.[45]

Table 8: Oil Cargo Outflow Probability for Double-Hull Tankers in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[46]	Cumulative Probability
0.002%	0.3589	0.3589
0.02%	0.1400	0.4989

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[43] Single or double hull on cargo tanks for tankers (tank ships) and tank barges. Note that articulated tank barges (ATBs) and integrated tank barges (ITB)s are considered tankers.
[44] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin et al. 2009.
[45] Rawson 1998; Yip *et al.* 2011b; NRC 1998; NRC 2001.
[46] Based on Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009; Rawson 1998; Yip *et al.* 2011b; NRC 1998; NRC 2001.

Table 8: Oil Cargo Outflow Probability for Double-Hull Tankers in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[46]	Cumulative Probability
0.05%	0.1200	0.6189
0.2%	0.1110	0.7299
0.7%	0.0900	0.8199
1.5%	0.0800	0.8999
3.4%	0.0700	0.9699
22%	0.0300	0.9999
50%	0.0001	1.0000

Table 9: Oil Cargo Outflow Probability for Single-Hull Tankers in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[46]	Cumulative Probability
0.002%	0.3589	0.3589
0.02%	0.1400	0.4989
0.05%	0.1200	0.6189
0.2%	0.1110	0.7299
0.7%	0.0900	0.8199
1.5%	0.0800	0.8999
3.4%	0.0700	0.9699
22%	0.0300	0.9999
100%	0.0001	1.0000

Outflow modeling has demonstrated that the volumes of outflows for the very largest incidents would be reduced by 50% with double hulls.[46] For Puget Sound, the largest tanker spill volume of 34 million gallons from a single-hulled tanker would result in spillage of 17 million gallons from a double-hulled tanker. The smaller spillage volumes would not be affected.

Note also that this is independent of the probability of spillage occurring with an impact accident. Double hulls on tankers accomplish two things – reduction of the probability of any spillage occurring in the first place, and reduction of the volume of spillage for the very largest incidents by 50%. This is not the case for double hulls on bunker tanks, for which there is a reduction in the probability of spillage occurring in an impact accident, but there is no reduction in spillage volume with large incidents.[46]

Oil Cargo Outflow Probability for Tankers in Other, Non-Impact Incidents

The hull type does not affect the probability of non-impact accident outflows. The probability of percentage outflow for single-hull and double-hull tankers involved in Other, Non-Impact incidents is as shown in Table 10. There is no difference between single- and double-hulled tankers for these types of incidents. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[47] which was in turn, adjusted to derive the same based probability density function of spill volumes based on 98% of volumetric cargo capacity rather than the original known cargo amounts.

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[47] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

Table 10: Oil Cargo Outflow Probability for Single or Double-Hull Tankers in Other, Non-Impact Incidents

% Actual Cargo Outflow	Probability $P(O_o)$[48]	Cumulative Probability
0.012%	0.50	0.5000
0.02%	0.15	0.6500
0.06%	0.11	0.7600
0.2%	0.08	0.8400
0.5%	0.08	0.9200
12.8%	0.08	1.0000

Oil Cargo Outflow Probability for Tank Barges in Impact Accidents

The probability of percentage of outflow for single-hull tank barges[49] involved in impact accidents (collisions, allisions, and groundings) is as shown in Table 11. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[50] which was in turn, adjusted to derive the same based probability density function of spill volumes based on 98% of volumetric cargo capacity rather than the original known cargo amounts.

Table 11: Oil Cargo Outflow Probability for Single-Hull Tank Barges in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[51]	Cumulative Probability
0.001%	0.180	0.1800
0.01%	0.220	0.4000
0.03%	0.200	0.6000
0.2%	0.110	0.7100
0.5%	0.090	0.8000
1.2%	0.070	0.8700
3.4%	0.060	0.9300
8%	0.030	0.9600
16%	0.020	0.9800
25%	0.018	0.9980
100%	0.002	1.0000

The probability distribution of percentage of outflow for double-hull tank barges involved in impact accidents is as shown in Table 12.

Table 12: Oil Cargo Outflow Probability for Double-Hull Tank Barges in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[52]	Cumulative Probability
0.001%	0.180	0.1800
0.01%	0.220	0.4000
0.03%	0.200	0.6000
0.2%	0.110	0.7100
0.5%	0.090	0.8000
1.2%	0.070	0.8700

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[48] Based on Etkin and Michel 2003; Etkin 2001; Etkin 2002.

[49] Note that the oil outflow only comes from the tank barge itself. Tugs (towboats and tugboats) are separately tracked under Other Vessels.

[50] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

[51] Based on Etkin and Michel 2003; Etkin 2001; Etkin 2002.

[52] Based on Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009; Rawson 1998; Yip *et al.* 2011b; NRC 1998; NRC 2001.

Table 12: Oil Cargo Outflow Probability for Double-Hull Tank Barges in Impact Accidents

% Actual Cargo Outflow	Probability $P(O_o)$[52]	Cumulative Probability
3.4%	0.060	0.9300
8%	0.030	0.9600
16%	0.020	0.9800
25%	0.018	0.9980
50%	0.002	1.0000

The probability distribution of percentage of outflow for single-hull and double-hull Tank Barges[53] involved in Other Non-Impact incidents is as shown in Table 13. There is no difference between single- and double-hulled tank barges for these types of incidents. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[54] which was in turn, adjusted to derive the same based probability density function of spill volumes based on 98% of volumetric cargo capacity rather than the original known cargo amounts.

Table 13: Oil Cargo Outflow Probability for Single/ Double-Hull Tank Barges in Other, Non-Impact Incidents

% Actual Cargo Outflow	Probability $P(O_o)$[55]	Cumulative Probability
0.0010%	0.450	0.4500
0.0015%	0.120	0.5700
0.0019%	0.100	0.6700
0.005%	0.080	0.7500
0.01%	0.070	0.8200
0.02%	0.060	0.8800
0.05%	0.040	0.9200
0.09%	0.030	0.9500
1%	0.020	0.9700
2%	0.014	0.9840
6%	0.004	0.9880
16%	0.004	0.9920
21%	0.004	0.9960
30%	0.004	1.0000

Oil Outflow for Tanker Oil-Cargo Transfer Incidents

The probability distribution of percentage of outflow for tankers involved in transfer error incidents is as shown in Table 14. Note that there is no difference between double- and single-hulled tankers with regard to oil outflow from transfer errors. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[56] which was in turn, adjusted to derive the same based probability density function of spill volumes based on 98% of volumetric cargo capacity rather than the original known cargo amounts.

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[53] Note that the oil outflow only comes from the tank barge itself. Tugs (towboats and tugboats) are separately tracked under Other Vessels.

[54] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

[55] Etkin 2001, 2002, 2003.

[56] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

Table 14: Oil Cargo Outflow Probability from Tanker Transfer Errors

% Actual Cargo Oil Outflow	Probability $P(O_o)$ [57]	Cumulative Probability
0.000003%	0.142	0.142
0.000007%	0.092	0.233
0.000009%	0.068	0.301
0.000018%	0.046	0.347
0.000021%	0.028	0.375
0.000025%	0.024	0.399
0.000029%	0.026	0.425
0.000036%	0.029	0.454
0.000045%	0.031	0.485
0.000054%	0.017	0.502
0.000073%	0.024	0.526
0.000091%	0.029	0.555
0.00010%	0.020	0.575
0.00012%	0.017	0.592
0.00014%	0.011	0.603
0.00016%	0.024	0.627
0.00019%	0.015	0.642
0.00023%	0.018	0.660
0.00027%	0.031	0.691
0.00036%	0.031	0.722
0.00045%	0.017	0.739
0.00054%	0.013	0.752
0.0006%	0.028	0.779
0.0007%	0.013	0.792
0.0008%	0.026	0.818
0.0009%	0.009	0.827
0.001%	0.015	0.842
0.002%	0.026	0.868
0.003%	0.015	0.882
0.004%	0.024	0.906
0.005%	0.020	0.926
0.008%	0.026	0.952
0.009%	0.018	0.971
0.03%	0.013	0.983
0.09%	0.006	0.989
0.18%	0.004	0.993
0.27%	0.004	0.996
0.36%	0.004	1.000

Spill Volumes from Tank Barge Oil Cargo Transfer Incidents

The probability distribution of percentage of outflow for tankers and tank barges involved in transfer error incidents is as shown in Table 15. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of bunker tanks in vessels.[58]

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[57] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin and Neel 2001; Etkin 2006.

[58] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

Table 15: Oil Cargo Outflow Probability from Tank Barge Transfer Errors

% Actual Cargo Outflow	Probability $P(O_o)$[59]	Cumulative Probability
0.0001%	0.384	0.384
0.0005%	0.267	0.651
0.002%	0.116	0.767
0.004%	0.081	0.849
0.007%	0.035	0.884
0.01%	0.023	0.907
0.02%	0.023	0.930
0.02%	0.023	0.953
0.03%	0.012	0.965
0.06%	0.012	0.977
0.2%	0.012	0.988
0.5%	0.012	1.000

Calculation of Spill Volume Probability Distributions – Bunker Fuel

If a spill of bunker fuel does occur, it will involve a volume (from very small to very large) based on the type of vessel, including hull type, and the accident cause. Based on historical data, a distribution of probabilities is assigned to the spill volumes. Generally, smaller spills are more common and very large spills are rare.

Bunker Spill Volume Distributions from Impact Accidents

Note that in the modeling, for tankers, it is assumed that the volume of spillage is for either bunker fuel or oil cargo, not a summation of both, as the probability of both spilling simultaneously is very small.

Spill volume is derived by multiplying the oil outflow percentage times the capacity as in Equation 7.

$$SV_b = O_b \times K_b \qquad [7]$$

The probability distribution of percentage of outflow for all vessels (except tank barges, which have no bunker fuel) involved in impact accidents is as shown in Table 16. Note that there is no difference between double- and single-hulled vessels with regard to oil outflow percentage. The probability that a spill will occur is reduced by the presence of a double hull. This is addressed in the spill probability algorithms. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the estimated or reported amount of bunker tanks in vessels at their "full" (i.e., 70% full) capacity.[60] The approach was verified by oil outflow modeling conducted for IMO.[61]

Table 16: Bunker Outflow Probability from All Vessel Impact Accidents

% Actual Bunker Outflow	Probability $P(O_b)$[62]	Cumulative Probability
0.01%	0.23	0.2300
0.03%	0.17	0.4000
0.15%	0.14	0.5400
1.6%	0.10	0.6400

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[59] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin and Neel 2001; Etkin 2006.

[60] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

[61] Michel and Winslow 1999, 2002; Barone *et al.* 2007; Yip *et al.* 2011a.

[62] Etkin and Michel 2003; Etkin 2001; Etkin 2002; Herbert Engineering *et al.* 2003; Michel and Winslow 1999, 2002; Barone et al. 2007; Yip et al. 2011a.

Table 16: Bunker Outflow Probability from All Vessel Impact Accidents

% Actual Bunker Outflow	Probability *P*(O_b)[62]	Cumulative Probability
4.3%	0.09	0.7300
10%	0.08	0.8100
16%	0.06	0.8700
33.3%	0.05	0.9200
59%	0.04	0.9600
100%	0.04	1.0000

Bunker Outflow from Transfer Errors in General Cargo Vessels, Tankers, and Bulk Carriers

The probability distribution of percentage of outflow for general cargo vessels, tankers, and bulk carriers involved in transfer error incidents during bunkering (fueling) operations[69] is as shown in Table 17. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of bunker tanks in vessels.[70]

Table 17: Bunker Outflow Probability from Tankers, Bulk Carriers, and General Cargo Vessels due to Transfer Errors during Bunkering Operations

% Actual Bunker Outflow	Probability *P*(O_b)[71]	Cumulative Probability
0.0005%	0.244	0.244
0.002%	0.197	0.441
0.008%	0.142	0.583
0.02%	0.105	0.687
0.04%	0.071	0.759
0.07%	0.062	0.820
0.12%	0.047	0.867
0.2%	0.041	0.908
0.3%	0.023	0.931
0.4%	0.017	0.948
0.7%	0.017	0.966
1.2%	0.014	0.979
2.0%	0.011	0.990
3.3%	0.005	0.995
6.2%	0.004	0.999
12%	0.001	1.000

Bunker Outflow from Transfer Errors in Other Vessels

The probability distribution of percentage of outflow for other vessels involved in transfer error incidents during bunkering (fueling) operations is as shown in Table 18. The percentage oil outflow probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of bunker tanks in vessels.[72]

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[69] Also referred to as "bunkering errors".

[70] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

[71] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin and Neel 2001; Etkin 2006.

[72] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin *et al.* 2009.

Table 18: Bunker Outflow Probability from Other Vessels: Transfer Errors during Bunkering

% Actual Bunker Outflow	Probability $P(O_b)$[73]	Cumulative Probability
0.001%	0.265	0.265
0.004%	0.176	0.441
0.011%	0.103	0.544
0.017%	0.088	0.632
0.024%	0.059	0.691
0.035%	0.074	0.765
0.05%	0.074	0.838
0.07%	0.044	0.882
0.10%	0.029	0.912
0.15%	0.029	0.941
0.23%	0.029	0.971
0.54%	0.015	0.985
1.1%	0.015	1.000

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Appendix E Supplemental Incremental Risk Results

Appendix E Supplemental Incremental Risk Results

This appendix contains additional results of the incremental risk analysis not found in the body of the report, but which are necessary to fully support the study objectives and conclusions drawn. These results include:

- Number of spills by subarea.
- Number of spills by incident type.
- Numer of Spills by subarea and incident type.
- Number of incidents by subarea.
- Annual oil outflow by subarea.
- Annual oil outflow subarea and incident type.

