Gateway Pacific Terminal (GPT)

Vessel Traffic and Risk Assessment Study

Prepared for
Washington State Department of Ecology
Lacey, Washington

Pacific International Terminals
Seattle, Washington

Lummi Natural Resources Department
Bellingham, Washington

In collaboration with
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References

1. 16 USC§67, *Aquatic Nuisance Prevention and Control,* 2014.
2. 33 CFR §110.230(b)(1), *The Regulations,* 2013.
3. 33 CFR §110.230, *Anchorages, Captain of the Port Puget Sound Zone, WA.*, 2013.
4. 33 CFR §161 Subpart C, *Vessel Traffic Service and Vessel Movement Reporting System Areas and Reporting Points*, 2013.
5. 33 CFR §161, *Vessel Traffic Management*, 2013.
6. 33 CFR §165, *Regulated Navigation Areas and Limited Access Areas*, 2013
7. 33 CFR §167, *Offshore Traffic Separation Schemes*, 2013
8. 33 CFR §168, *Escort Requirements for Certain Tankers*, 2013.
9. 46 CFR §15.812, *Shipping*, 2013.
10. af Geijerstam, K. and Svensson, H., *Ship Collision Risk: An Identification and Evaluation of Important Factors in Collisions with Offshore Installations*, Lund University, Sweden, Report No. 5275, 2008.
11. *Aids to Navigation Manual Administration*, US Coast Guard, Department of Homeland Security, Commandant Instructions No. COMDTINST M16500.7A, 2 March 2005.
12. Alaska Department of Revenue. "Crude Oil and Natural Gas Prices." *Alaska Department of Revenue - Tax Divison: Crude Oil and Natural Gas Prices.* Alaska Department of Revenue, 2014. Available at http://www.tax.alaska.gov/programs/oil/dailyoil/dailyoil.aspx. Accessed on 8 April 2014.
13. Alyeska Pipeline. "Valdez Marine Terminal: Tankers." *Alyeska Pipeline - TAPS - Valdez Marine Terminals and Tanker: Tanker.* Alyeska Pipeline, 1 January 2011. Available at http://www.alyeska-pipe.com/TAPS/ValdezTerminalAndTankers/Tanker. Accessed on 29 January 2013.
14. *Anchorage Use Data*, Sector Puget Sound, United States Coast Guard (USCG), prepared at the request of Northern Economics, Inc., September 2012.
15. *Annual Energy Outlook 2011 with Projections to 2035*, US Energy Information Administration, DOE/EIA-0383(2011), April 2011.
16. “Appendix F: Marine Traffic and Ship Collision Modeling to the Independent Risk Analysis (Appendix C1),” *Cabrillo Port LNG Deepwater Port Independent Risk Assessment*, Risknology, Inc., January 2006 .
17. “Appendix IV: Ship Oil Spill Risk Models,” *Report for Australian Maritime Safety Authority: Assessment of the Risk of Pollution from Marine Oil Spills in Australian Ports and Waters*, Det Norse Veritas, Report No. PP002916, Rev. 5, 14 December 2011 .
18. "Application Procedure," 33 CFR §66.01-5, *Private Aids to Navigation*, 2013.

19. *Ballast Water Treatment Advisory*, American Bureau of Shipping (ABS), Houston, Texas, April 2011.

20. *Ballast Water Treatment Technology Update*, Lloyd's Register, March 2012.

21. Bateman, P. (email), "Puget Sound Ballast Totals," Washington Department of Fish and Wildlife, 4 April 2014.

22. Board of Pilotage Commissioners – Powers and Duties, RCW 88.16.035, State of Washington, 2006.

23. Bradsæter, A. and Hoffman, P. "Mitigated Risk Evaluation," *Technical Data Report: Marine Shipping Quantitative Risk Analysis: Enbridge Northern Gateway Project,* Section 8, Det Norske Veritas (DNV), Olso, Norway: 2010, Rev. Draft, pp. 8-118 to 8-137.

24. British Columbia (B.C.) Ferries. "Map of Ferry Routes." *BC Ferries - Reservations and Schedules.* Available at https://www.bcferries.com/bcftravelcentre. Accessed on 18 December 2012.

25. Brown, A.J., "Collision Scenarios and Probabilistic Collision Damage," *Marine Structures*, 15(4): 335-365, 2002 .

26. BST. *2009 Marine Cargo Forecast: Technical Report*. Prepared for the Washington Public Ports Association and Washington State Department of Transportation. 23 March 2009.

27. BST. *Washington Public Ports Association 2011 Study: Puget Sound Projection*. Provided at the request of Northern Economics, Inc. 16 October 2012.

28. *Bulk Carriers: Guidance and Information on Bulk Carrier Cargo Loading and Discharging to Reduce the Likelihood of Over-stressing the Hull Structure*, International Association of Classification Societies (IACS), London, UK, 1997.

29. "Bunkering Operations within the Waters of the Puget Sound and the Strait of Juan de Fuca," Puget Sound Harbor Safety Committee, *Harbor Safety Plan*, April 2012.

30. *Bunkering Overview 2009-2011*, Washington State Department of Ecology.

31. *Bunkerworld Price History for IFO380 at Seattle, Vancouver, Shanghai, and Xiamen from 2009*, Bunkerworld.

32. *Bureau Veritas Registry Data: MV Good Luck,* Bureau Veritas (BV), *VeriSTAR*, BV Registry No. 13319E, IMO No. 9492517, Accessed 2014.

33. *Canada Shipping Act*, Statute of Canada, S.C. 2001 c26 C-10.15, Minister of Justice, Canada, 2013.

34. *Canada/United States Co-cooperative Vessel Traffic System Agreement-Purpose and Objective*, US Coast Guard District 13, US Department of Home land Security, Available at http://www.uscg.mil/d13/cvts/purposeandobjective.asp, Accessed 11 October 2012.

35. *Canadian bound bunker barges (Canadian bound bunker barges 2008-2013.xlsx),*Washington State Department of Ecology, 29 May 2014.

36. *Coastal Engineering Design and Analysis System (CEDAS)*, Veri-Tech, Inc., ACES Version 4.03, 2012.

37. Commercial Fishing Entry Commission (CFEC). "Permit and Fishing Activity by Year, State, Census Area or Alaskan City: Juneau, Alaska." *CFEC Fishery Statistics - Participation and Earnings*. Available at http://www.cfec.state.ak.us/fishery_statistics/earnings.htm. Accessed 10 December 2012.

38. Committee on Assessing Numeric Limits for Living Organisms in Ballast Water, National Research Council, *Assessing the Relationship Between Propagule Pressure and Invasion Risk in Ballast Water*, The National Academies Press, 2011.
39. Convention on the International Regulations for Preventing Collisions at Sea, International Maritime Organization (IMO), 1972.
40. "Dalian Bunker Prices: 'IFO380 in Dalian vs. Port Angeles,'" Bunker Ports News, 18 October 2012.
41. Eaton, G. (memo) [Northern Economics], "Interview with Evan Kopko, Manager of Operations at International Chartering Services Ltd. (ICS)," 29 May 2014.
42. Edmond, E.D., Maggs, R.P.; "How Useful Are Queue Models in Port Investment Decisions for Container Berths?," Journal of the Operational Research Society, 29(8): 741-750, 1978 .
43. Etkin, D.S. Vessel Allison and Collision Oil Spill Risk Analysis for the Cape Wind Project in Nantucket Sound, Environmental Research Consulting, 11 December 2006.
44. *Errata Sheet,Gateway Pacific Terminal Project Alternatives Report Errata Sheet*, Pacific International Terminals, 15 October 2014.
45. Etkin, D.S., *Worldwide Analysis of In-Port Vessel Operational Lubricant Discharges and Leakages,* Proceedings of the 33rd Arctic & Marine Oilspill Program Technical Seminar, pp. 529 - 554, 2010.
46. Fitzgerald, K. (personal interview), 2014.
47. Fowler, T. G. and Sørgård, E. (2000), "Modeling Ship Transportation Risk." Risk Analysis, 20(2): 225–244. doi: 10.1111/0272-4332.202022.
48. Friis-Hansen, P., Ravn, E. S., & Engberg, P. C.; Basic Modeling Principles for Prediction of Collision and Grounding Frequencies, IWRAP MKII, Rev. 3, Technical University of Denmark, 5 December 2009.
49. FSA of Bulk Carriers Fore-End Watertight Integrity Annex 1: Basic Definitions and Abbreviations, International Association of Classification Societies (IACS), 2001.
50. *Gateway Pacific Terminal Project Alternatives Report*, Pacific International Terminals, Inc., 18 April 2014.
51. General Guidelines for Vessels Transiting Restricted Waterways or Ports, Puget Sound Pilots, 25 September 2012.
52. *Grand Amanda* and *Golden Future Ship Particulars*, ABS Eagle Record, American Bureau of Shipping (ABS), accessed on 27 November 2012.
53. Grand Amanda[tropical maritime photos], Shipspotting.com, http://cdn2.shipspotting.com/photos/middle/6/9/3/1429396.jpg, Accessed 11 April 2014.
54. *Green Flag Incentive Program Monthly Report 1/1/2014 - 6/30/2014 Operator Compliance at 20nm*, Port of Long Beach, 14 July 2014.
55. Henry, K.; Singleton, P.; Turcotte, C. (WDFW),"Tribal Fisheries Landings and Effort Data." WADFW, 2012. Provided by request to Northern Economics.
56. Hiatt, T.; Dalton, M.; Felthoven, R.; Fissel, B.; Garber-Yonts, B.; Haynie, A.; and Seung. C. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2010. National Oceanic and Atmospheric Administration, Economic and Social Sciences Research Program, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine

Fisheries Service, 2011. Available at http://www.afsc.noaa.gov/refm/docs/2011/economic.pdf.
57. Historical Data for Station CHYW1 - 9449424 at Cherry Point, Washington, National Data Buoy Center, National Oceanographic and Atmospheric Administration, Accessed from http://www.ndbc.noaa.gov/station_history.php?station=chyw1.
58. Hunter, J.D. "Matplotlib: A 2D Graphics Environment." Computing in Science & Engineering, 9(3): 90-95. 2007.
59. *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers*, International Maritime Organization (IMO), 7 July 1978, as amended.
60. International Energy Statistics (database), US. Energy Information Administration (EIA), http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm, Accessed 2014.
61. *International Tug of Opportunity System (ITOS) Fact Sheet*, USCG, 26 June 2002.
62. Jones, E., Oliphant, T., Peterson, P., and others. Scipy: Open Source Scientific Tools for Python. 2001-. Available at http://www.scipy.org/.
63. Judson, B., "Collision Risk Circumstances and Traffic Routing in the Approaches to the Strait of Juan de Fuca," *Journal of Navigation*, 45(3): 400-413, 1992.
64. *"K Class" Vessel Specifications: DHL Pacific*, Intership Navigation, IMO No. 9587350, http://www.intership-cyprus.com/k-class, Accessed 2014.
65. Kinder Morgan. *Trans Mountain Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act*. December 2013. Available at http://transmountain.s3.amazonaws.com/application/Application-Summary-Volume-8---Marine-Transportation_FINAL.pdf. Accessed on 7 April 2014.
66. Kirtley, E. N., *Notes from June 5th phone call with Mark Ashley, Director VTS for the GPT VTARAS*, The Glosten Associates, File No. 12096.02, 17 June 2014.
67. Knapp, G. and Lowe, M., Economic and Social Impacts of BSAI Crab Rationalization on the Communities of King Cove, Akutan, and False Pass, University of Alaska Anchorage Institute of Social and Economic Research, November 2007.
68. Kriebel, D. L. and Seelig, W. N., "An Empirical Model for Ship-Generated Waves," Waves 2005, Fifth International Symposium on Ocean Wave Measurement and Analysis, Madrid, 2005.
69. Lawrence, D. J.; and Cordell, J. R., "Relative Contributions of Domestic and Foreign Sourced Ballast water to Propagule Pressure in Puget Sound, Washington, USA," *Biological Conservation,* 143(3), pp. 700-709, 2010.
70. *Load Lines: International Convention on Load Lines, 1966 and Protocol of 1988, as amended in 2003 and 2008*, London: International Maritime Organization (IMO).
71. Lummi Natural Resources Department, "Lummi Nation Official Website." Available at http://www.lummi-nsn.org. Accessed on 20 February 2013.
72. *Map of Historic Reef Net Fishing Sites off Lummi Island*, The Lummi Nation, 2012.
73. Marine Environmental Protection Committee (MEPC), *Bulk Carrier Safety: Formal Safety Assessment Fore-End Watertight Integrity Submitted by IACS*, International Maritime Organization (IMO), Marine Safety Circular No. MSC 74/5/X, February 2001.
74. Marine Environmental Protection Committee (MEPC)*, Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances (G9),* International Maritime Organization (IMO), Resolution MEPC.169(57) Annex 1, 4 April 2008.
75. *Marine Exchange of Puget Sound*, Northern Economics, Inc., August 2012.

76. "Marine Facilities," *Port of Port Angeles - Official Website*, http://www.portofpa.com/index.aspx?NID=208, Accessed 16 April 2014.
77. *Maritime Buoyage System and Other Aids to Navigation*, IALA AISM, 2009.
78. Merrick, J. R.; Van Dorp, J. R.; Blackford, J. P.; Shaw, G. L.; Harrald, J.; and Mazzuchi, T. A. "A Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model," *Reliability Engineering and System Safety*, 81(2): 119-132, 2003.
79. Merrick, J.R. "VTRA 2010 Risk Management Presentation," George Washington University and Virginia Commonwealth University Collaborative NSF Maritime Risk Project, 5 June 2013.
80. Modern Ship Size Definitions, Lloyd's Register, 26 July 2007, http://www.lr.org/documents/173543-index-of-shipping-information-sheets.aspx, Accessed 21 September 2012.
81. Montewka, J.; Hinz, T.; Kujala, P.; Matusiak, J., "Probability Modelling of Vessel Collisions," *Reliability Engineering & System Safety*, 95(5): 573-589, May 2010.
82. Montewka, J.; Krata, P.; Kujala, P.; "Selected Problems of Maritime Traffic Risk Modelling," *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability,*225(3): 307-322, September 2011.
83. National Marine Fisheries Service Northwest Regional Office. *History of L.E. Permits (P.19)*. Sustainable Fisheries Division, Permits Branch, Northwest Regional Office, National Marine Fisheries Service. Available at https://nwr2.nmfs.noaa.gov/nwp_public_ss/home/index_pub_permits_ss.cfm. Accessed on 23 November 2012.
84. National Oceanic and Atmospheric Administration (NOAA). "Image of Cherry Point, Washington." Available at http://www.noaanews.noaa.gov/stories2009/20091120_cherrypoint.html. Accessed on 29 January 2013.
85. National Oceanic and Atmospheric Administration (NOAA). *Port Angeles*, US Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Chart No. 18468, Appendix l.
86. *Navigation Rules, International - Inland*, US Coast Guard, Commandant Instruction No. COMDTINST M16672.2D, Change No. 20, 1 July 2013.
87. *Neah Bay Tug Shifts from Public to Private Funding July 1*, Department of Ecology, State of Washington, News Release, 29 June 2010 http://www.ecy.wa.gov/news/2010news/2010-147.html, Accessed 29 October 2012.
88. Neptune Terminals. *Community Update Summer 2012*. Available at http://www.neptuneterminals.com/wp-content/uploads/2012/04/Neptune_Information-Summer_2012.pdf. Accessed on 16 April 2014.
89. Newman, J. *Marine Hydrodynamics*, The MIT Press, Cambridge, Massachusetts, 1986.
90. Northern Economics, Inc. *Sector and Regional Profiles of the North Pacific Groundfish Fisheries– 2001*. North Pacific Fishery Management Council, November 2001. Available at http://www.fakr.noaa.gov/npfmc/PDFdocuments/resources/SectorProfiles/NorthernEconomics1.htm.
91. Oil Tankers – Restricted Waters – Standard Safety Features Required – Exemptions, Revised Code of Washington (RCW) 88.16.190, State of Washington, 1994.

92. P-0610 Turn Point – Special Operating Area, US Coast Guard, 29 July 2008.
93. *Pacific Pilotage Regulations*, Minister of Justice, Canada, Consolidated Regulations of Canada (C.R.C.) c. 1270, 10 December 2009.
94. PITLocationgraphic [figure], Lummi Indian Business Council, 24 October 2014.
95. Pleus, A., *Status of Washington State's Ballast Water Management Program*, Washington Department of Fish and Wildlife, Pacific Ballast Work Group, 15 February 2012.
96. Pleus, A., *Review of Washington State's Ballast Water Management Program*, Washington Department of Fish and Wildlife, Pacific Ballast Work Group, 15 April 2014.
97. *Port Angeles*, National Oceanic and Atmospheric Administration, US Department of Commerce, NOAA Chart No. 18468, Appendix l.
98. Port Metro Vancouver Finance Department, Decision Support Services. Historic Vessel Data. Prepared at the request of Northern Economics, Inc. 31 August 2012.
99. "Ports and Waterways Activities," *Marine Safety Manual*, US Coast Guard , US Department of Homeland Security, Volume VI, 2004.
100. "Projections," *Generate World Oil Balance Application*, US Energy Information Administration (EIA), (2013).
101. Przywarty, M., "Models of Ship-Ship Collision," Maritime Traffic Engineering Conference, Malmö, Sweden , 19-22 October 2009.
102. "Puget Sound Anchorages," Puget Sound Harbor Safety Plan, Puget Sound Harbor Safety Committee, Seattle, Washington, April 2012, p 61.
103. *Puget Sound Commercial Crab Management Regions and Corresponding Marine Fish/Shellfish Catch Areas*, Washington State Department of Fish and Wildlife (WDFW), http://wdfw.wa.gov/fishing/commercial/crab/pugetsound/graphics/crabregions.jpg, Accessed 28 April 2014
104. Puget Sound Harbor Safety Committee (PSHSC). *Harbor Safety Plan: Tanker Size Limitations for Puget Sound*. 2013. Available at http://cdn.assets.sites.launchrocketship.com/3ce74667-d320-4623-8287-04eee9a9f4f8/files/22ec52a9-24f1-448a-9877-0ac99814b3e1/harbor_safety_plan_2013_final_4-3-2013.pdf
105. Puget Sound Harbor Safety Plan, Puget Sound Harbor Safety Committee, April 2012.
106. *Puget Sound Salmon Management and Catch Reporting Areas (WA 220-22-030)*, Washington State Department of Fish and Wildlife (WDFW), http://wdfw.wa.gov/fishing/commercial/salmon/wac_220-022-030.pdf, Accessed 28 April 2014
107. Python(x,y) Python distribution, version 2.7.2.3. Available at https://code.google.com/p/pythonxy/
108. RBN Energy LLC. "Crude Loves Rock'n'Rail – West Coast Destinations." Available at http://www.rbnenergy.com. Accessed on 26 July 2013.
109. *Response to Request for Inputs for Glosten Queuing Model Analysis, Gateway Pacific Terminal, Vessel Traffic and Risk Assessment Study Glosten Queuing Analysis,* SSA Marine, 18 July 2014.

110. Reuters. “Bakken Crude Breakeven prices as low as $58/bbl in 2014.” Available at http://www.reuters.com/article/2014/04/02/energy-crude-bakken-idUSL1N0MU21Z20140402. Accessed on 11 April 2014.
111. Revised Code of Washington (RCW) §88.16.190, “Oil Tankers – Restricted Waters – Standard Safety features Required – Exemptions.”
112. Revised Code of Washington (RCW) §88.16.195, “Oil Tankers—Not to Exceed Speed of Escorting Tug.”
113. Revised Code of Washington (RCW) §88.16.170, “Oil Tankers – Intent and Purpose.”
114. Revised Project Information Document; Gateway Pacific Terminal, Whatcom County, Washington, Pacific International Terminals, March 2012.
115. *Sailing Directions:Pacific Ocean and Southeast Asia*, National Geospatial-Intelligence Agency, Publication 120, 2011.
116. *Scope of Work for Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study*, Pacific International Terminals – Gateway/Cherry Point, 26 April 2012.
117. *"Sea Robin Class” Tug Specifications: Sea Breeze*, Crowley , IMO No. 7404114.
118. “Services—VTS Measures and Operating Requirements,” *United States Coast Pilot 7: Pacific Coast: California, Oregon, Washington, and Hawaii*, 44th Edition, Office of Coast Survey, National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce, Washington, DC, Chapter 2, 2012.
119. *Significant Ships*, The Royal Institution of Naval Architects, 1990-2011.
120. SOLAS V.10, *Ships' Routing*, International Maritime Organization (IMO), 2012.
121. Steinberg, A (email), "GPT Vessel Time at Berth," 1 November 2012.
122. “Strait of Juan De Fuca and Georgia,” United States Coast Pilot 7 - 44th Edition, US Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC, Chapter 12, 2012.
123. *Study of Tug Escorts in Puget Sound*, prepared for State of Washington Department of Ecology, The Glosten Associates, Inc., in collaboration with Herbert Engineering, Environmental Research Consulting, and Grabowski, M., File No. 04075, 25 February 2005.
124. *Synopsis of State-funded Neah Bay Emergency Response Vessel Assists: 1999-2010*, Department of Ecology, State of Washington, http://www.ecy.wa.gov/programs/spills/response_tug/synopsis_statefundedtug.pdf, Accessed 29 October 2012.
125. “Terms,” Crowley Pacific Northwest Schedule of Tugboat Rates and Terms, Crowley Maritime, effective 1 February 2011.
126. Thevik, H. J.; Sørgård, E.; and Fowler, T. "A Method for Assessing the Risk of Sea Transportation: Numerical Examples for the Oslofjord," Proceedings of ESREL, 2001.
127. UKOOA Guidelines for Ship/Installation Collision Avoidance, UK Offshore Operators Association, Issue 1, February 2003.
128. United Nations Conference on Trade and Development (UNCTAD) Secretariat, Review of Maritime Transport, United Nations, New York and Geneva, 2011.
129. United States Ballast Water Regulations, US Coast Guard, http://el.erdc.usace.army.mil/zebra/zmis/zmishelp/united_states_ballast_water_regulations.htm, Accessed 20 September 2012.
130. van Dorp, J.R.; Harrald, J.R.; Merrick, J.R.W.; Grabowski, M., Vessel Traffic Risk Assessment Final Report: Assessment of Oil Spill Risk due to Potential Increased Vessel

Traffic at Cherry Point, Washington, The George Washington University, 31 August 2008.
131. van Dorp, J.R.; Merrick, J.R.W.; Harrald, J.R.; Mazzuchi, T.A.; Grabowski, M. "A Risk Management Procedure for the Washington State Ferries." Risk Analysis 21(1):127-142.
132. "Vessel Traffic Management," Navigation and Navigable Waters, 33 CFR, Part 161, Subpart C, 2011.
133. Vessel Traffic Risk Assessment (VTRA) 2010 Final Report: Preventing Oil Spills from Large Ships and Barges in Northern Puget Sound & Strait of Juan de Fuca, George Washington University and Virginia Commonwealth University, 19 February 2014.
134. VTS User's Manual, US Coast Guard Sector Puget Sound Vessel Traffic Service, 2013
135. Washington Administrative Code (WAC) §363.116.500, *Tug escort requirements for oil tankers*, 2013.
136. Washington Ballast Water Treatment Program: Monthly Summary Report, Washington Department of Fish and Wildlife, December 2013.
137. Washington State Department of Ecology (WDOE). Phillips 66 Ferndale Refinery (formerly ConocoPhillips), 2013. Available at http://www.ecy.wa.gov/programs/swfa/industrial/oil_phillips.html. Accessed on 29 January 2013.
138. Washington State Department of Ecology (WDOE), Spill Prevention, Preparedness and Response Program. Vessel Entries and Transits for Washington Waters (VEAT) 1995–2010. WDOE Publication 11-08-11. March 2011.
139. Washington State Department of Ecology (WDOE). BP Cherry Point Refinery, 2013. Available at http://www.ecy.wa.gov/programs/swfa/industrial/oil_bp.html. Accessed on 29 January 2013.
140. Washington State Department of Transportation. Washington State Ferries, San Juan Islands Route Map, 2012. Available at http://www.wsdot.wa.gov/ferries/info_desk/route-maps/. Accessed on 18 December 2012.
141. W*est Coast Groundfish Fishery, Measuring the Effects of Catch Shares*, MRAG Americas, Inc., http://catchshareindicators.org/catch-shares-and-fisheries-overview/west-coast-groundfish, accessed 14 October 2014.
142. Westshore Terminals Limited Partnership. Vessel Lineup, 2013. Available at http://www.westshore.com/pdf/misc/vessellineup.pdf. Accessed 2013.
143. Westshore Terminals Limited Partnership. Westshore Terminals Reinvestment Project, 2014. Available at http://www.westshore.com/p2s5/index.html#advantage. Accessed on 16 April 2014.
144. Winningham, Brian of BST Associates (email). "RE: Questions on 2011 Commodity Forecasts." 2 November 2012.
145. xlrd, version 0.7.7. Available at https://pypi.python.org/pypi/xlrd
146. Yaremko, R. Golden Future at Cowichan Bay [photos], MarineTraffic.com, http://www.marinetraffic.com/en/photos/of/ships/photo_keywords:9443607/ship_name:GOLDEN%20FUTURE, Accessed 2014.

Definitions

As used throughout this report, the following terms, acronyms, and abbreviations shall have the meanings stated below:

Term	Definition
Abeam	Perpendicular to the centerline of a vessel.
Activity Type *(a)*	A scenario parameter. The four (4) project-specific activity categories are: 1. Underway 2. Maneuvering 3. Docked 4. Anchored
AIR	Adjusted Incident Rate
Alaska Marine Highway System (AMHS)	A ferry service operated by the government of the US state of Alaska, which operates along the south-central coast of the state, the eastern Aleutian Islands, and the Inside Passage of Alaska and British Columbia.
Allision	The striking of one object by another when one of the two objects is stationary, usually wherein at least one of the objects is a ship.
Alternative Management System (AMS)	A ballast water management system that has been type-approved by a flag state other than the US, in accordance to the International Maritime Organization's Ballast Water Convention criteria, and has been designated by the US Coast Guard as an acceptable alternative to a US Coast Guard type-approved system.
Area to Be Avoided	An area within defined limits in which either navigation is particularly hazardous, or should be avoided by all ships, or by certain classes of ships.
Articulated Tug and Barge (ATB)	An articulated tug and barge (ATB) consists of a barge and a large, powerful tug that is positioned in a notch in the stern of the barge, which enables the tug to propel and maneuver the barge. The ATB has an articulated or "hinged" connection system between the tug and barge that allows movement in one axis, or plane, in the critical area of fore and aft pitch.
Assist Tug (Docking/Undocking)	A tug that may be attached to the side of the ship by a line, allowing the tug to push or pull the ship in the desired direction to assist the ship handler in maneuvering to or away from a berth. It may also act as a brake to slow down or stop a ship.

Term	Definition
Automatic Identification System (AIS)	A maritime transponder/receiver system used by ships and other marine vessels for identification at sea and includes the marine vessel's ID, position, course, speed, and other ship data.
Ballast Water	A liquid that is brought on board a vessel to increase the draft, change the trim, regulate the stability, or to maintain stress loads within acceptable limits.
Barrels of Oil (BBL)	An oil barrel is 42 US gallons, approximately 159 liters or 35 imperial gallons.
Barrels of Oil Per Day (BPD or BOPD)	1 BOPD is equivalent to 0.0292 gallons per minute or 48.8 tonnes per year.
British Columbia (BC)	A province of Canada located on the West Coast of Canada.
British Columbia Coast Pilots (BCCP)	Group of maritime pilots supplying pilot service to the Canadian coastline and Strait of Georgia.
British Columbia Ferry Services (BC Ferries)	An independently managed, publicly owned company that provides all major passenger and vehicle ferry services for coastal and island communities in the Canadian province of British Columbia.
Bollard	A thick, low post, usually of iron or steel, mounted on a wharf or the like, to which mooring lines from vessels are attached.
Bollard Pull	Force produced when pulling against a bollard or the zero speed pulling capability.
Bulk Ship (Bulker)	A ship designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in its cargo holds.
Bunker Fuel	A type of liquid fuel that is fractionally distilled from crude oil and used to power a ship. Also known as fuel oil, there are two basic types of marine fuels: distillate and residual. A third type is a mixture of these two, commonly called "intermediate." Distillate fuel is composed of petroleum fractions of crude oil that are separated in a refinery by a boiling or "distillation" process. Residual fuel or "residuum" is the fraction that did not boil, sometimes referred to as "tar" or "petroleum pitch."
Bunkering Activity (Bunkers)	The act or process of supplying a ship with fuel (bunkers), generally at a berth or transferred from a barge alongside.
BWM	Ballast Water Management

Term	Definition
Canadian Coast Guard (CCG)	Owns and operates the Canadian government's civilian fleet, and provides key maritime services to Canadians. The CCG is a Special Operating Agency of the Department of Fisheries and Oceans Canada (DFO), and helps the DFO meet its responsibility to ensure safe and accessible waterways for Canadians. The CCG also plays a key role in ensuring the sustainable use and development of Canada's oceans and waterways.
Capesize Ship	Bulk ships that are typically above 160,000 long tons deadweight (DWT), used for transporting coal, ore, and other commodity raw materials.
Captain of the Port (COTP)	A US Coast Guard officer, usually the Commander of a United States Coast Guard Sector, with the rank of Captain. Duties involve enforcing port safety and security, marine environmental protection regulations, anchorages, security zones, safety zones, regulated navigation areas, safe movements of vessels, establishing anchorages and restricted areas, and supervising the handling and storage of explosive cargos.
Captain of the Port of Puget Sound	Commander of the United States Coast Guard Sector Puget Sound – District 13
Case Parameter *(c)*	The parameter describing traffic volume case. The three (3) project-specific traffic volume cases are: 1. Baseline Traffic 2. Baseline + GPT Traffic 3. Baseline + GPT + Cumulative Traffic
CCTV	Closed-Circuit TV
CDF	Cumulative Distribution Function
CFR	US Code of Federal Regulations
Closest Point of Approach (CPA)	An estimated point in which the distance between two objects, of which at least one is in motion, will reach its minimum value. This estimate is used to evaluate the risk of a collision of, for example, two ships.
Collision	The act of colliding; a coming violently into contact; crash.
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
Contaminant	Bunker oil, cargo oil, and dry bulk cargo.