Number of Spills by Subarea

Table 1 shows the average number of spills predicted by the oil outflow model for each subarea for the seven cases.

Table 1 Average Number of Spills per Subarea

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Straits of Juan de Fuca West	0.86	0.87	0.84	0.94	0.98	1.19	1.24
Straits of Juan de Fuca East	2.28	2.22	2.20	2.39	2.38	3.51	3.55
Haro Strait and Boundary Pass	0.15	0.15	0.16	0.19	0.19	0.36	0.36
Guemes Channel and Fidalgo Bay	2.36	2.32	2.36	2.97	2.95	3.54	3.53
Saddlebag	1.31	1.29	1.26	2.29	2.29	2.93	2.93
Rosario Strait	0.12	0.11	0.12	0.12	0.13	0.16	0.16
Cherry Point	2.93	2.93	2.93	3.48	3.76	4.88	5.19

Table 2 shows the 50th percentile (median) number of spills predicted by the oil outflow model for each subarea[1] for all seven cases.

Table 2 50th Percentile (Median) Number of Spills per Subarea

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Straits of Juan de Fuca West	1	1	1	1	1	1	1
Straits of Juan de Fuca East	2	2	2	2	2	3	3
Haro Strait and Boundary Pass	0	0	0	0	0	0	0
Guemes Channel and Fidalgo Bay	2	2	2	3	3	3	3
Saddlebag	1	1	1	2	2	3	3
Rosario Strait	0	0	0	0	0	0	0
Cherry Point	3	3	3	3	4	5	5

Table 3 shows the 95th percentile (median) number of spills predicted by the oil outflow model for each subarea for all seven cases.

Table 3 95th Percentile Annual Number of Spills per Subarea

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Straits of Juan de Fuca West	3	3	3	3	3	3	3
Straits of Juan de Fuca East	5	5	5	5	5	7	7
Haro Strait and Boundary Pass	1	1	1	1	1	2	2
Guemes Channel and Fidalgo Bay	5	5	5	6	6	7	7
Saddlebag	3	3	3	5	5	6	6
Rosario Strait	1	1	1	1	1	1	1
Cherry Point	6	6	6	7	7	9	9

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[1] Note that the sum of number of spills per subarea for each case for a given probability (percentile) does not necessarily equal the median number of spills across the entire study area for that case. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 99th percentile number of spills. It is highly unlikely that the 99th percentile number of spills for each subarea will all occur in the same year, so the 99th percentile number of spills across all subareas will intuitively be less than the sum of the 99th percentile of each subarea.

Figure 1 through Figure 7 show the cumulative distribution functions of predicted number spills per subarea for the seven cases. Because the Poisson distribution is used to sample for the number of incidents in each scenario, the number of annual incidents, and thus spills, is always calculated as an integer value.