Term	Definition
Cooperative Vessel Traffic Service (CVTS)	A system of vessel traffic management established by a formal agreement signed in 1979, jointly operated by the United States and Canada within adjoining waters for the Juan De Fuca region and its seaward approaches. CVTS facilitates traffic movement and anchorages, avoids jurisdictional disputes, and renders assistance in emergencies in adjoining United States and Canadian waters.
Cumulative Distribution Function (CDF)	This function shows the probability that any quantity will be exceeded (the probability of non-exceedance).
Dead Weight Tonnage (DWT)	A measure of how much weight a ship is carrying or can safely carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew. Deadweight tonnage was historically expressed in long tons (2,240 pounds) but is now usually given internationally in tonnes; the mass equal to 1,000 kilograms (2,204.6 pounds) or 1 megagram (1 Mg), also known as a metric ton in the United States.
Demurrage	Demurrage is an hourly fee typically paid by the terminal to an arriving vessel that is delayed due to lack of berth availability at the fault of the terminal.
Deep-Water Route	A route within defined limits that has been accurately surveyed for clearance of sea bottom and submerged articles.
Docking Assistance Tug	Tug used to assist ships in docking.
DWT	Dead Weight Tonnage
ERC	Environmental Research Consulting
EEZ	Exclusive Economic Zone – a seazone prescribed by the *United Nations Convention on the Law of the Sea* over which a sovereign state has special rights over the exploration and use of marine resources, including energy production from water and wind. It stretches from the baseline out to 200 nautical miles from a sovereign state's coast.
EPA	US Environmental Protection Agency
ETV	US Environmental Technology Verification
Fathom	A unit of length equal to 6 feet (1.83 meters), used principally in the measurement and specification of marine depths.

Term	Definition
General Cargo Vessel	Cargo Vessels designed to carry packaged items like chemicals, foods, furniture, machinery, motor and military vehicles, footwear, garments, boxes, barrels, bales, crates, packages, bundles, and pallets, often designed specifically for the cargo that they will carry. Cranes and other heavy equipment needed to move, load and unload cargo are usually carried or mounted onboard.
Glosten	The Glosten Associates
GPT	Gateway Pacific Terminal
GPT Tank Barges	Tank barges are defined as GPT tank barges when they are supporting bunkering for GPT-calling vessels.
GPT Tugboats	Tugboats are defined as GPT tugboats during the time they are transiting to or from the GPT dock and while docking GPT-calling vessels.
Harbor Safety Committee (HSC)	A local committee dedicated to addressing issues that affect the safety, mobility, security, and environmental protection of a waterway or port.
Horsepower (hp)	A unit of power equal to 746 watts.
IMO Emissions Control Area	Near shore areas within 24 miles of West Coast where there are stricter requirements on which bunker fuels are used as a method of controlling Sulphur Oxide (SO_x) emissions.
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 Error *For the purposes of this study, the term "bunker" is used inclusive of fuel used by smaller boats, like tugs.

Term	Definition
Inshore Traffic Zone	A designated area between the landward boundary of a TSS and the adjacent coast.
Integrated Tank Barge (ITB)	A tug and barge that are locked together in a rigid connection and become for practical purposes one unit.
International Maritime Organization (IMO)	A specialized agency of the United Nations that is responsible for measures to improve the safety and security of international shipping and to prevent marine pollution from ships.
Lightering	The process of transferring cargo between vessels of different sizes, usually between a barge and a bulker or oil tanker. Lightering is undertaken to reduce a vessel's draft in order to enter port facilities which cannot accept very large ocean-going vessels.
Length (LOA)	Length Overall
Location (*l*)	A scenario parameter. The seven (7) project-specific subareas 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
Long Ton (LT)	A unit of mass equal to 2,240 pounds.
Marine Communications and Traffic Services (MCTS)	A program of the Canadian Coast Guard that provides marine safety communications and manages the movement of traffic.
Marine Exchange of Puget Sound (MX)	A member-based, non-profit organization that provides comprehensive communications and information services to its membership by tracking and monitoring vessel movements starting about 15 days prior to arrival in Puget Sound or Grays Harbor.

Term	Definition
MARPOL	*International Convention for the Prevention of Pollution from Ships*, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997.
Maximum Continuous Rating (MCR)	The maximum output in megawatts that an electric power generating station is capable of producing continuously under normal conditions over a year without failure.
MCR	Maximum Continuous Rating
MCTSOs	Marine Communication and Traffic Services Officer
Median	50th percentile.
Metric Ton (mt)	A unit of mass equal to 1,000 kg or 2,204.6 pounds.
Molded Breadth	The maximum beam or breadth (width), of the ship measured inside the inner shell strakes of plating, and usually occurs amidships.
Molded Depth	The vertical distance between the molded base line (a line lying in the longitudinal plane of symmetry and parallel to the designed summer load waterline) and the top of the beams of the uppermost continuous deck measured at the side amidships.
Monte Carlo Simulation	The process of calculating a sufficient number of stochastic results to produce high-resolution probability distributions.
Nautical Mile (nm)	One minute of latitude; by international agreement it has been set at 1,852 meters, approximately 6,076 feet or about ⅛ longer than the statute mile of 5,280 feet.
Nautical Mile per Hour (knot)	A unit of speed equal to one nautical mile (1.852 km) per hour, approximately 1.151 mph or one minute of geographic latitude in one hour.
NBIC	US National Ballast Information Center
NEI	Northern Economics, Inc.
NI	Number of Incidents
NIS	Non-Indigenous Species
NOAA	US National Oceanic and Atmospheric Administration

Term	Definition
Panamax Ship	The size limit for ships traveling through the Panama Canal not to exceed 294,13 m (965 feet) in length, 32,31 m (106 feet) in beam and 12,04 m (39.5 feet) in draft. These vessels have an average capacity of 65,000 DWT, and are primarily used in transporting coal, crude oil, and petroleum products.
Parameter	An attribute with a set of prescribed, possible values for selection to input or for calculation to output.
Pilot	An individual responsible for navigating vessels through dangerous or congested waters. Pilots possess detailed knowledge of local waterways and are licensed by their state. Pilots are required by US and Canadian law to assist in navigating large trade vessels upon their entry into national waters.
Poisson Distribution	This statistical model for event frequency is used to describe the probability of event occurrence for events whose average rate of occurrence is known. For this model, the events occur independently of the time since the last event.
Precautionary Area	An area within defined limits where ships must navigate with particular caution and within which the direction of flow of traffic may be recommended.

Term	Definition
Probability Distribution	A probability distribution is a function describing the likelihood of each outcome from an event. For instance, rolling two six-sided dice is an event, and the outcome is the sum. The outcome will be any integer between 2 and 12. Since each die has 6 sides and there are two die, there are $6^2 = 36$ potential outcomes. Only one combination of rolls will produce the sum of 2; the probability of this outcome is 1/36. There is a 2/36 chance that the sum will be 3, a 3/36 chance that the sum will be 4, and so on. Seven is the most likely or most probable outcome; the probability function is P(7)= 6/36. By adding up the probabilities from each proceeding outcome, the cumulative probability is found. There is a 92% chance that the sum will be 10 or less. The below table[1] shows the potential outcomes, the probability function, and the cumulative probability function: The two dice roll probability distribution described by the table below is discreet, meaning there are a finite number of possible outcomes. A probability distribution can also be continuous, meaning there are an infinite number of possible outcomes. For instance, consider the weight of a healthy newborn baby, which may be four pounds, eleven pounds, or anywhere in between.
Puget Sound Harbor Safety Committee	A nonprofit corporation created in 1997 by stakeholders to promote safety and the protection of Puget Sound and provide a proactive forum for identifying, assessing, planning, communicating, and implementing those operational and environmental measures, beyond that which is in laws or regulations, which promote safe, secure, and efficient use of Puget Sound and adjacent waters.
Puget Sound Marine Exchange	See *Marine Exchange of Puget Sound.*
Puget Sound Pilots (PSP)	Group of maritime pilots supplying pilot service to Puget Sound.
Quartering	Coming from a point well abaft the beam of a ship but not directly astern.

1

Outcome	2	3	4	5	6	7	8	9	10	11	12
Probability	1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36
Cumulative Probability	1/36	3/36	6/36	10/36	15/36	21/36	26/36	30/36	33/36	35/36	36/36
Cumulative Probability (%)	3%	8%	17%	28%	42%	58%	72%	83%	92%	97%	100%

Term	Definition
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.
RACON	Radio Beacon
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.
Recommended Route	A route of undefined width for the convenience of ships in transit that is often marked by centerline buoys.
Regression Analysis	Interpolation of data in order to estimate a value that is not explicitly available or given.
Roundabout	A separation point or circular separation zone and a circular traffic lane within defined limits.
RRO	Risk Reduction Option
Safe Working Load (SWL)	Also known as Working Load Limit. The maximum load that includes mass or force, that should ever be applied to load carrying equipment in a specified configuration or application.
Scenario	A combination of project-specific parameters present during a particular incident, which includes vessel type (v), activity type (a), incident type (i), and location (l).
Separation Zone or Line	A zone or line separating traffic lanes in which ships are proceeding in opposite or nearly opposite directions; or separating a traffic lane from the adjacent sea area; or separating traffic lanes designated for particular classes of ship proceeding in the same direction.
SOLAS	International Convention for the Safety of Life at Sea
Special Operating Area (SOA)	An area or zone established to enhance order and predictability, ensure the efficient and safe movement of goods and services, and to reduce the risk of accidents with respect to vessels transiting certain waterways or channels.