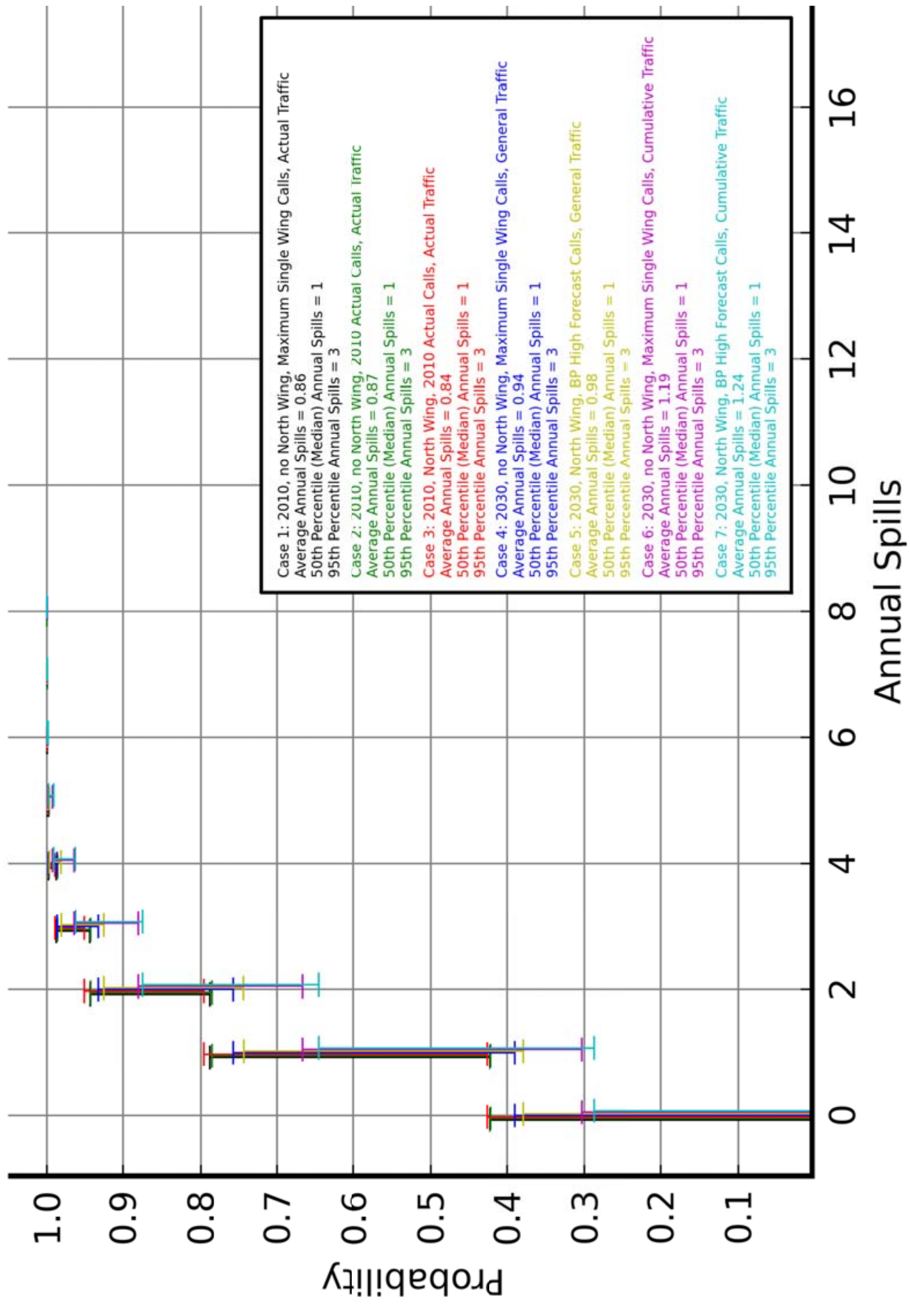

Figure 1 CDF of Annual Number of Spills in Strait of Juan de Fuca West

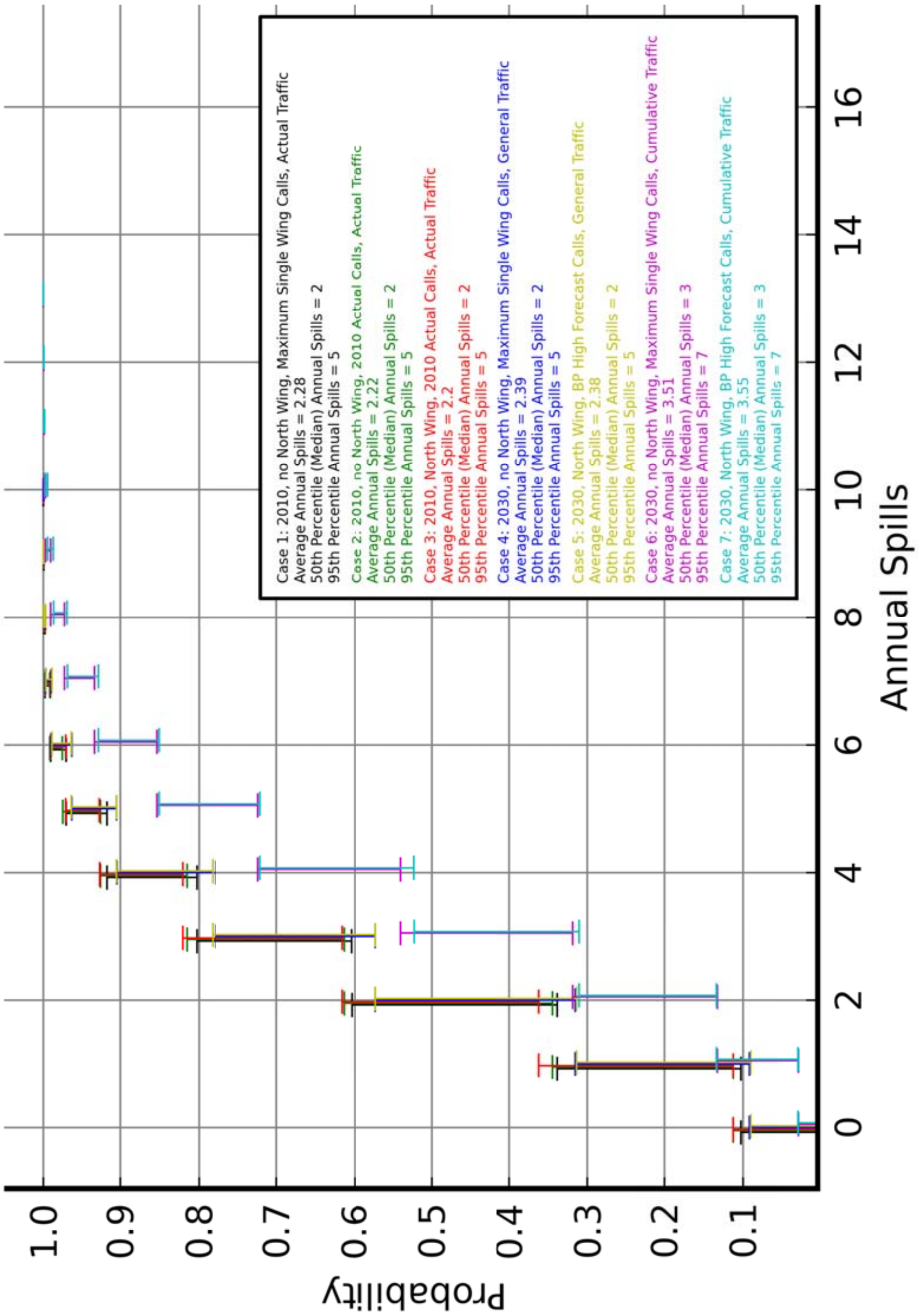

Figure 2 CDF of Annual Number of Spills in Strait of Juan de Fuca East

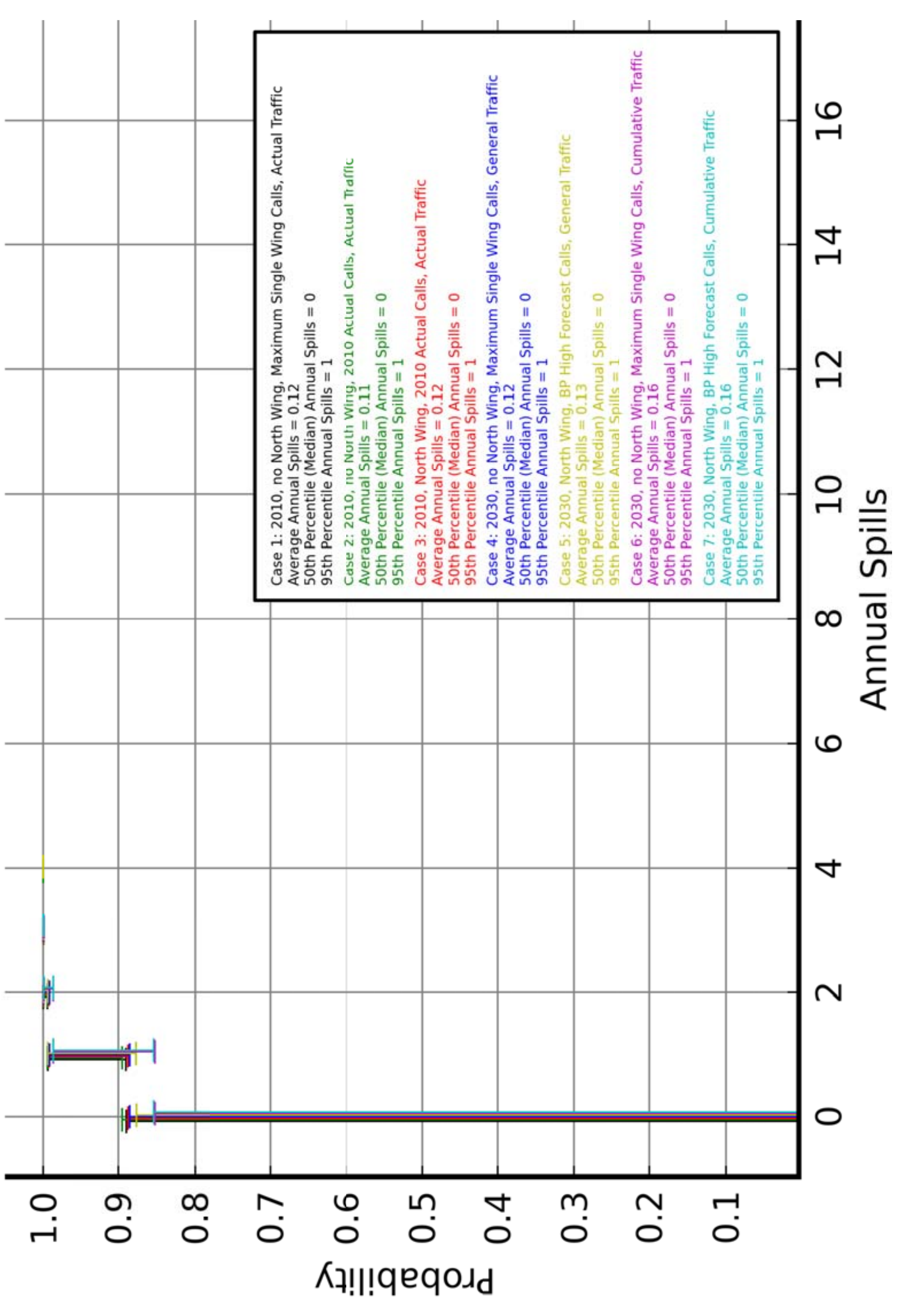

Figure 3 CDF of Annual Number of Spills in Rosario Strait

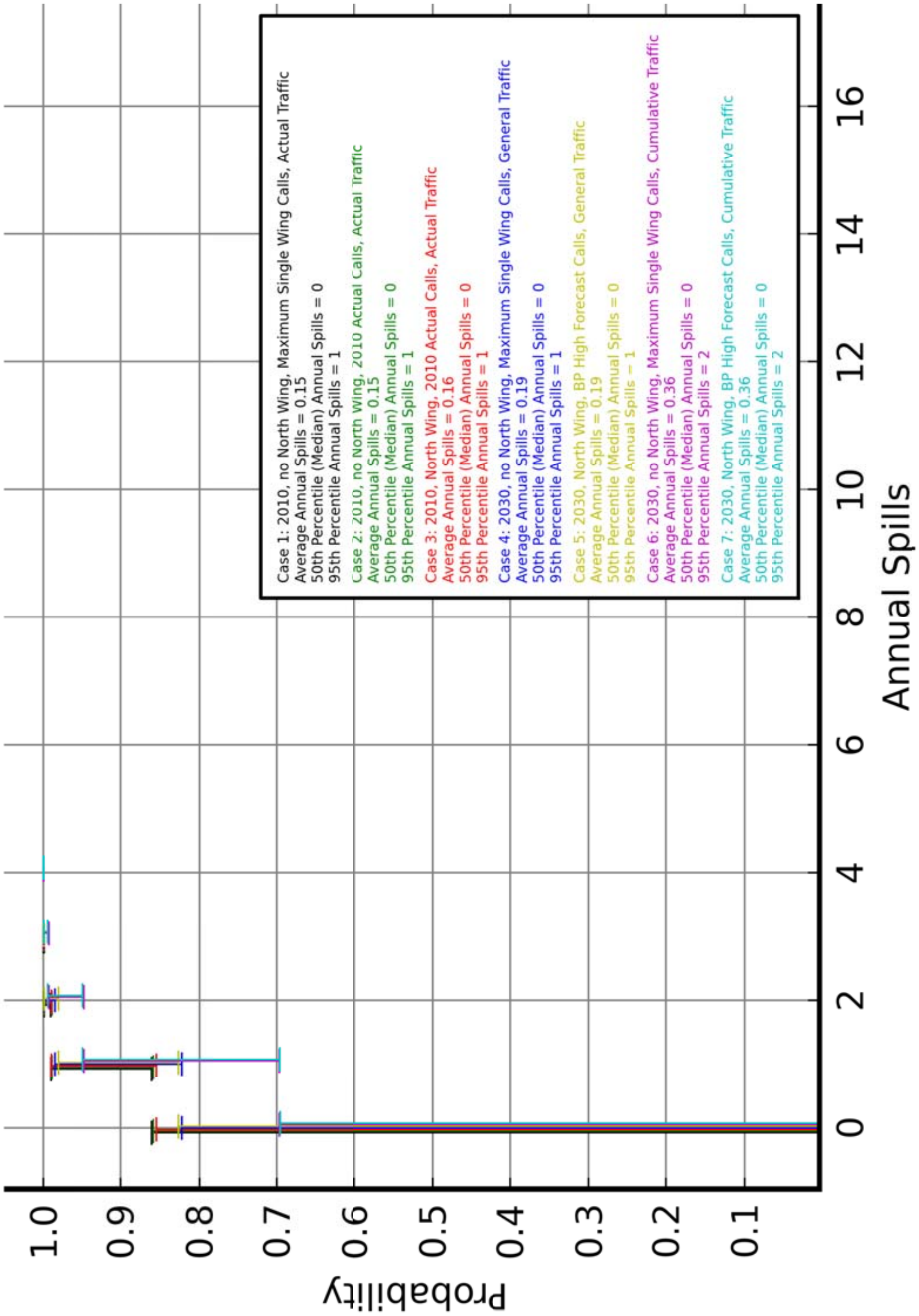

Figure 4 **CDF of Annual Number of Spills in Haro Strait and Boundary Pass**

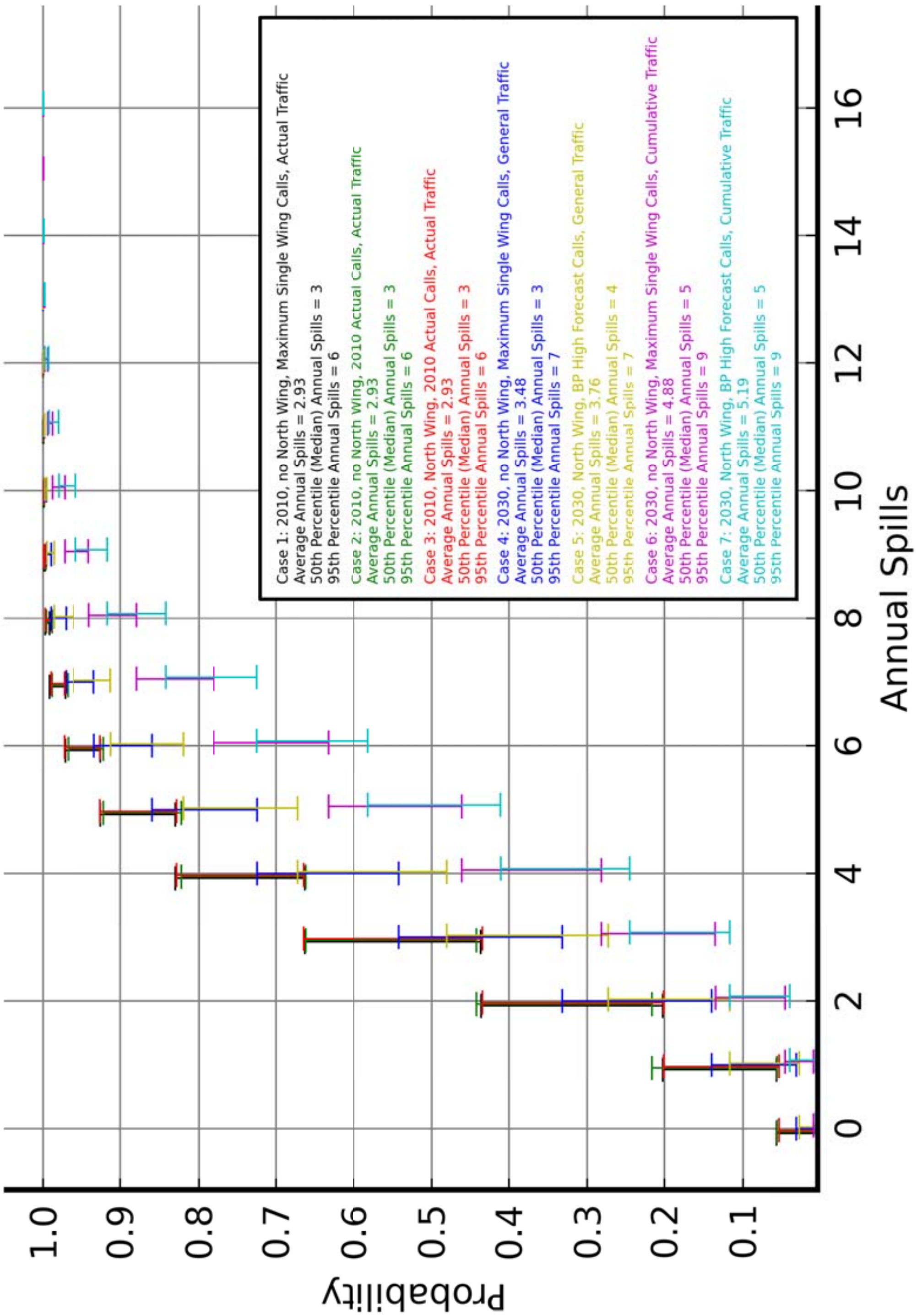

Figure 5 **CDF of Annual Number of Spills in Cherry Point**

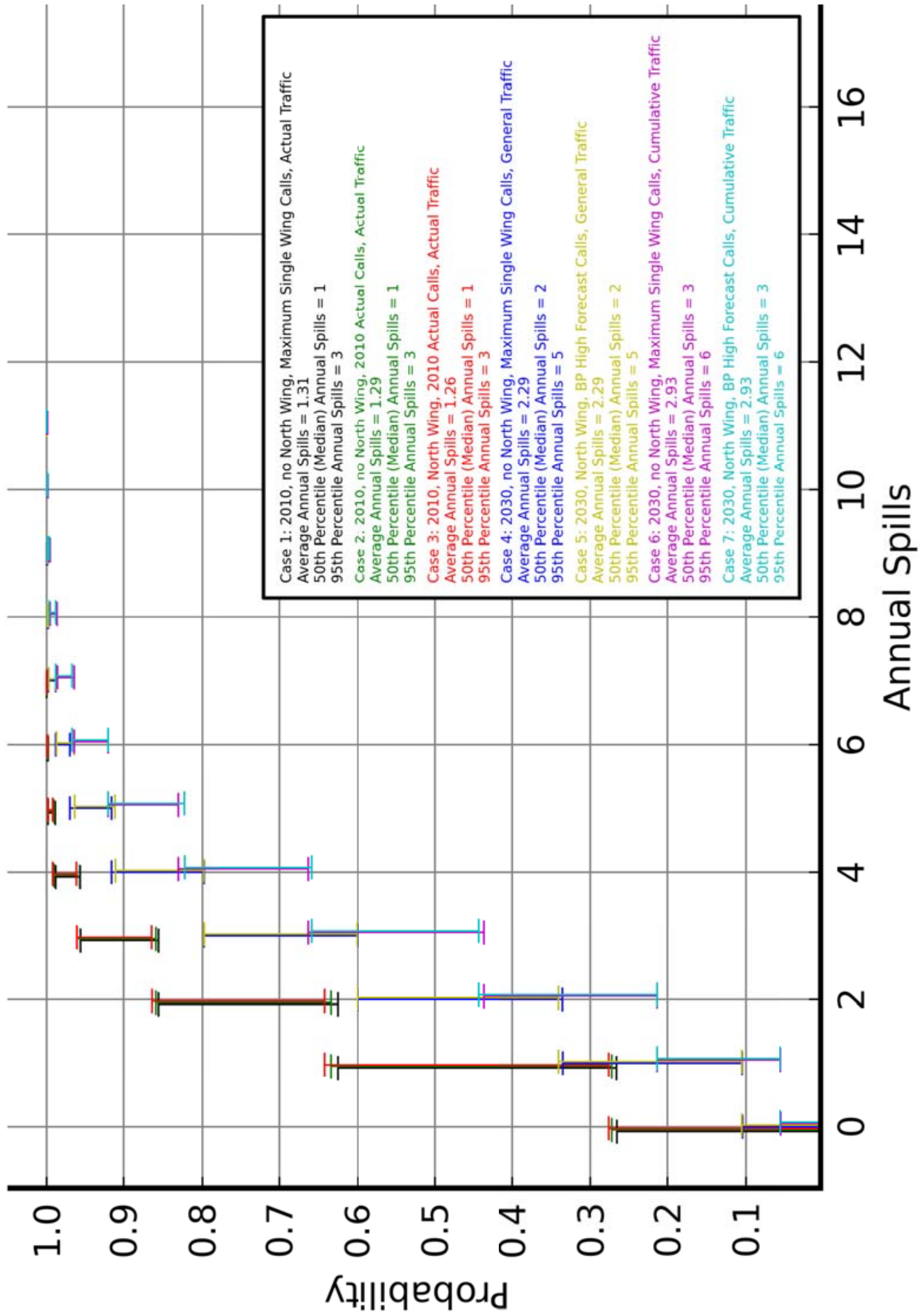

Figure 6 CDF of Annual Number of Spills in Saddlebag

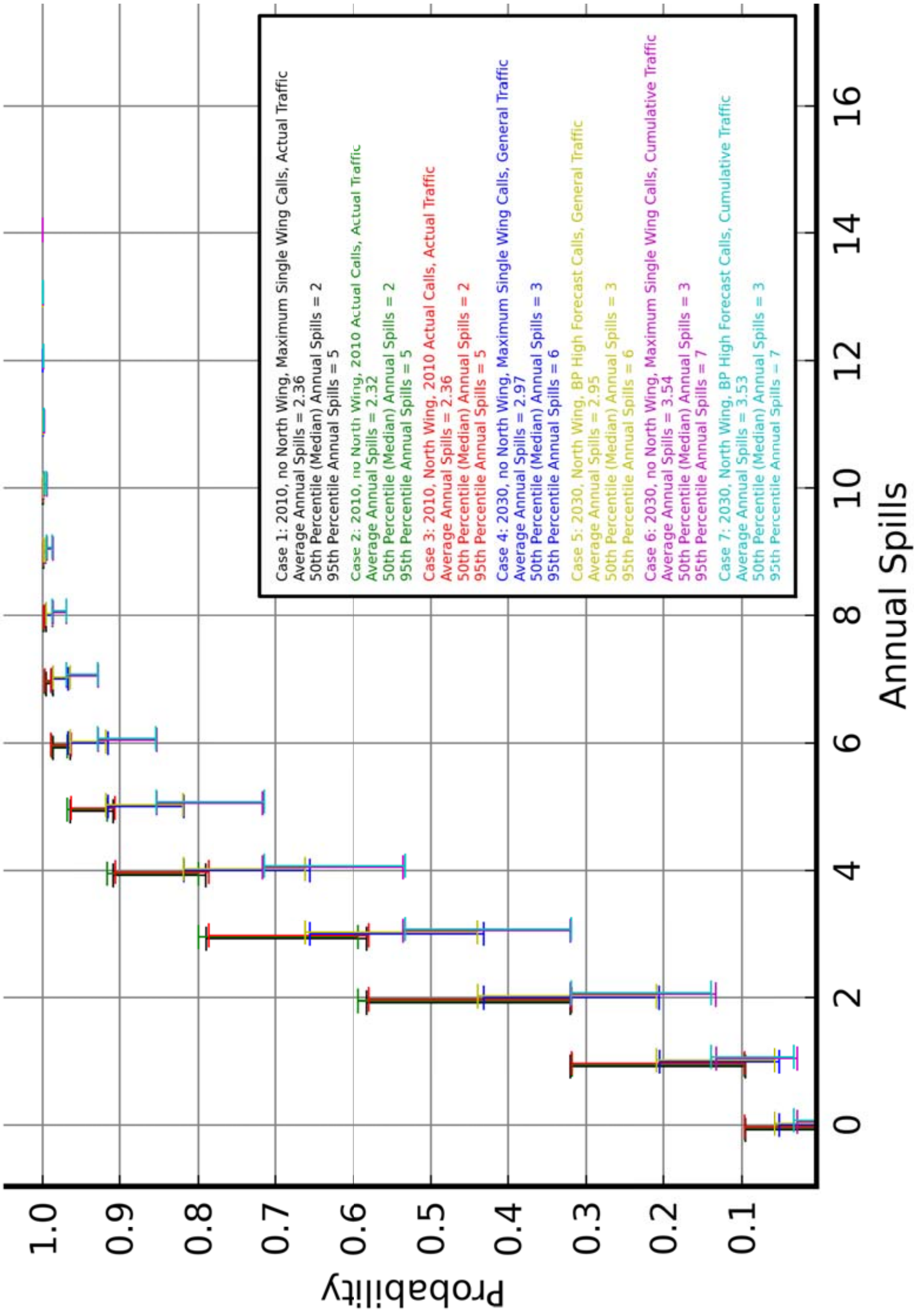

Figure 7 CDF of Annual Number of Spills in Guemes Channel and Fidalgo Bay

Number of Spills by Incident Type

Table 4 shows the average number of spills predicted by the oil outflow model by incident type for the seven cases.

Table 4 Average Number of Spills by Incident Type

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	0.11	0.10	0.11	0.07	0.08	0.10	0.10
Grounding	0.14	0.14	0.13	0.11	0.11	0.14	0.14
Allision	0.15	0.14	0.15	0.13	0.13	0.21	0.22
Transfer Error	2.18	2.16	2.14	2.13	2.25	2.73	2.89
Bunker Error	2.09	2.09	2.09	3.87	3.87	5.24	5.25
Other Non-Impact	5.34	5.25	5.25	6.08	6.25	8.16	8.36

Table 5 shows the 50th percentile (median) number of spills predicted by the oil outflow model by incident type[2] for the seven cases.

Table 5 50th Percentile (Median) Annual Number of Spills by Incident Type