Term	Definition
Spot Charter	A charter for a particular vessel to move a single cargo between specified loading port(s) and discharge port(s) in the immediate future, or a contract to charter a vessel for an agreed period of time at a set daily rate. This daily rate can either be a contract to carry a specific cargo for a per day rate or a per ton carry amount, depending on the agreement with the charterer.
SOC	Standards of Care
Stochastic Result	One possible contaminant outflow result; obtained by sampling all 1,008 scenarios (*v,a,i,l* combinations) once each.
Study Area	The geographic bounds of the area considered in the study. The area covered by all locations (*l*), as shown in Figure ES-1.

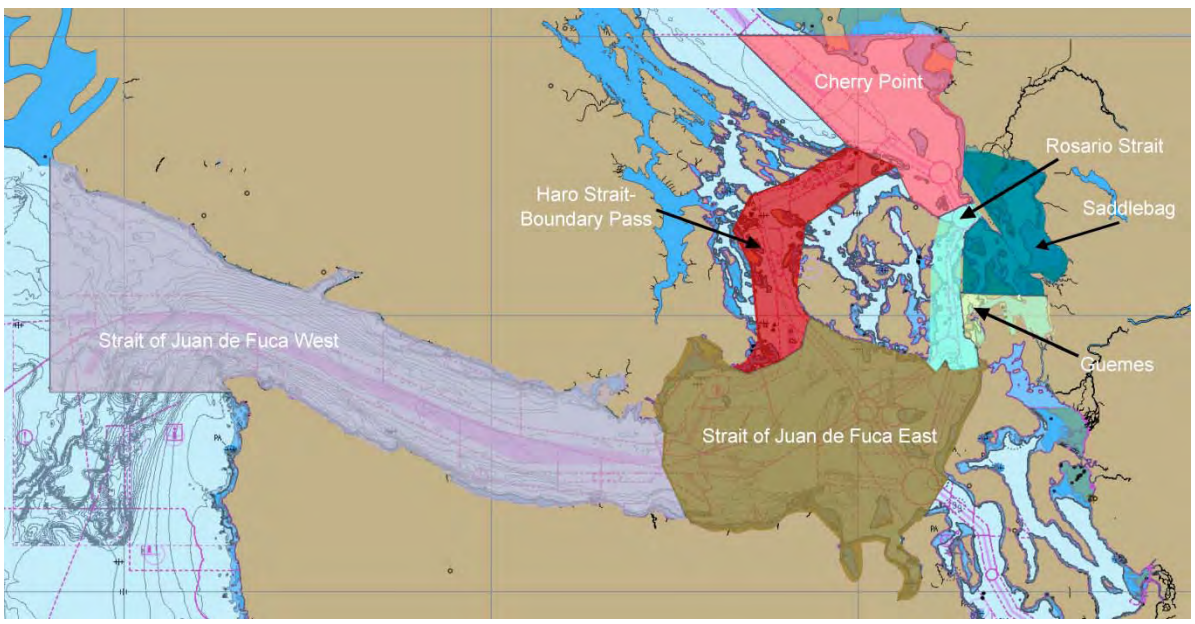

Figure ES-1 Project study area showing subareas (locations)

Subarea	See *Location*.
Tank Ship (Tanker)	A merchant vessel designed to transport liquids or gases in bulk within its cargo spaces, without the use of barrels or other containers. Major types of tank ships include the oil tanker, the chemical tanker, and gas carrier.
Tractor Tug	A tug that is specifically designed to pull craft over distances, designed with a good shape to go through the water, and with more maneuverability than other tugs.

Term	Definition
Traffic Day *(TD)*	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*).
Traffic Lane	An area within defined limits in which one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary
Traffic Separation Scheme (TSS)	Used to regulate the traffic in busy, confined waterways or around capes. Within a TSS, it is normal to have at least one traffic-lane in each main direction, as well as turning points, deep-water lanes, and separation zones between the main traffic lanes. The direction of travel in each traffic lane is indicated by arrows on the chart. The body of water between two opposite lanes is a separation zone, and travel within them in US waters is generally prohibited.
Trim	To cause a ship to assume a desired position in the water
Tug Escort	A tug that travels alongside or near a tanker to assist in case of an emergency (in the event that the tanker loses power and or has steering problems). The tug is available to improve the steering and arresting properties of the tanker by means of a tow line generally connected from the tug's towing winch to the tanker's center bollard aft.
US Coast Guard (USCG)	A branch of the US military with a maritime, military, and multi-mission service unique among the US military branches. The USCG has federal legal authority for both armed service and maritime law enforcement with jurisdiction in both domestic and international waters. The USCG also has a federal regulatory agency mission for maritime security, maritime safety, and maritime stewardship.
USC	United States Code
U&A	Lummi Nation Usual and Accustomed grounds and stations.
Vessel Capacity	The capacity of a given vessel type for a given contaminant type (oil or bulk), including cargo and bunkers (fuel).

Term	Definition
Vessel Captain (Master)	A licensed mariner in ultimate command of the ship, the captain is responsible for its safe and efficient operation, including cargo operations, navigation, crew management and ensuring that the vessel complies with local and international laws, as well as company and flag state policies. All persons on board, including officers and crew, other shipboard staff members, passengers, guests and pilots, are under the captain's authority and are his ultimate responsibility.
Vessel Entries and Transits (VEAT)	A database of vessel activity maintained by the Washington Department of Ecology.
Vessel Movement Reporting System (VMRS)	A system used to monitor and track vessel movements in a VTS or VMRS area.
Vessel Traffic Lane	Approaches in coastal waters and inland passages where vessel traffic is controlled with marker buoys known as channel markers used for guiding a vessel through an area known to be safe for passage, and provide a traffic separation scheme.
VTOSS	Vessel Traffic Operational Support System
Vessel Traffic System (VTS)	A marine traffic monitoring system established by harbor or port authorities, similar to air traffic control for aircraft. Typical VTS systems use radar, closed-circuit television (CCTV), VHF radiotelephony and automatic identification system (AIS) to keep track of vessel movements and provide navigational safety in a limited geographical area.
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
Voith Tug (VSP)	A system for tug propulsion, serving both as propeller and rudder, that consists of one or two vertical-axis, underwater rotors. Rotor disks are flush with the shell plating which is approximately horizontal, and five to eight spade like vertical-impeller blades are fitted around, near the periphery of each disk.
VTARAS	Vessel Traffic and Risk Assessment Study

Term	Definition
VTS Vessel	A vessel belonging to one of the project-specific vessel types.
Washington State Pilot Commission	Maintains efficient and competent pilotage service on Washington State's inland waters.
Washington Department of Fish and Wildlife (WDFW)	An agency of the Washington State government whose mission is to preserve, protect, and perpetuate fish, wildlife and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities.
Washington State Department of Ecology (Ecology)	An agency of the Washington State government whose mission is to protect, preserve and enhance Washington's environment, and to promote the wise management of the state's air, land and water for the benefit of current and future generations.
y	Year Index for 1995-2010
Z-Drive Tug (ASD)	Azimuthing Stern Drive Tugs use conventional or controllable pitch propellers encased in steerable nozzles, in the after section of the vessel, that can be rotated a full 360 degrees to provide thrust vectors in any direction without the use of a rudder.

Executive Summary

Project Background

In 1992, Pacific International Terminals (PIT) applied to Whatcom County for a permit to develop a multi-use marine terminal at Cherry Point, Washington. The proposed marine terminal was to be composed of a deep-water wharf with upland commodity storage and would be known as the Gateway Pacific Terminal (GPT). A terminal permit, known as the Shoreline Substantial Development permit, was issued by Whatcom County in 1997,[2] but was subsequently appealed by several agencies:

- The Washington State Department of Ecology.
- The Washington Department of Fish and Wildlife.
- North Cascades Audubon Society.
- People for Puget Sound.
- League of Women Voters of Bellingham/Whatcom County.
- The Washington Environmental Council.

A settlement agreement was reached in 1999 between the above parties that resolved the appeals to the 1997 permit. An agreement made during the 1999 settlement required that the Washington Department of Ecology oversee an analysis by PIT of the additional ship traffic brought by the proposed GPT.

In addition, during 2011 the Lummi Nation, which was not a party to the 1999 Settlement Agreement, identified additional topics that it wanted addressed as part of a vessel traffic analysis for the modified version of the GPT project proposed during 2011. Both Ecology and PIT agreed to include the topics identified by the Lummi Nation in the vessel traffic analysis.

Initially the vessel traffic analysis was to be performed by Jack Herrald, PhD. and Captain Jim Townley. During 2011, it was determined by the parties participating in the 1999 settlement agreement that it was no longer feasible for Messrs. Herrald and Townley to perform the vessel traffic analysis and it was agreed that the analysis would be performed by The Glosten Associates and their subcontractors (Glosten). In late June 2012, Glosten started the vessel traffic analysis for the proposed GPT.

PIT forecasts full capacity for the proposed GPT to be 487 total annual vessel calls. For the purposes of this study, GPT-calling vessels are assumed to export bulk commodities to Asia. PIT anticipates that these calls will be split between two vessel sizes: Panamax-sized bulkers and Capesize bulkers. This study defines vessels between 65,000 deadweight tons (DWT) and 80,000 DWT as Panamax bulkers. Vessels between 160,000 DWT and 180,000 DWT are considered to be Capesize bulkers. The proposed GPT will have capacity for vessels up to

[2] A multi-use marine terminal project of the type proposed by PIT also requires a number of other permits and/or authorizations, such as a Clean Water Act Section 404 permit and a Clean Water Act Section 401 water quality certification, a Rivers and Harbors Act Section 10 permit, an Air Operating Permit, and a WDFW Hydraulic Project Approval.

250,000 DWT (Reference 50), and smaller Handymax sized vessels may also call at the terminal. There are three berths along the wharf. Two Capesize and one smaller ship can be at berth concurrently. Of the total annual vessel calls, it is projected that there would be 318 Panamax and 169 Capesize vessels (Reference 44).

The number of annual calls at full capacity considers time for berthing, loading, and unberthing vessels, as well as a 70% utilization rate to account for down time. At full capacity, the proposed terminal would export 54 million metric tons, 48 million metric tons of it open storage commodities, such as coal, and six (6) million metric tons of it other dry bulk, closed storage commodities. PIT forecasts more than enough market demand for this level of throughput. "I*nitial operation of the Terminal is anticipated to occur in 2019 at full capacity*," (Reference 50).

The split between the Panamax and Capesize vessels is based on an internal business plan by PIT for total throughput. Their plan considers capacity at the proposed wharf, recent trends in vessel sizes, and a conservative approach. PIT's Alternatives Analysis reports, "*the average size of the bulk commodity fleet has grown steadily from an average of approximately 43,500 deadweight tons (dwt) in 1990, to an average of about 64,400 deadweight tons in 2012."*[3] Larger vessels offer economies of scale. With larger loads, larger vessels can achieve greater fuel efficiency, and charter rates are competitive with smaller vessels (Reference 50). However, to take a conservative approach, a greater percentage of vessel calls are allocated to the smaller Panamax vessels (65%) than to the Capesize vessels (35%). In forecasting the risks associated with vessel traffic, it is conservative to forecast more vessel traffic.

Vessel Traffic and Risk Assessment Study

This Vessel Traffic and Risk Assessment Study (VTARAS) was conducted by Glosten on the proposed GPT, a multi-modal dry bulk commodities terminal. The purpose of the study is to assess potential risks posed by new traffic that the proposed terminal would bring to the northern part of Puget Sound. This new traffic falls into three main categories:

1) GPT-calling bulkers.
2) GPT-calling assist tugs.
3) Tugs and tank barges which support bunkering GPT vessels.

Existing and forecasted traffic levels are considered for the study area (Figure ES-2), which includes the designated Puget Sound vessel transit lanes in the Strait of Juan de Fuca, Rosario Strait, Boundary Pass, and Haro Strait, the maneuvering area near the proposed GPT at Cherry Point, the local anchorage areas, and the transit routes for tugs assisting GPT traffic. Figure ES- 3 shows the location and vicinity of the proposed terminal. This study addresses the following questions:

- What will be the demands on anchorages, bunkering volumes, ballast water management, vessel traffic management, and pilots in the study area?

[3] Institute of Shipping Economics and Logistics, Shipping Statistics and Market Review (2012).

- What is the incremental impact of the proposed GPT and of the proposed cumulative projects upon potential incidents and spills from marine traffic?
- What are some of the impacts of the GPT upon the Lummi Nations' fishing and cultural resources?

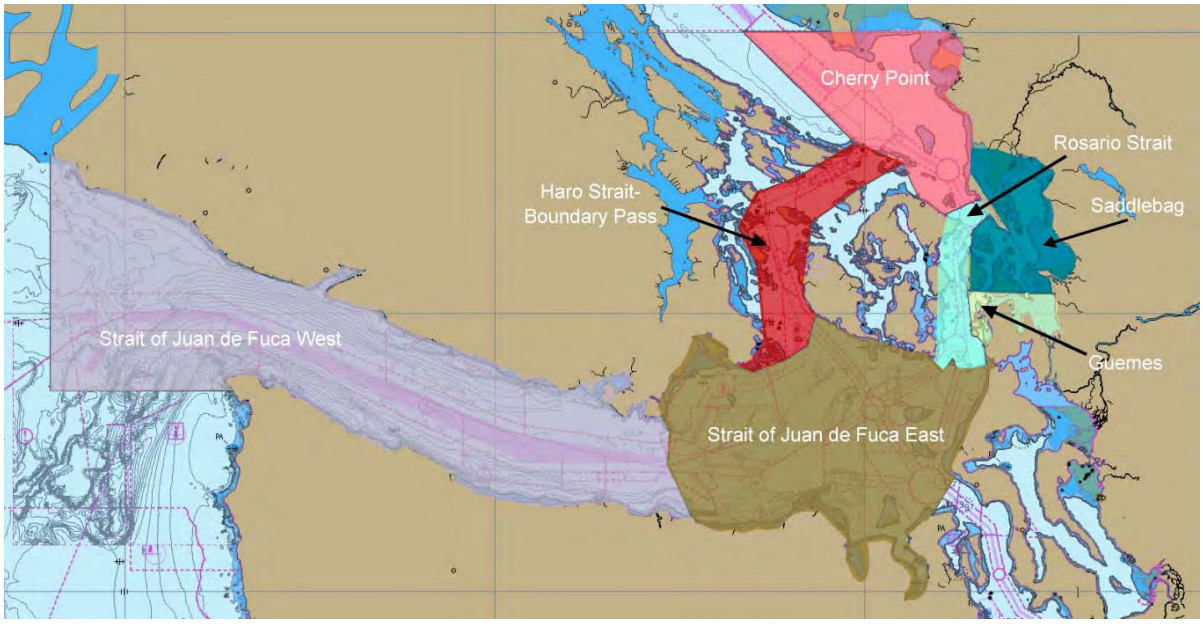

Figure ES-2 Project study area showing subareas (locations)

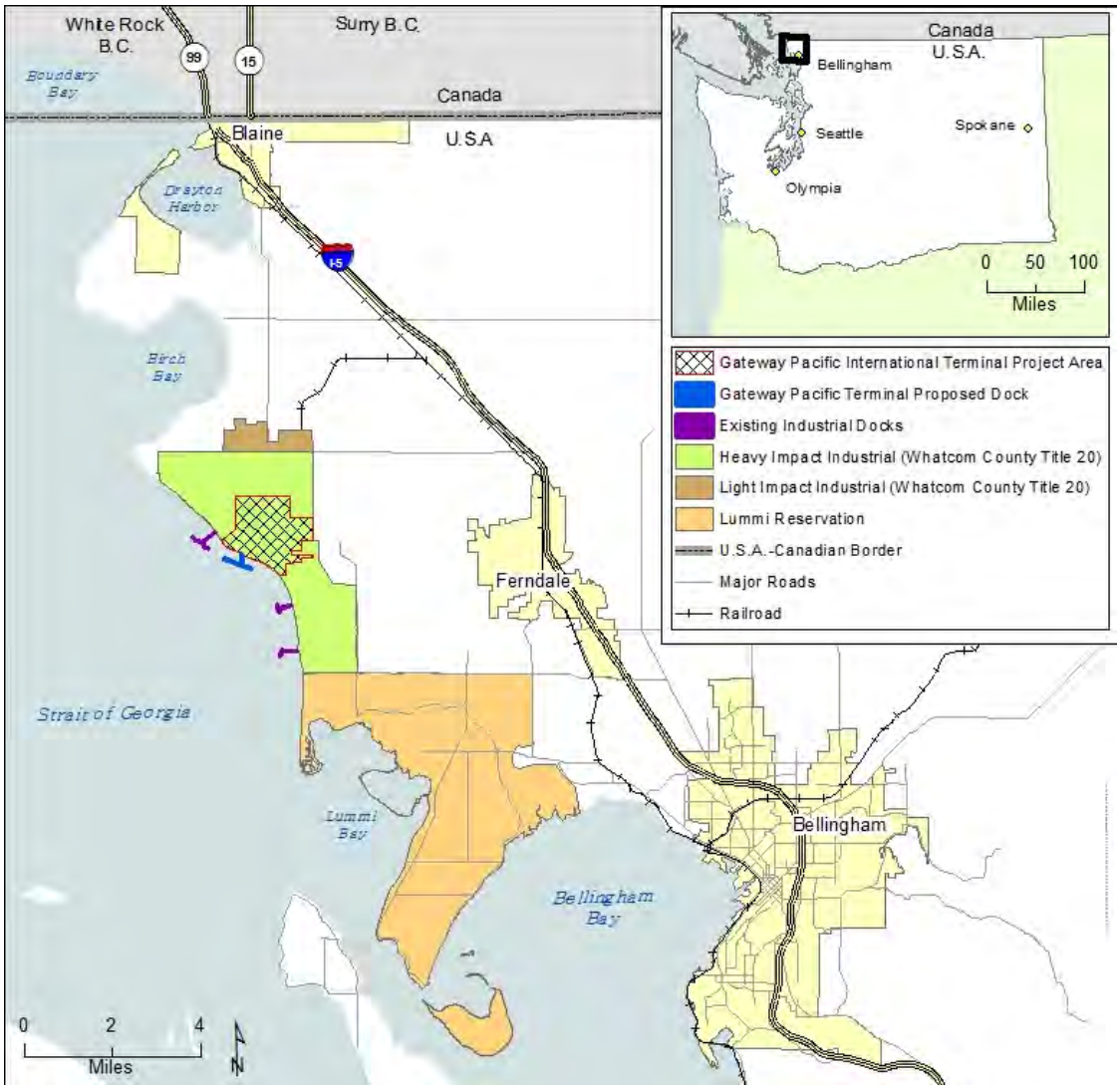

Figure ES- 3 Location of the proposed GPT, Reference 94

Note: Docks not shown to scale.

The final VTARAS report achieves compliance with the requirements of the settlement agreement, and it is expected that it will be used in preparation of an Environmental Impact Statement (EIS) by the third party contractor, CH2M Hill, for the proposed GPT project under the National Environmental Policy Act (NEPA) and State Environmental Policy Act (SEPA).

Peer Review Plan

A Peer Review Plan was developed with members of the GPT VTARAS Work Group concurrently with beginning this study. The GPT VTARAS Work Group was comprised of representatives from the Washington Department of Ecology, Pacific International Terminals, and the Lummi Nation. The peer review plan was developed to solicit feedback and obtain consensus from the GPT VTARAS Work Group. Glosten followed the peer review plan to receive comments on interim working documents and to then incorporate feedback into revisions. All interim working documents went through this peer review process with the GPT VTARAS Work Group.

Drafts of interim working documents were distributed to all members of the GPT VTARAS Work Group for review. Comments were then collected from each GPT VTARAS Work Group representatives, and consolidated. The GPT VTARAS Work Group convened four times – three times preceding a draft final and once preceding this final report. At these meetings, the GPT VTARAS Work Group members' comments were each reviewed within the context of the interim working document. Discussions were held to clarify issues, and generally consensus among the GPT VTARAS Work Group was reached. Comments were then included, excluded, or determined to require additional analysis. All comments from the GPT VTARAS Work Group have been addressed within this final report.