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	0	0	0	0	0	0	0
Grounding	0	0	0	0	0	0	0
Allision	0	0	0	0	0	0	0
Transfer Error	2	2	2	2	2	3	3
Bunker Error	2	2	2	4	4	5	5
Other Non-Impact	5	5	5	6	6	8	8

Table 6 shows the 95th percentile number of spills predicted by the oil outflow model by incident type for the seven cases.

Table 6 95th Percentile Annual Number of Spills by Incident Type

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	1	1	1	1	1	1	1
Grounding	1	1	1	1	1	1	1
Allision	1	1	1	1	1	1	1
Transfer Error	5	5	5	5	5	6	6
Bunker Error	5	5	5	8	8	10	10
Other Non-Impact	9	9	9	10	11	13	13

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[2] Note that the sum of number of spills by incident type for each case for a given probability (percentile) does not necessarily equal the median number of spills across all incident types for that case. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 99th percentile number of spills. It is highly unlikely that the 99th percentile number of spills for each incident type will all occur in the same year, so the 99th percentile number of spills across all incident types will intuitively be less than the sum of the 99th percentile of each incident type.

Figure 8 through Figure 13 show the cumulative distribution functions of predicted number spills by incident type for the seven cases. Because the Poisson distribution is used to sample for the number of incidents in each scenario, the number of annual incidents, and thus spills, is always calculated as an integer value.