Report Organization

This Executive Summary reviews the study's scope, approach, and findings. Following a brief report Introduction and Peer Review Plan, the rest of the report is organized into three sections:

- Section 2, Vessel Traffic Infrastructure and Operations, which reviews the existing and expected traffic in the study area, with respect to traffic management, routing, anchorages, bunker demand, and ballast water discharge.
- Section 3, Vessel Traffic Analysis, which quantitatively analyzes the forecast traffic and risk statistics.
- Section 4, Select Vessel Traffic Impacts to the Lummi Nation, which assesses select GPT impacts through ballast water discharge volume, wake energy arriving at the shoreline, disruption to fishing activities, and collision risk with fishing vessels.

Additionally, a glossary of terms and acronyms is provided at the beginning, and the report closes with an exploration of potential risk mitigation measures.

Seven appendices provide additional data sources and analysis. The comprehensive vessel traffic study by Northern Economics, Inc. is contained in Appendix A Analysis Format and Vessel Traffic Data. Appendix B Small Vessel Memo addresses tugs (other than tugs with tank barges), commercial fishing vessels less than 60 feet in length, and recreational vessels. Appendices C, D, and E by Environmental Research Consulting, Inc. provides background data and input to the incident probability statistics and outflow model. Assembly of Questions for Lummi Fishers and Puget Sound Pilot Section – Questions for Pilots are Appendices F and G.

Approach

The bulk of this report is the quantitative, statistical analysis of three forecast vessel traffic cases:

- Case A – 2019 Baseline Vessel Traffic;
- Case B – 2019 Baseline traffic plus vessel traffic attributable to the GPT operating at full capacity in that year;
- Case C – 2019 Baseline plus GPT plus vessel traffic from other projects expected in the study area after 2019.

Representative risk statistics are calculated for each case for the purpose of finding the incremental, relative change between cases (Figure ES-4). The potential change in risk with the proposed GPT project is estimated by the change from Case A to Case B. The incremental impact of both the proposed GPT and other projects is estimated by the change from Case A to Case C.

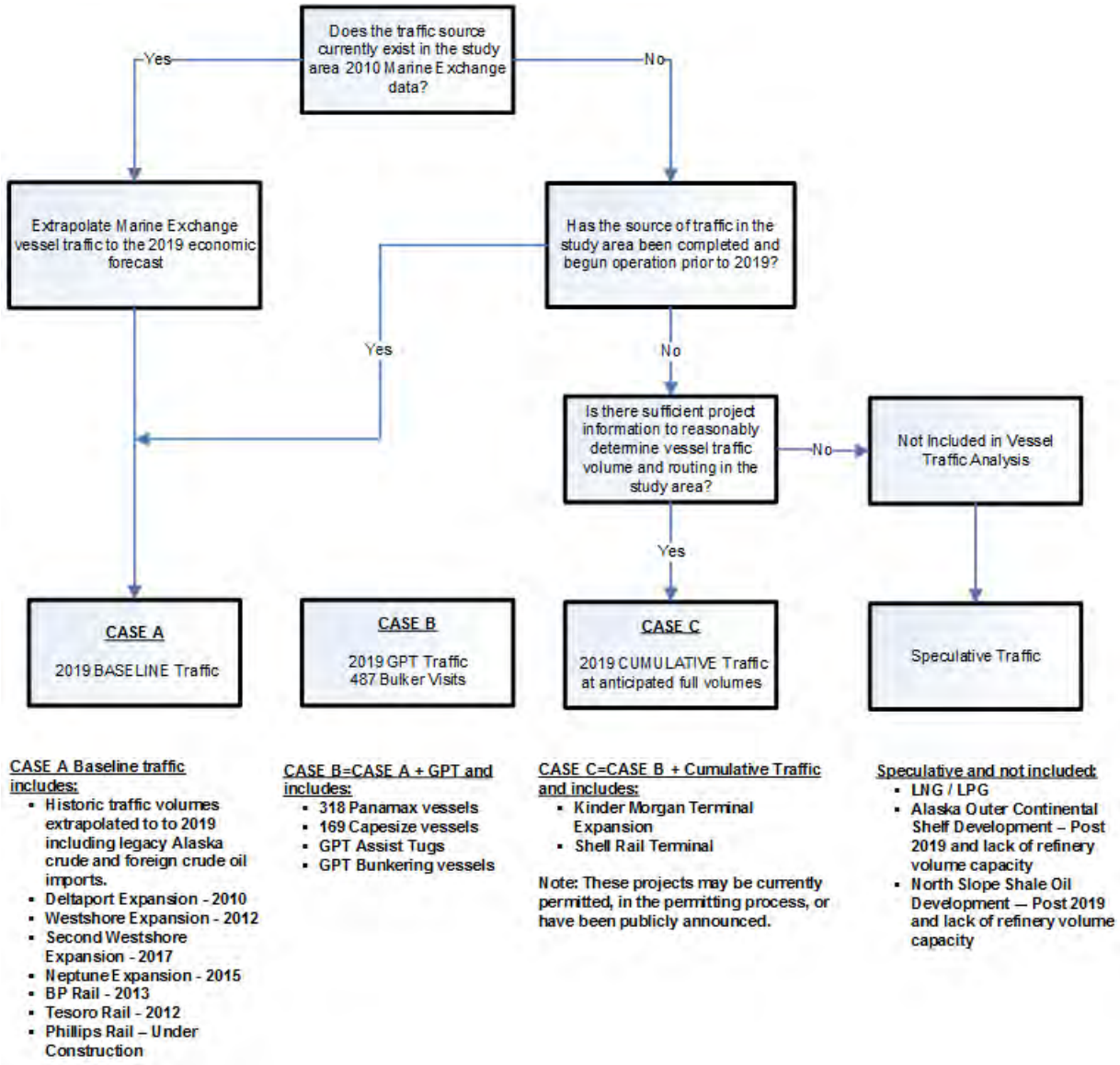

Figure ES-4 Logic flow to differentiate forecast cases

The approach used by Glosten to perform the analysis of the additional vessel traffic brought to the study area for the proposed GPT included:

- Procure, compare, check, and compile historical and current data for traffic volumes and routes and for incidents and spills to assemble a more complete, project-specific dataset from the assorted, available data sources.
- Establish a baseline of existing vessel traffic. Existing vessel traffic includes numbers of vessels, types and sizes of vessels, and typical vessel routing. Reasonable attempts

were made to identify vessels not included in the available vessel tracking data, and to confer with vessel owners/operators to estimate their vessel traffic and routes.

- Perform interviews with Puget Sound and Canadian Pilots to verify conclusions and assumptions regarding vessel traffic data.
- Submit questionnaires to the Lummi Nation to obtain information on the Lummi fishing fleet, fishing practices, and cultural resources.
- Forecast traffic volumes based on an underlying economic forecast of commodity throughput.
- Identify all reasonable future traffic sources, volumes and routing of vessel traffic based upon existing and proposed initiatives.
- Statistically analyze incident rates in the study area.
- Perform a statistical Monte-Carlo analysis to predict probability distributions for a potential range of the number of oil and bulk spills and spill volumes attributable to GPT vessel traffic in the study area.
- Compare predictions to historical data and to prior model predictions. Check that a change in output can be attributed to a change in input or in the calculation method. Check that outputs make sense given historical precedent.

Throughout the study, the GPT VTARAS Work Group used a conservative approach when processing data, making assumptions, and formulating calculations. A conservative approach is taken because of limited historical data and the inherent uncertainty in forecasting.

In the context of this study conservative means considering the worst possible circumstances or outcome of a given situation, and then basing our analysis upon it, and using it in our calculations.

Some examples of this conservative approach include:

- Despite no incidents during the 16-year historical baseline, we assumed an incident would happen in year 17.
- We predict cargo oil outflow from all tankers, not just oil tankers. By including liquid and chemical tankers, potential cargo oil outflow may be overestimated.
- In determining the energy of vessel wake reaching the shore, the study used a tug transiting at 14 knots, one-quarter mile offshore as the baseline. A slower tug, a bulker, or a further distance to shore would produce less wake energy arriving at the shoreline.

A result of the conservative approach used is that the study results may reflect higher potential risk than may actually occur because of the compounding effect of the conservative assumptions. While the study assesses a set of discrete, known risks, there is the additional potential for unknown risks. Unknown risks may be inconsequential or of great consequence; by definition, no unknown risk is included in this study.

Vessel Traffic Infrastructure and Operations

The Vessel Traffic Infrastructure and Operations section of the Vessel Traffic and Risk Assessment Study focuses on the operational parameters of GPT-calling vessels, for both existing and projected operations at full capacity in 2019. Study area routes, landmarks, and other operational considerations are presented. Vessel traffic management is discussed, including a list of vessel traffic management alternatives developed by Glosten and ranked by potential effectiveness. These alternatives were developed separately and are presented separately from the Risk Reduction Options discussed later in this Executive Summary. Additionally, the Vessel Traffic Infrastructure and Operations section uses a blend of qualitative and quantitative analysis to address anchorage capacity and usage, additional bunkering demand of GPT-calling vessels and assist tugboats, and ballast water management for GPT-calling vessels.

Alternative Vessel Traffic Management Schemes

This sub-section discusses alternative vessel traffic management schemes and ranks them in terms of their potential effectiveness. For the purposes of this section, effectiveness is defined as the inferred likelihood that a particular scheme could prevent a collision, allision, or grounding of any vessel traffic in the study area. Cost was not a consideration. This list and evaluation of effectiveness is purely qualitative, based on Glosten's own expertise, and is not intended to imply that systems currently in place for vessel traffic management are somehow deficient or ineffective. This list is offered for potential future discussion and consideration. The alternative management schemes are ranked as follows:

1. Mandatory Tug Escort
2. Voluntary Speed Reduction
3. Standby Rescue/Response Tugs
4. Area Transit Plans
5. Complements to the Existing Traffic Separation Scheme
6. Supplemental Aids to Navigation

Anchorage Capacity, Usage, and Demand

This section reviews existing USCG managed locations for vessels to anchor in the study area, compares their utilization, and then analyzes whether the existing anchorage areas have adequate capacity for GPT-calling traffic at anticipated levels. Anchorage data are published in the Puget Sound Harbor Safety Plan (Reference 102). The 28 anchorages in Puget Sound have never been filled to full capacity (Reference 66). The five primary anchorage areas used by shipping in the study area are located at Cherry Point, Bellingham Bay, Vendovi Island (East and South), Anacortes (West, Central, and East), and Port Angeles. Within the five study area anchorage areas, 20 vessels can be accommodated, Table ES- 1.