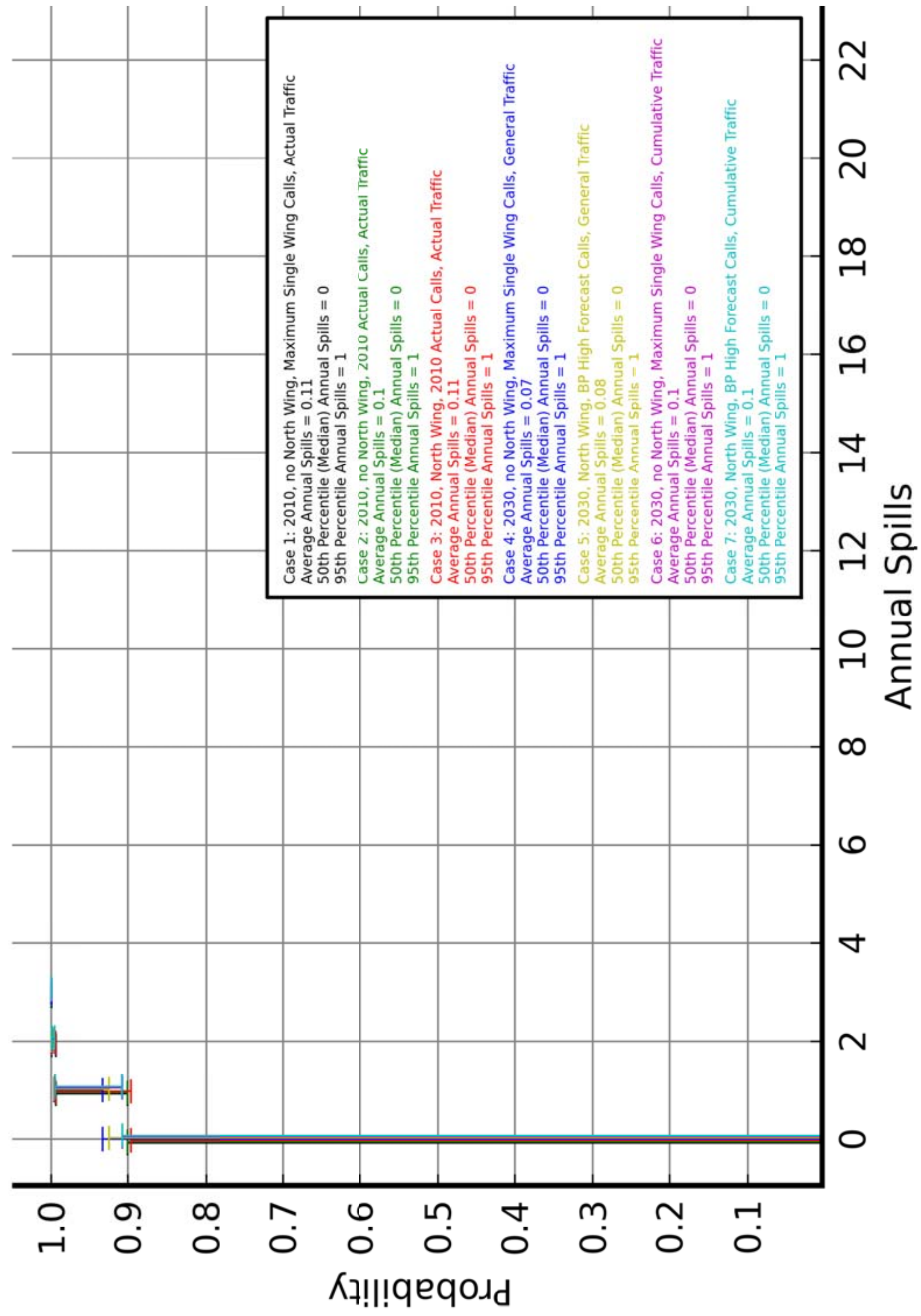

Figure 8 **CDF of Annual Number of Spills due to Collision**

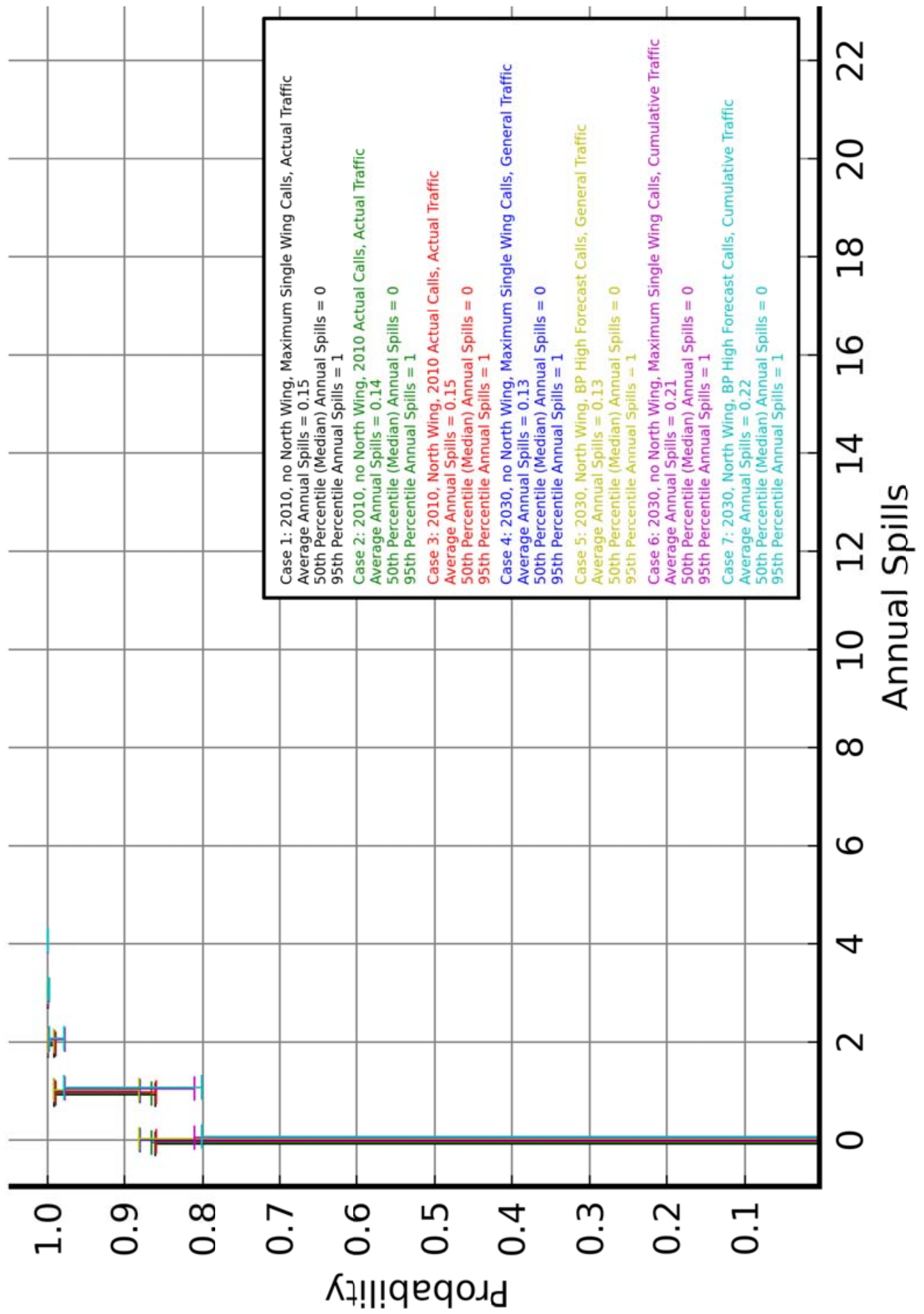

Figure 9 CDF of Annual Number of Spills due to Allision

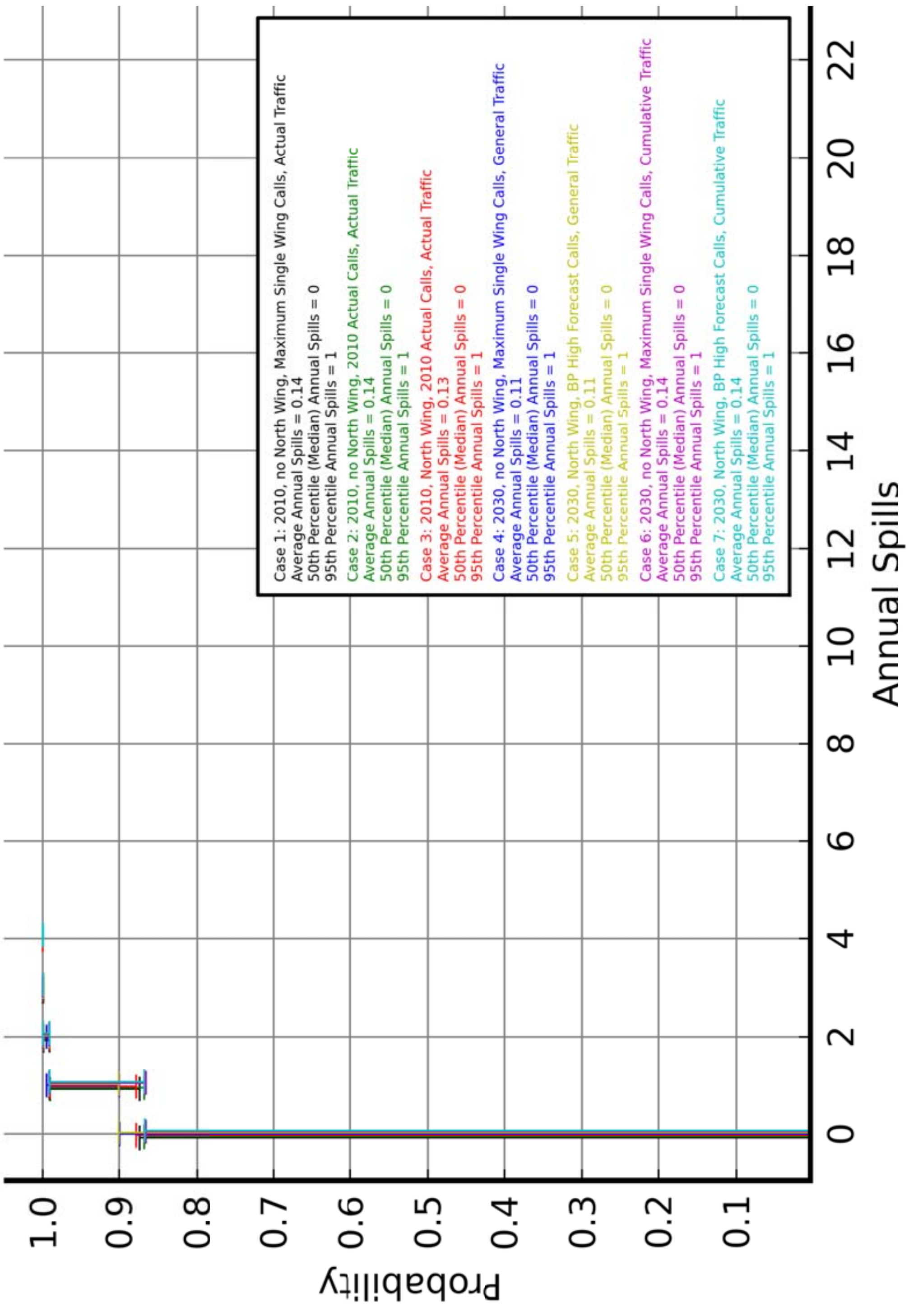

Figure 10 CDF of Annual Number of Spills due to Grounding

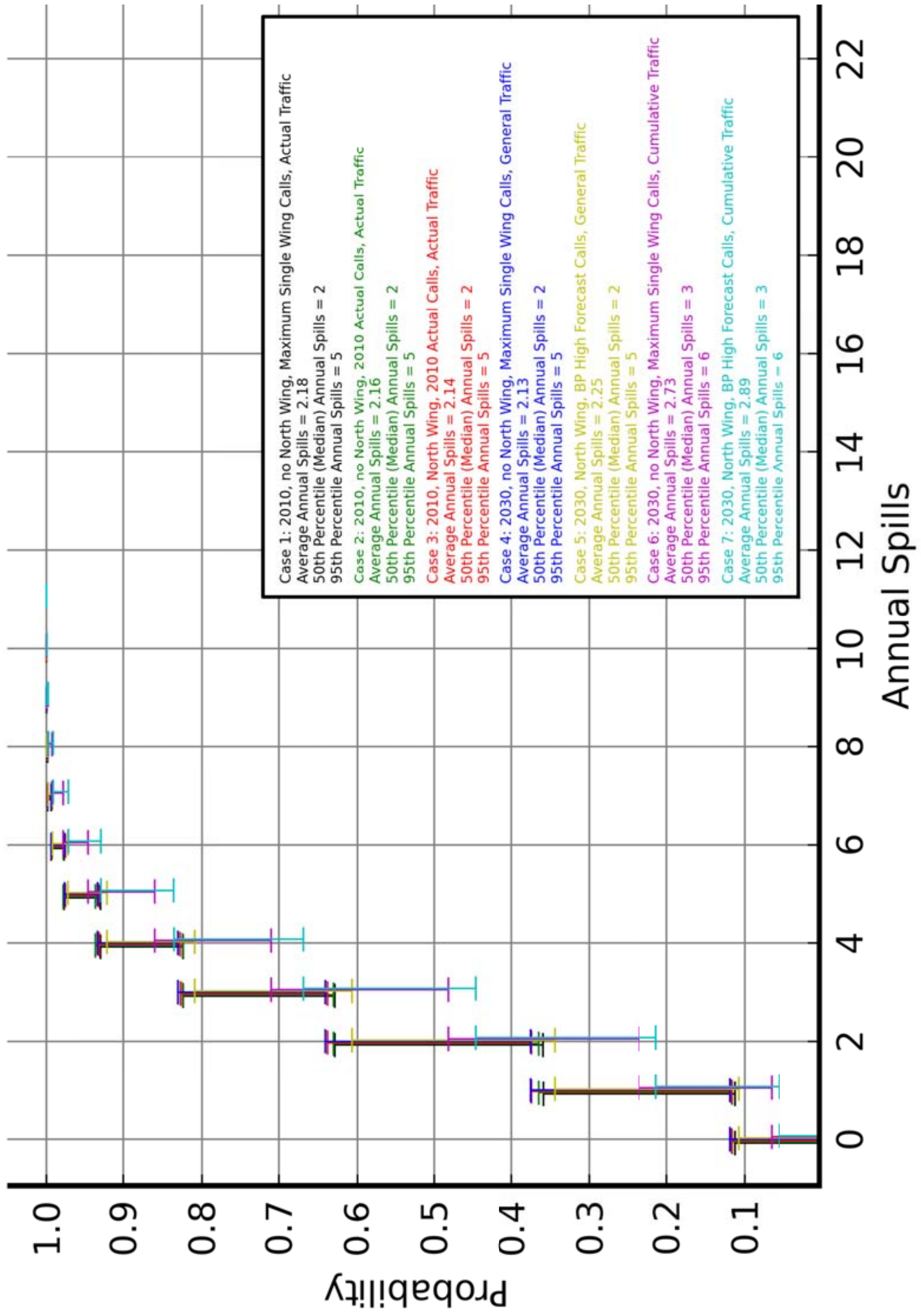

Figure 11 CDF of Annual Number of Spills due to Transfer Errors

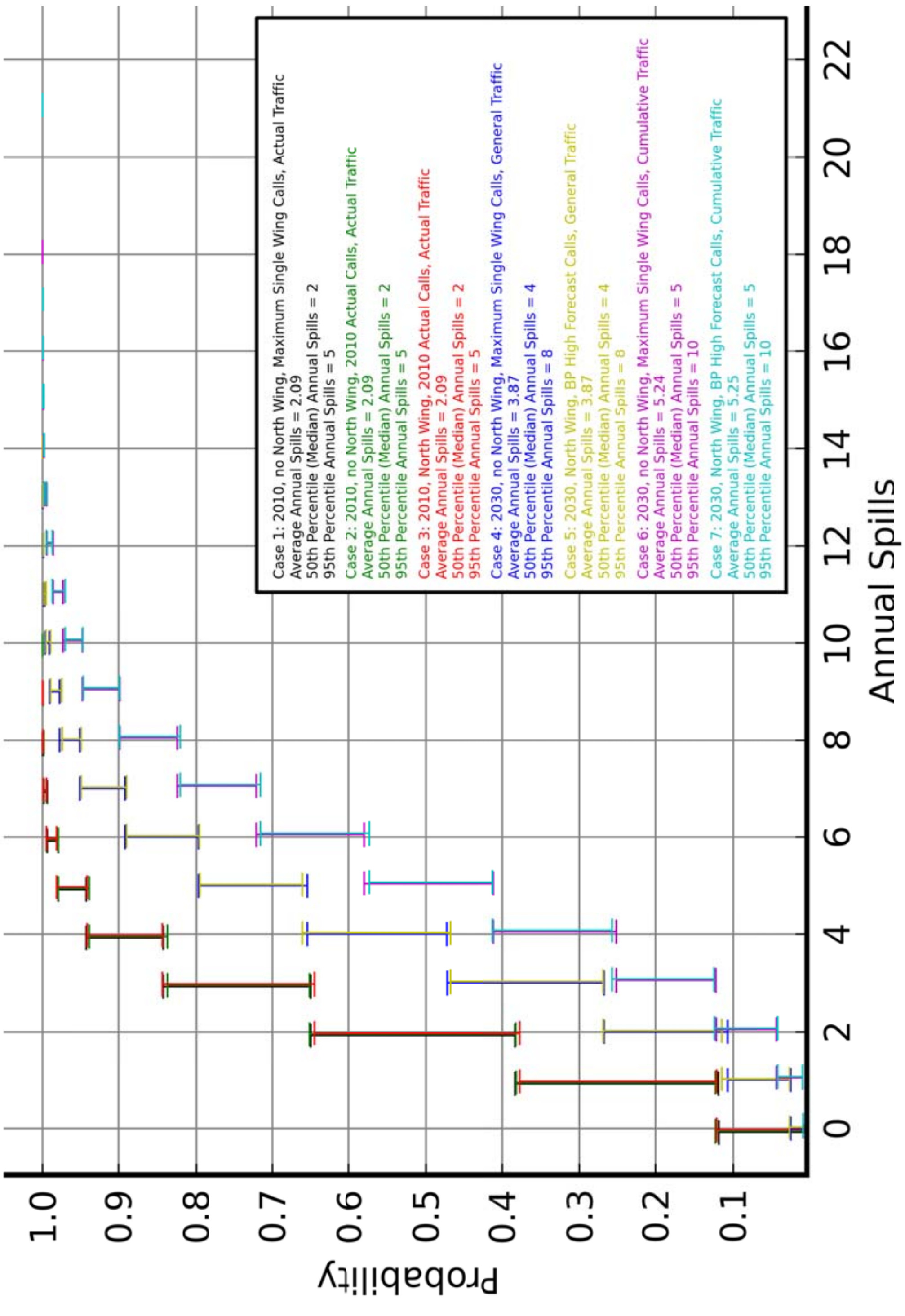

Figure 12 CDF of Annual Number of Spills due to Bunker Errors

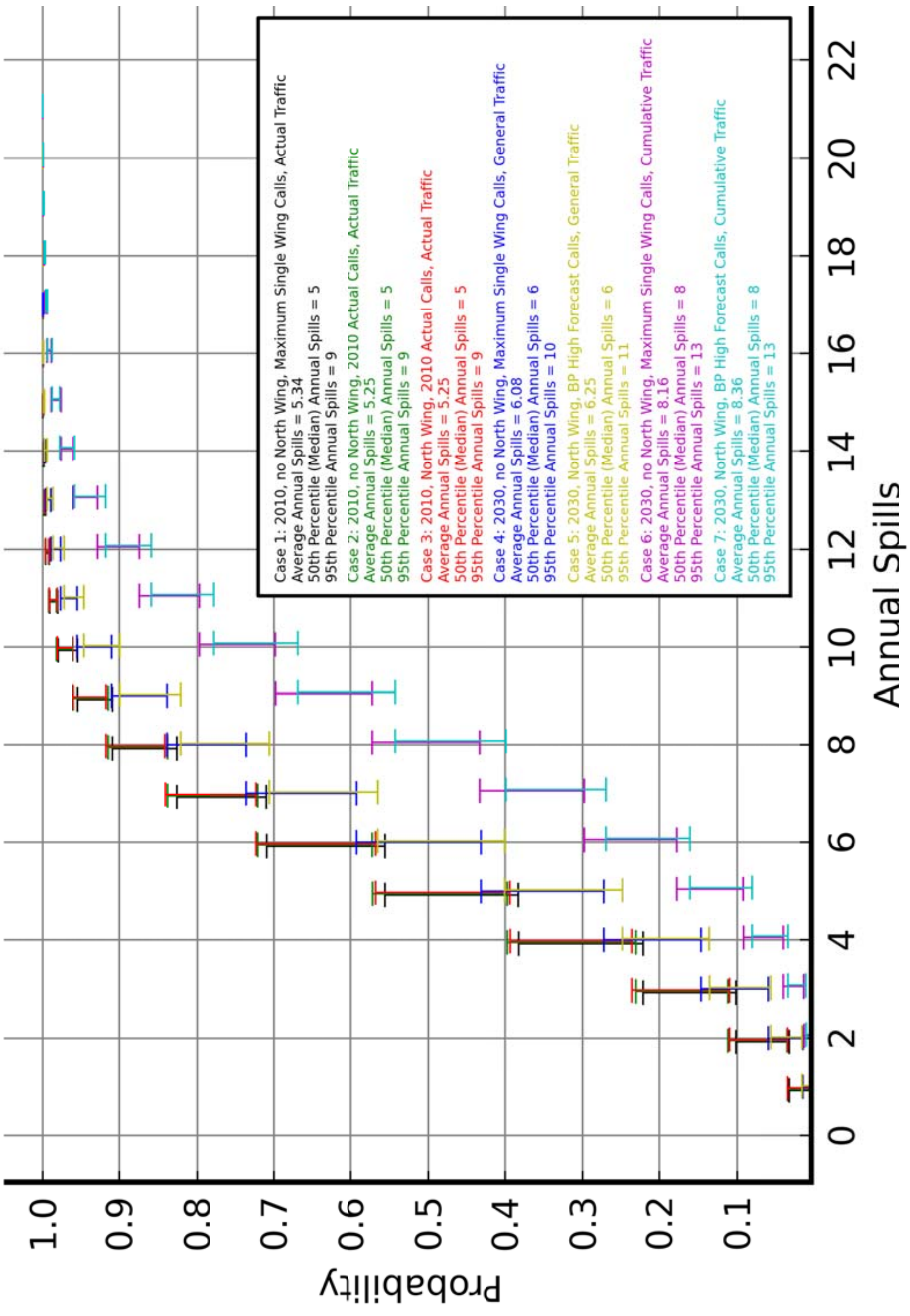

Figure 13 CDF of Annual Number of Spills due to Other Non-Impact Errors

Number of Spills by Incident Type and Subarea

Table 7 through Table 13 show the average, median, and 95th percentile numbers of spills by subarea and each incident type for the seven cases.

Table 7 Predicted Number of Spills by Incident Type in western Strait of Juan de Fuca

		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Collision	Average	0.0210	0.0226	0.0206	0.0142	0.0158	0.0211	0.0189
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0315	0.0319	0.0314	0.0241	0.0209	0.0314	0.0277
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0114	0.0100	0.0128	0.0082	0.0091	0.0112	0.0119
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.0006	0.0006	0.0010	0.0011	0.0008	0.0011	0.0010
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Bunker Error	Average	0.0031	0.0046	0.0036	0.0075	0.0078	0.0074	0.0078
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Other Non-Impact Incident	Average	0.7921	0.7990	0.7697	0.8819	0.9210	1.1199	1.1708
	Median	1	1	1	1	1	1	1
	95th Percentile	2	2	2	3	3	3	3

Table 8 Predicted Number of Spills by Incident Type in eastern Strait of Juan de Fuca

		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Collision	Average	0.0234	0.0230	0.0250	0.0170	0.0169	0.0224	0.0234
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0322	0.0354	0.0310	0.0279	0.0283	0.0367	0.0354
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0363	0.0344	0.0349	0.0250	0.0270	0.0446	0.0428
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.5157	0.5082	0.5008	0.4619	0.4488	0.8575	0.8713
	Median	0	0	0	0	0	1	1
	95th Percentile	2	2	2	2	2	3	3
Bunker Error	Average	0.3090	0.3126	0.3116	0.4378	0.4263	0.4974	0.4934
	Median	0	0	0	0	0	0	0
	95th Percentile	1	1	1	2	2	2	2
Other Non-Impact Incident	Average	1.3586	1.3092	1.2984	1.4165	1.4377	2.0507	2.0886
	Median	1	1	1	1	1	2	2
	95th Percentile	3	3	3	4	4	5	5

Table 9 Predicted Number of Spills by Incident Type in Haro Strait and Boundary Pass

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Average	0.0001	0.0005	0.0004	0.0004	0.0003	0.0001	0.0005
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0006	0.0003	0.0004	0.0003	0.0004	0.0004	0.0004
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0113	0.0117	0.0100	0.0167	0.0119	0.0485	0.0499
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.0018	0.0018	0.0018	0.0014	0.0013	0.0012	0.0016
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Bunker Error	Average	0.0380	0.0368	0.0382	0.0573	0.0620	0.1341	0.1400
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	1	1	1	1
Other Non-Impact Incident	Average	0.0976	0.1014	0.1052	0.1173	0.1173	0.1796	0.1691
	Median	0	0	0	0	0	0	0
	95th Percentile	1	1	1	1	1	1	1

Table 10 Predicted Number of Spills by Incident Type in Guemes Channel and Fidalgo Bay

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Average	0.0200	0.0226	0.0213	0.0129	0.0158	0.0174	0.0168
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0220	0.0262	0.0244	0.0174	0.0187	0.0216	0.0230
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0254	0.0271	0.0268	0.0202	0.0193	0.0244	0.0278
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.6204	0.6068	0.6272	0.6033	0.5919	0.7216	0.7117
	Median	0	0	0	0	0	1	1
	95th Percentile	2	2	2	2	2	2	2
Bunker Error	Average	0.6873	0.6857	0.6917	1.2287	1.2150	1.4521	1.4528
	Median	0	0	0	1	1	1	1
	95th Percentile	2	2	2	3	3	4	4
Other Non-Impact Incident	Average	0.9809	0.9515	0.9708	1.0883	1.0867	1.2998	1.2975
	Median	1	1	1	1	1	1	1
	95th Percentile	3	3	3	3	3	3	3

Table 11 Predicted Number of Spills by Incident Type in Saddlebag

		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Collision	Average	0.0093	0.0072	0.0084	0.0058	0.0061	0.0090	0.0103
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0131	0.0118	0.0109	0.0099	0.0111	0.0130	0.0131
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0179	0.0171	0.0190	0.0150	0.0137	0.0229	0.0219
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.1293	0.1237	0.1040	0.1242	0.1108	0.1437	0.1232
	Median	0	0	0	0	0	0	0
	95th Percentile	1	1	1	1	1	1	1
Bunker Error	Average	0.5356	0.5354	0.5357	1.2443	1.2584	1.5965	1.5888
	Median	0	0	0	1	1	1	1
	95th Percentile	2	2	2	3	3	4	4
Other Non-Impact Incident	Average	0.6040	0.5913	0.5850	0.8920	0.8942	1.1498	1.1754
	Median	0	0	0	1	1	1	1
	95th Percentile	2	2	2	3	3	3	3

Table 12 Predicted Number of Spills by Incident Type in Rosario Strait

		Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Collision	Average	0.0007	0.0007	0.0007	0.0005	0.0007	0.0007	0.0006
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0011	0.0010	0.0010	0.0007	0.0005	0.0010	0.0005
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0210	0.0213	0.0220	0.0230	0.0229	0.0342	0.0353
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Bunker Error	Average	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Other Non-Impact Incident	Average	0.0928	0.0878	0.0965	0.0988	0.1053	0.1255	0.1229
	Median	0	0	0	0	0	0	0
	95th Percentile	1	1	1	1	1	1	1

Table 13 Predicted Number of Spills by Incident Type in Cherry Point

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Average	0.0309	0.0280	0.0327	0.0204	0.0236	0.0271	0.0266
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Grounding	Average	0.0352	0.0343	0.0320	0.0250	0.0282	0.0389	0.0414
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Allision	Average	0.0244	0.0233	0.0250	0.0201	0.0225	0.0265	0.0316
	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
Transfer Error	Average	0.9080	0.9169	0.9086	0.9400	1.0947	1.0070	1.1806
	Median	1	1	1	1	1	1	1
	95th Percentile	3	3	3	3	3	3	3
Bunker Error	Average	0.5162	0.5187	0.5138	0.8919	0.8970	1.5538	1.5693
	Median	0	0	0	1	1	1	1
	95th Percentile	2	2	2	3	3	4	4
Other Non-Impact Incident	Average	1.4111	1.4071	1.4209	1.5866	1.6919	2.2304	2.3402
	Median	1	1	1	1	2	2	2
	95th Percentile	4	4	4	4	4	5	5

Annual Oil Outflow by Subarea

Table 14 shows the 50th percentile (median) annual oil outflow predicted by the model for each subarea for all seven cases.

Table 14 Predicted Median Annual Oil Outflow per Subarea (gallons)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Straits of Juan de Fuca West	< 1	< 1	< 1	< 1	< 1	2	2
Straits of Juan de Fuca East	18	18	16	18	19	68	73
Haro Strait and Boundary Pass	0	0	0	0	0	0	0
Guemes Channel and Fidalgo Bay	12	12	13	23	22	40	41
Saddlebag	2	1	1	13	12	22	23
Rosario Strait	0	0	0	0	0	0	0
Cherry Point	40	40	41	57	72	153	193

Table 15 shows the 95th percentile annual oil outflow predicted by the model for each subarea for all seven cases.

Table 15 Predicted 95th Percentile Annual Oil Outflow per Subarea (gallons)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Straits of Juan de Fuca West	4,368	5,609	4,269	2,669	3,372	5,692	7,002
Straits of Juan de Fuca East	9,310	11,316	8,164	6,926	8,109	16,407	16,170
Haro Strait and Boundary Pass	5	5	4	13	10	93	108
Guemes Channel and Fidalgo Bay	3,066	2,869	3,259	2,515	2,534	3,361	3,305
Saddlebag	795	641	669	1,267	1,291	1,830	1,948
Rosario Strait	3	3	4	3	4	11	8
Cherry Point	11,751	10,344	10,427	8,053	10,475	16,170	16,866

Figure 14 through Figure 20 show the cumulative distribution functions of oil outflow per subarea for all seven cases.

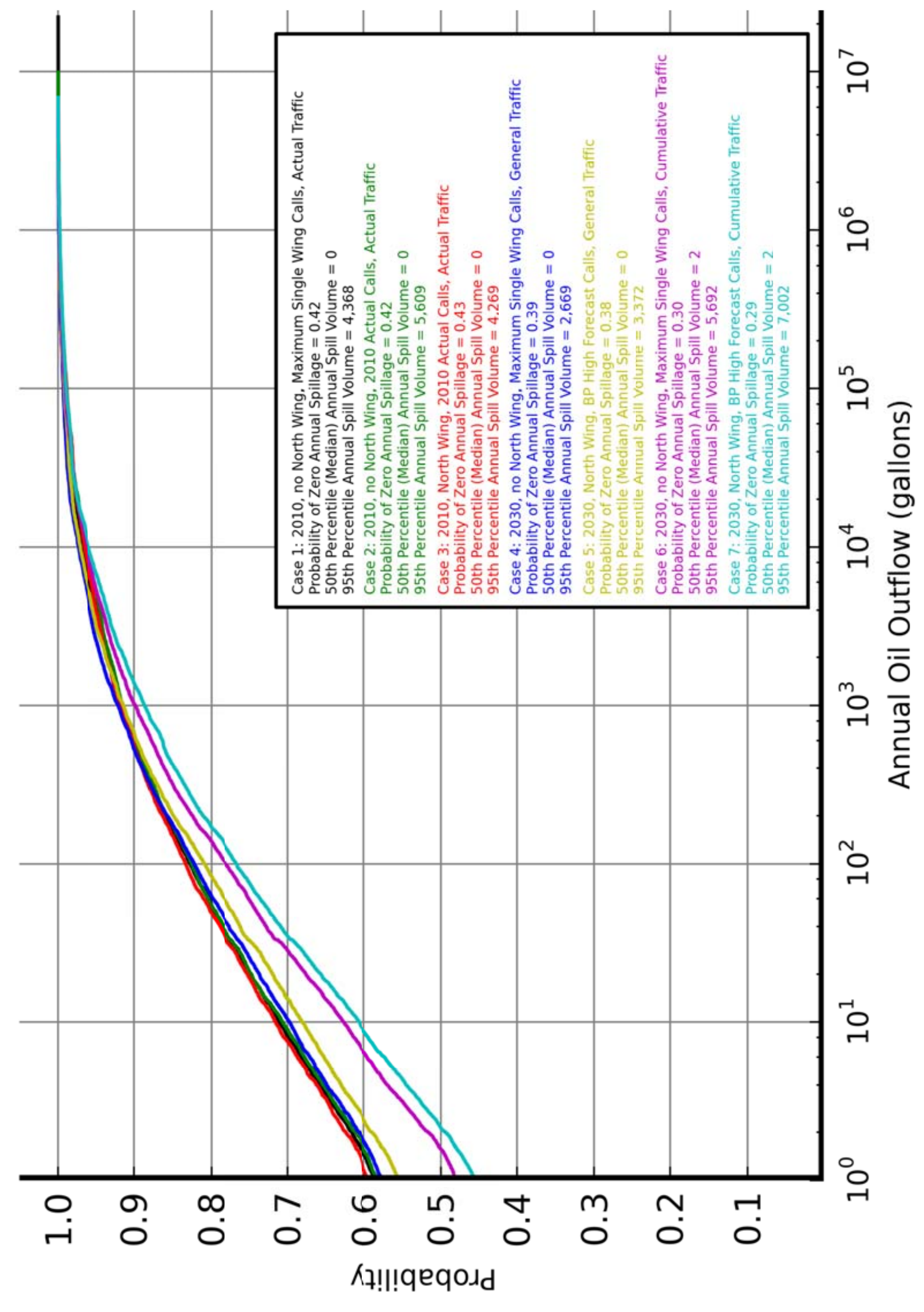

Figure 14 CDF of Predicted Total Annual Volume of Oil Outflow in Strait of Juan de Fuca West

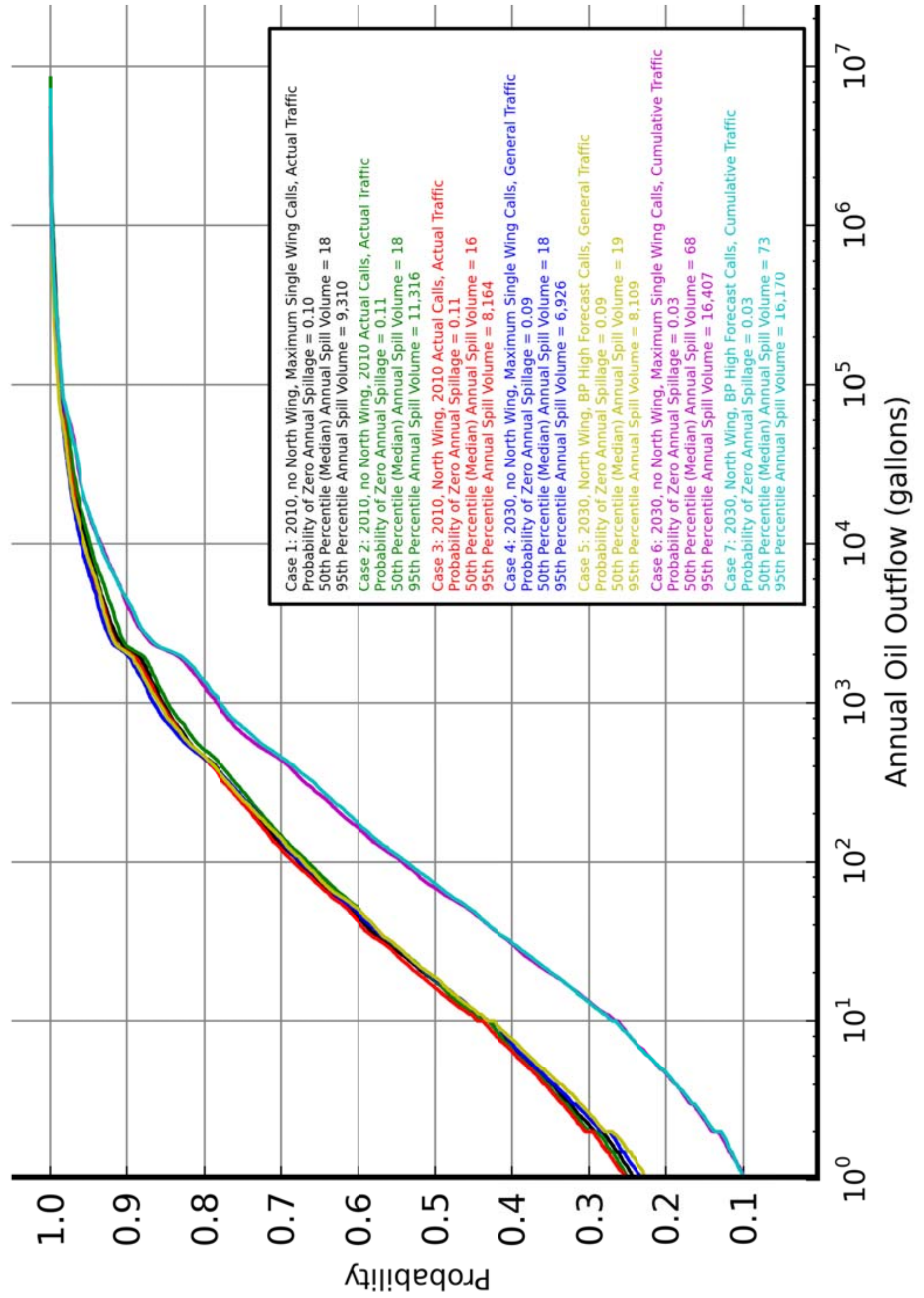

Figure 15 CDF of Predicted Total Annual Volume of Oil Outflow in Strait of Juan de Fuca East

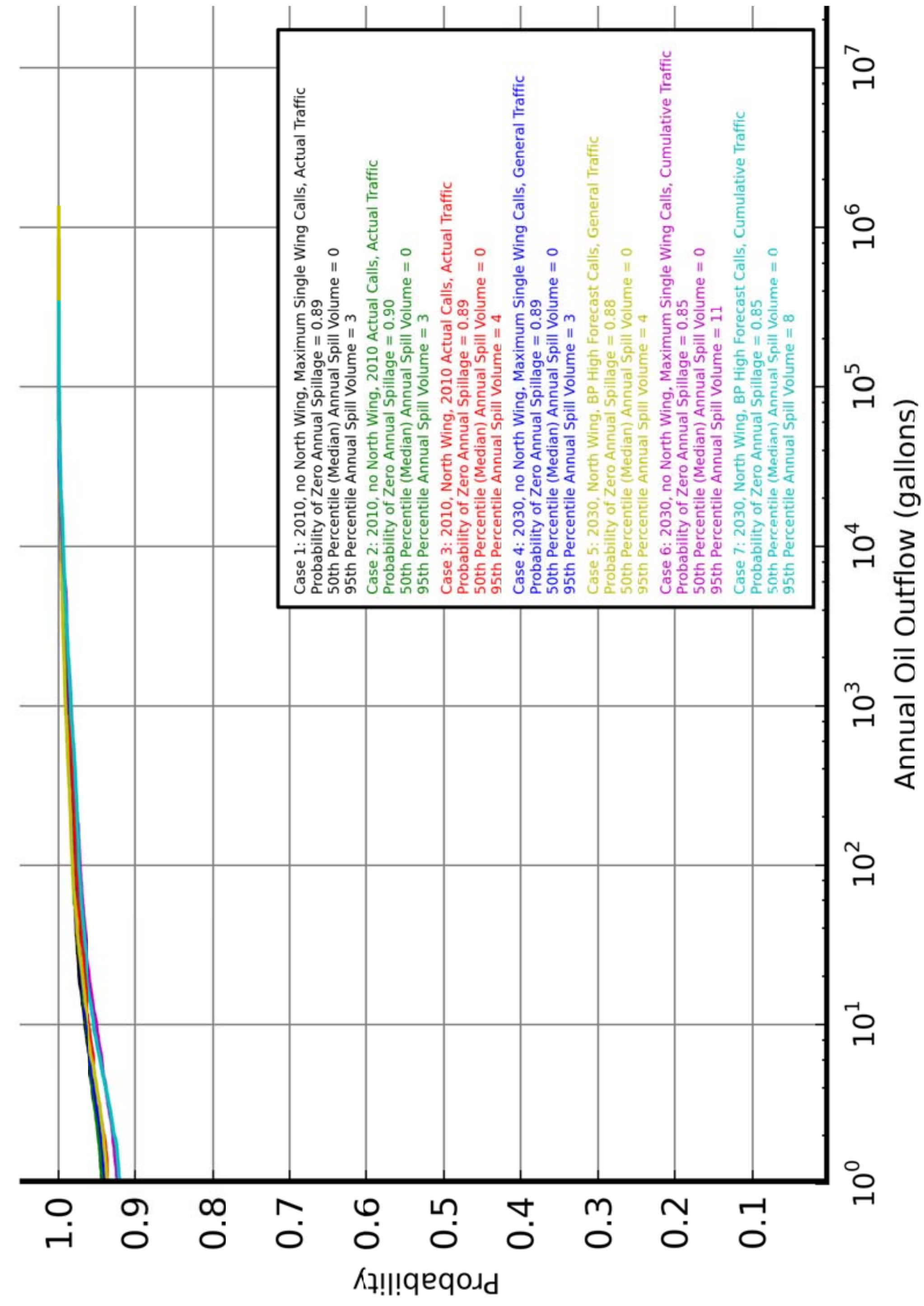

Figure 16 CDF of Predicted Total Annual Volume of Oil Outflow in Rosario Strait

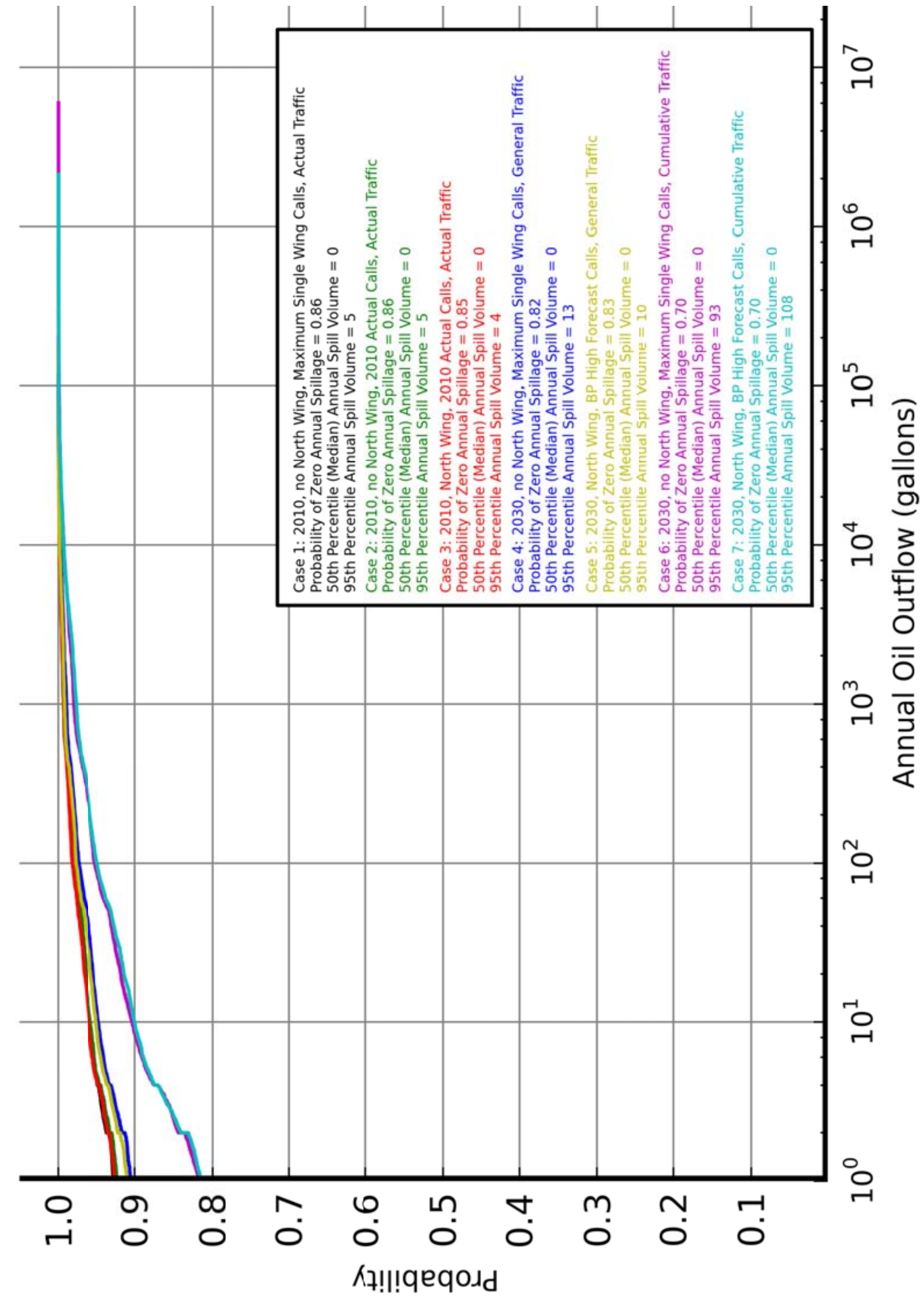

Figure 17 CDF of Predicted Total Annual Volume of Oil Outflow in Haro Strait and Boundary Pass

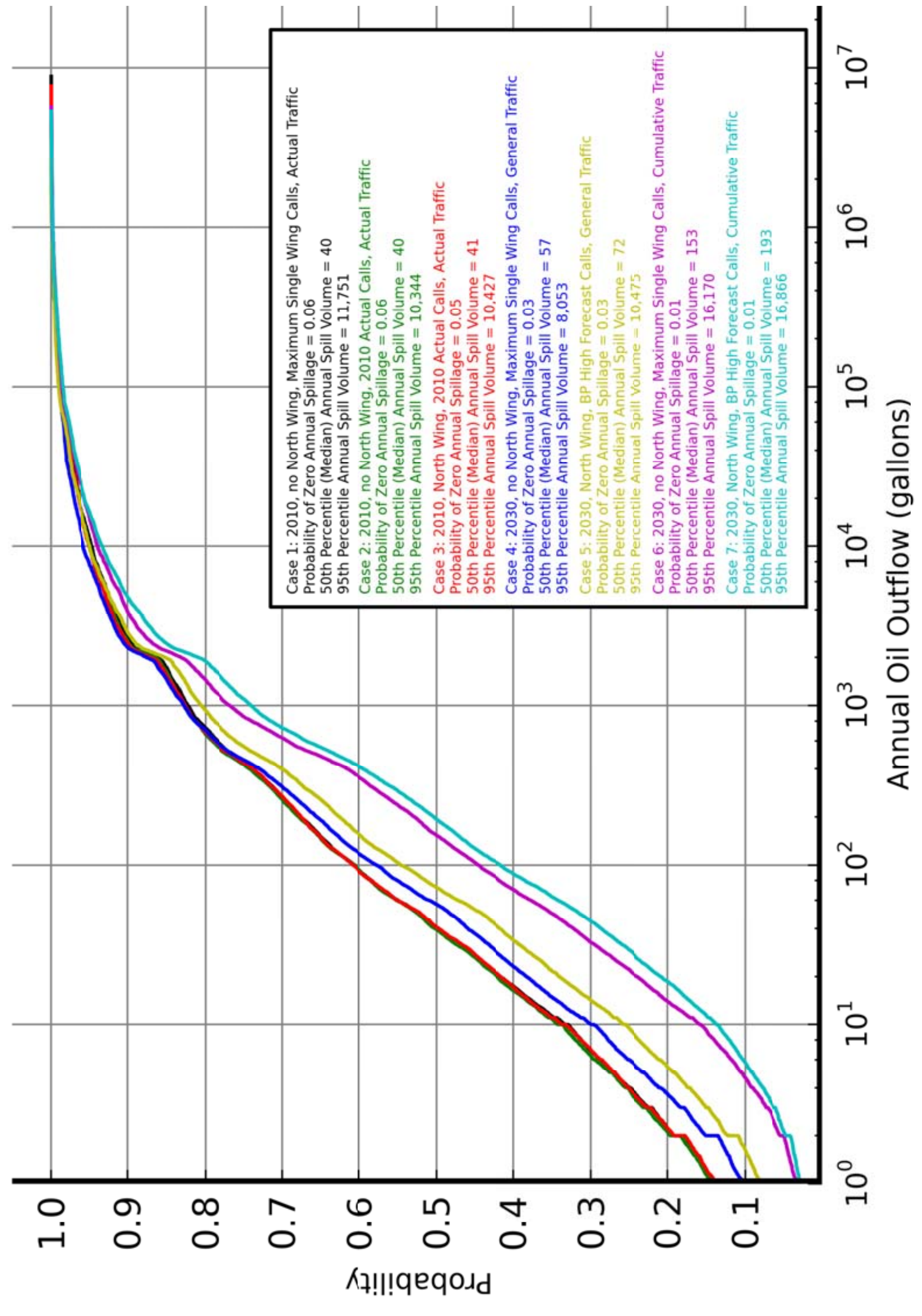

Figure 18 CDF of Predicted Total Annual Volume of Oil Outflow in Cherry Point

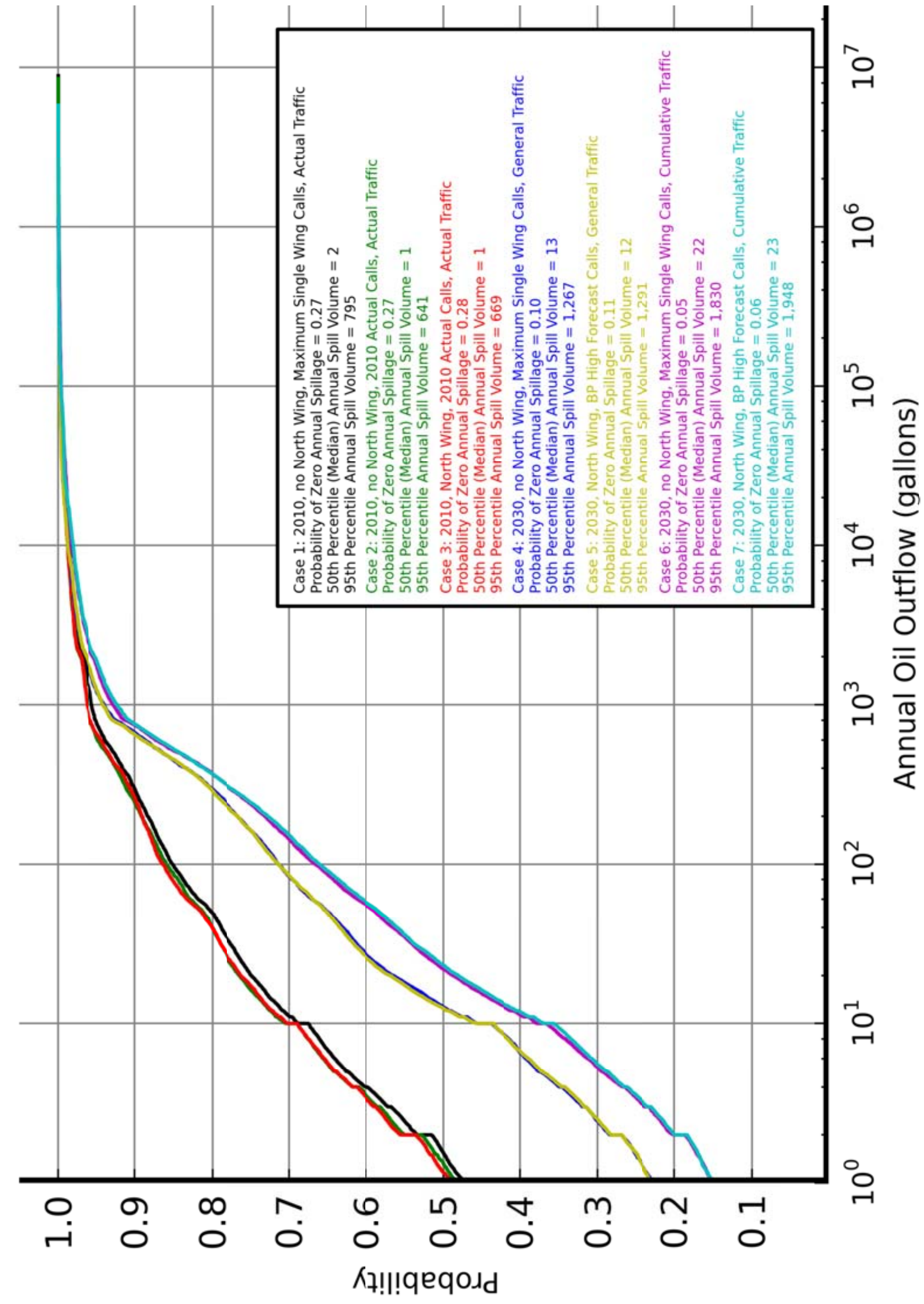

Figure 19 CDF of Predicted Total Annual Volume of Oil Outflow in Saddlebag

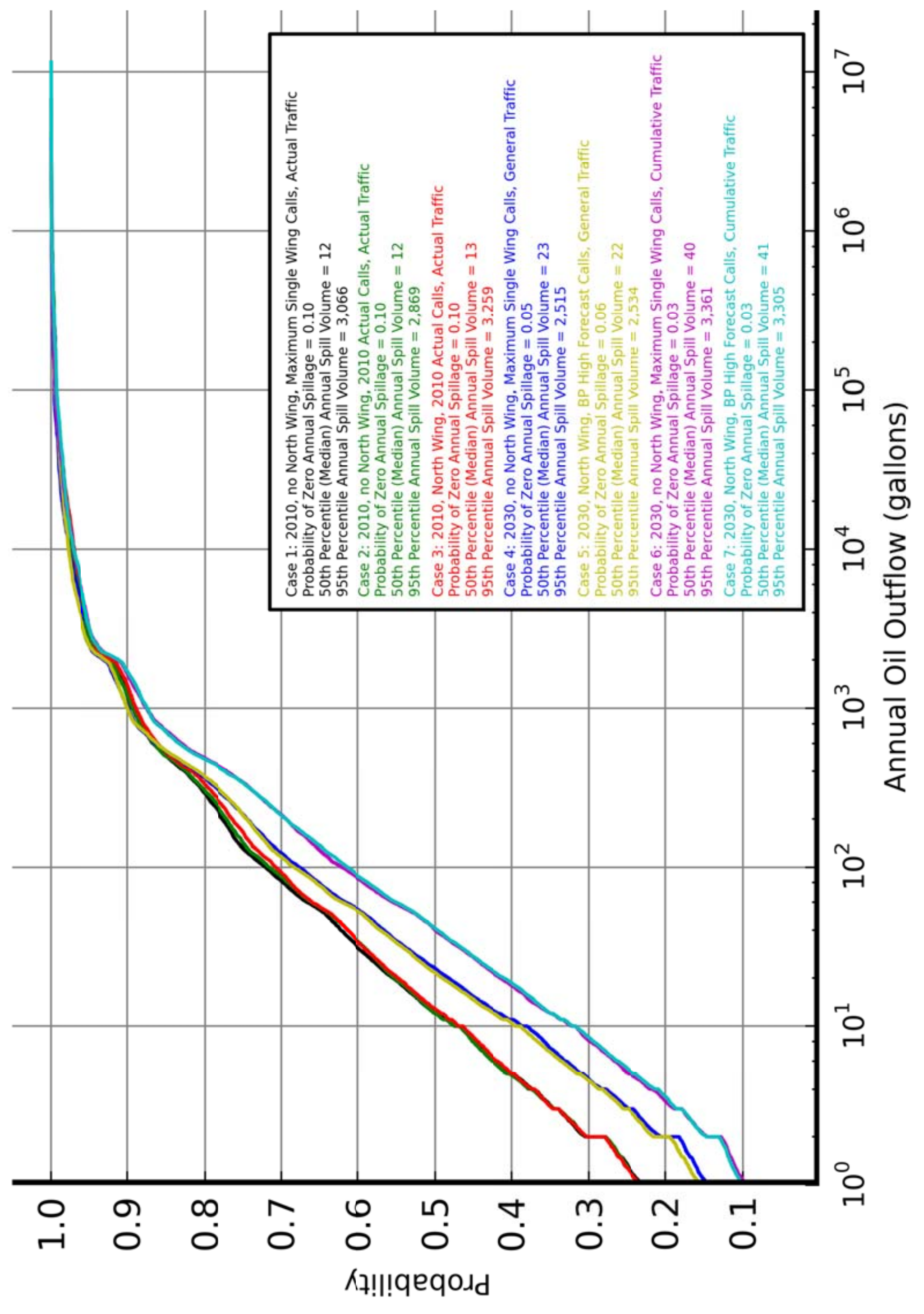

Figure 20 CDF of Predicted Total Annual Volume of Oil Outflow in Guemes Channel and Fidalgo Bay

Annual Oil Outflow by Subarea and incident type

Table 16 through Table 22 show the median, 95th percentile, and 99th percentile spill volumes for each subarea and incident type.

Table 16 Predicted Spill Volume by Incident Type in western Strait of Juan de Fuca

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	1,896	3,385	1,775	135	165	1,165	1,276
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	4,972	8,362	6,006	1,024	852	4,531	5,181
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	20	0	57	0	0	6	43
Transfer Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Bunker Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Other Non-Impact Incident	Median	< 1	< 1	< 1	< 1	< 1	< 1	1
	95th Percentile	1,178	1,275	1,067	1,340	1,689	2,281	2,723
	99th Percentile	14,636	19,549	16,339	13,888	15,248	19,240	19,741

Table 17 Predicted Spill Volume by Incident Type in eastern Strait of Juan de Fuca

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	1,341	1,982	1,169	292	260	1,570	2,013
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	6,152	5,783	2,382	1,420	2,956	7,048	11,170
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	22,083	23,557	16,893	4,230	9,838	32,237	29,500
Transfer Error	Median	0	0	0	0	0	1	1
	95th Percentile	427	405	403	306	191	1,306	1,548
	99th Percentile	2,136	2,171	2,138	2,179	2,144	2,232	2,227
Bunker Error	Median	0	0	0	0	0	0	0
	95th Percentile	52	56	56	140	133	184	163
	99th Percentile	522	556	547	619	608	631	646
Other Non-Impact Incident	Median	2	1	1	2	2	10	11
	95th Percentile	2,488	2,647	2,099	2,246	2,329	5,460	5,709
	99th Percentile	20,275	22,397	20,079	19,356	21,669	48,075	37,782

Table 18 Predicted Spill Volume by Incident Type in Haro Strait and Boundary Pass

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	3	3	0	15	3	3,514	4,149
Transfer Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Bunker Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	1	1	3	3
	99th Percentile	4	4	4	35	43	130	115
Other Non-Impact Incident	Median	0	0	0	0	0	0	0
	95th Percentile	< 1	< 1	< 1	1	1	5	5
	99th Percentile	102	111	109	250	206	320	363

Table 19 Predicted Spill Volume by Incident Type in Guemes Channel and Fidalgo Bay

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	299	468	369	21	138	428	191
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	310	1,021	2,865	219	260	445	1,019
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	1,861	1,046	1,978	210	335	1,009	1,805
Transfer Error	Median	0	0	0	0	0	1	< 1
	95th Percentile	486	480	501	452	463	599	721
	99th Percentile	2,220	2,196	2,176	2,193	2,174	2,221	2,216
Bunker Error	Median	0	0	0	2	2	3	3
	95th Percentile	214	208	283	423	429	454	442
	99th Percentile	574	582	635	741	734	766	725
Other Non-Impact Incident	Median	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	95th Percentile	679	595	588	615	600	1,040	924
	99th Percentile	9,558	9,754	12,408	10,577	7,985	13,292	11,561

Table 20 Predicted Spill Volume by Incident Type in Saddlebag

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	1
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	7	8	1	0	2	15	11
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	98	43	75	12	6	433	318
Transfer Error	Median	0	0	0	0	0	0	0
	95th Percentile	10	6	3	4	2	10	5
	99th Percentile	696	469	474	463	499	506	491
Bunker Error	Median	0	0	0	3	4	5	6
	95th Percentile	141	133	160	579	565	571	584
	99th Percentile	574	581	622	824	793	815	849
Other Non-Impact Incident	Median	0	0	0	< 1	< 1	< 1	< 1
	95th Percentile	129	120	79	408	449	655	729
	99th Percentile	3,270	2,817	2,336	5,518	6,225	7,927	7,698

Table 21 Predicted Spill Volume by Incident Type in Rosario Strait

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	88	154	254	204	99	1,539	2,053
Transfer Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Bunker Error	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	0	0	0	0	0	0	0
Other Non-Impact Incident	Median	0	0	0	0	0	0	0
	95th Percentile	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	99th Percentile	45	47	115	37	45	116	58

Table 22 Predicted Spill Volume by Incident Type in Cherry Point

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Collision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	2,350	2,861	2,275	499	1,113	2,285	3,052
Grounding	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	10,567	14,579	10,506	4,874	6,189	19,706	21,506
Allision	Median	0	0	0	0	0	0	0
	95th Percentile	0	0	0	0	0	0	0
	99th Percentile	4,266	1,636	1,977	435	1,031	2,056	7,030
Transfer Error	Median	1	1	1	1	1	1	2
	95th Percentile	1,498	1,709	1,546	1,476	1,924	1,858	1,965
	99th Percentile	2,263	2,272	2,273	2,242	2,482	2,391	3,139
Bunker Error	Median	0	0	0	1	1	5	5
	95th Percentile	189	169	170	331	342	583	580
	99th Percentile	621	599	589	626	700	850	818
Other Non-Impact Incident	Median	2	2	2	3	4	12	16
	95th Percentile	3,278	2,846	2,899	3,179	4,022	5,459	5,521
	99th Percentile	28,128	28,244	29,794	27,081	29,045	42,517	45,484

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