Table ES- 1 Anchorages in North Puget Sound, Reference 102

General Anchorages	Abbreviation	Number of Vessels / Anchorage Spaces	Maximum Stay	Radius*
Designated Anchorages				
Cherry Point	CP	1	30 Days	1,620 yds.
Bellingham Bay	BB	6	30 Days	2,000 yds.
Anacortes West	ANW	1	6 Days	600 yds.
Anacortes Central	ANC	1	10 Days	600 yds.
Anacortes East	ANW	1	10 Days	600 yds.
Non-Designated Anchorages				
Vendovi Island East	VIE	4	10 Days	1,660 yds.
Vendovi Island South	VIS	1	10 Days	648 yds.
Port Angeles Harbor	PA	5	10 Days	506 yds.

*Bellingham Bay anchorage is defined in 33 CFR §110.230 - 2(i). Port Angles anchorage is defined in 33 CFR §110.230 – 14. All anchorages are then divided into swing radii to fit the defined number of ships in the Harbor Safety Plan for each anchorage.

Within the five study area anchorage areas, there are 17 anchorage spaces available that could be used by GPT-calling vessels. Three anchorage spaces at the Bellingham Bay anchorage are subtracted from the 20 total anchorage spaces available, under the assumption that they are incompatible with GPT-calling vessels due to a combination of relatively shallow depth, poor holding ground, and exposure. This assumption is incorporated into the vessel traffic model. The Cherry Point anchorage space is included in the 17 anchorage spaces available, but it is only available for 274 days of the year due to adverse weather conditions in winter. After accounting for the subtracted anchorage spaces at Bellingham Bay and seasonal availability in Cherry Point, the 17 anchorage spaces have a capacity of 6,114 vessel days per year.

Past anchorage usage is compared to a capacity of 6,114 vessel days per year. The maximum utilization during the 2006-2010 was in 2007 with 1,444 vessel days, or 23.6% utilization. On average (2006-2010), there was 79.6% remaining availability. The daily average was 13.4 available anchorage spaces, and the forecasted daily average number of anchorage spaces available is also 13.4, assuming an even annual distribution of anchorage usage throughout the year. In practice, anchorage availability varies day to day.

The demand for anchorage from GPT vessels was estimated with a queuing analysis. GPT-calling bulkers are predicted to queue at-anchor while waiting for an available berth. Average wait time was 1.5 days per call. The probability that the number of vessels in the queue will exceed the number of available anchorage spaces (13) is less than 1%. This means that anchorage capacity may be fully utilized for about 3 days of the year. Therefore, the available anchorages are presumed to be adequate to meet the demand from GPT-calling bulkers for the majority of the time. The queuing analysis and USCG feedback both suggest that existing anchorages have sufficient capacity to accommodate increased traffic due to the proposed GPT project.

This queueing model is based on annual averages and does not take into account real-time operational management, which would reduce queuing time. Pilots, vessel agents, and the terminal are regularly in communication. This communication helps facilitate just-in-time

arrivals at the berth. This means that both the cargo and the vessel arrive on schedule, so that neither is waiting for the other. For exports, the cargo is ready to be loaded onto the vessel and the berth is available when the vessel arrives. If a vessel has enough advance notice from the destination terminal that there is a delay, then the vessel may potentially reduce its speed earlier in the journey, before entering the study area, to manage arrival time and reduce cost and risk. There are costs associated with storing cargo at the terminal and with a vessel going to anchor. While at anchor, dragging anchor and other incidents are a risk. The cargo owner, terminal, and vessel are all incentivized to keep on schedule. In practice, delays occur. Even so, these operational practices could result in less queuing time than is predicted by the queuing model.

Bunker Demand

Additional vessel traffic of GPT-calling vessels will consume fuel oil. Fuel market trends indicate that GPT bulkers will meet at least part of this additional demand in the Pacific Northwest. Port Angeles is historically the most active bunkering site of the existing anchorage areas at Anacortes, Bellingham, Everett, Ferndale (Cherry Point), and Port Angeles. Due to variability and uncertainty in consumption rates and future bunkering locations, the projected increase in bunkering demand is given in a range. For the purposes of this study, we have assumed that between 50% and 100% of GPT–calling bulkers will bunker within the study area. This is a conservative estimate as non-GPT deep draft vessels calling in Puget Sound do not historically bunker at the high end of this range, nor do vessels transiting the study area and calling at Canadian ports (Reference 40). GPT-calling bulkers and assist tugs are forecast to bunker between 2,185,000 and 4,337,000 bbls within the study area per year that the terminal operates at full capacity, 487 vessel calls. Over the volume bunkered in 2011, this forecasted volume represents an increase of 122% to 243%.

Ballast Water Discharge

The primary risk of ballast water discharges to the environment is the introduction of non-indigenous species and pathogens. These risks can be reduced by decreasing the discharge frequency, the total quantity of viable organisms discharged, and the concentration density of viable organisms. However, there is a lack of data that can quantify the reduction in invasion risk due to control of these factors. In light of this lack of data, this study only projects the quantity of discharged ballast water and the standard to which that ballast water is required to be managed. GPT-calling bulkers are forecast to discharge 13,861,800 m^3 (3,661,410,000 gallons) of ballast water in 2019.

The 2019 GPT-calling bulkers nearly triple the volumes of ballast water discharged within the study area compared to 2013 volumes. Discharge from GPT-calling bulkers will occur almost exclusively within the Cherry Point subarea. Assuming they are adequately and reliably enforced, existing and evolving ballast water regulations are expected to mitigate the impact of the ballast water discharged at GPT. Existing vessels of high ballast water capacity, such as bulk carriers calling at GPT, will require refitting with ballast water treatment systems at their first drydocking after 1 January 2016. Assuming a five-year drydocking schedule, this fleet would complete its refitting by 31 December 2020.

Vessel Traffic Analysis

The Vessel Traffic Analysis section of the Vessel Traffic and Risk Assessment Study focuses on the potential change in risk with the proposed GPT upon potential incidents and spills from all marine traffic in the study subarea. This section comprises the bulk of the report and contains the quantitative, statistical analysis of the three forecast vessel traffic cases.

Vessel Traffic Analysis Statistical Approach

The objective of the Vessel Traffic Analysis Statistical Approach is to characterize the expected incremental number of potential incidents, the number of potential spills, and the combined volumes of dry bulk cargo, liquid cargo, or vessel fuel spilled in the study area. The predictions in this section are based on historical data from Puget Sound. Within the study area over a 16-year baseline, there were eight (8) collision, allision, or grounding incidents from deep draft vessels. Of the eight incidents, there was one spill; the spill volume recorded was one gallon. Due to the scarcity of events in Puget Sound, supplemental national and international data were also used to estimate outflow volumes in the event of a spill. The calculated risk prediction parameters for 2019 are shown in Table ES-2[4].

Table ES-2 Calculated risk prediction parameters

Risk Prediction Parameter	Analysis Performed
Annual vessel traffic days (24 hours of time in the study area)	By vessel type, activity, and geographic subarea
Incident Rates	By vessel type, activity, incident type, and geographic subarea
Probability of a spill when an incident occurs	By vessel type and incident type
Annual number of potential incidents	Total for study area By vessel type, activity, incident type, and geographic subarea
Annual number of potential spills	Total for study area By vessel type, activity, incident type, and geographic subarea
Annual volume of potential oil outflow	Total for study area By subarea, by vessel type, and incident type
Annual volume of potential bulk cargo outflow	Total for study area By subarea and incident type

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 input parameters. The simulation is repeated 10,000 times, each time randomly selecting inputs

[4] Risk is commonly defined as a combination of probability and consequence. The first five risk prediction parameters of Table ES-2 are a measure of probability. Analysis of these parameters gives an annual frequency or likelihood for certain events: traffic, incidents, and spills. Incidents and spills may also be interpreted as a consequence. Outflow volumes are a measure of consequence.

from the underlying input parameters. This generates 10,000 predictions. These predictions can then be sorted to determine a range and probability distribution for possible outcomes. Thus, instead of predicting singular incident, spill, and outflow values for the required comparisons, a probability distribution is calculated for each of these three risk parameters.

Predicted probability distributions are compared using representative statistics from the distribution. The statistics of the distributions are a measure of the probability of the predicted values and ranges of values. They are not a prediction of the statistics of what will occur in the forecast year. Each prediction has equal certainty. The reported distribution statistics are to be interpreted as a measure of risk. The selected statistics to characterize incremental risk are:

- The average (or "mean").
- The 50th percentile.
- The 95th percentile.

The average is simply the mean, or statistical average, of the 10,000 predictions. When all 10,000 predictions are sorted from smallest to largest, the 50th percentile, or median, is the 5,000th prediction. Half of the predictions are larger than the median, and half are smaller. Similarly, the 95th percentile is the 9,500th prediction out of 10,000. Only 5% of the predictions were larger, while 95% were the same size or smaller than the 95th percentile. In other words, should any one prediction be sampled at random, there is a 95% likelihood, or a 95% chance, that the sampled value is the same size or smaller than the 95th percentile. To compare the prediction for the number of potential incidents or for the number of potential spill between analysis cases, an appropriate statistic is the average. With respect to volume of outflow, it is appropriate to compare the median or some other percentile value (e.g., 95th), rather than the average. The next subsection discusses why different statistics are used to represent different risk parameters in this VTARAS report.

Comparison of Risk Statistics:

The number of potential incidents and number of potential spills are integer numbers; i.e., there cannot be a fraction of an incident or a fractional number of spills. The average of 10,000 integers may not be an integer. For example, consider the case of 10,000 predictions, where three (3) incidents were predicted 2,500 times, and zero (0) incidents were predicted 7,500 times. The median of these 10,000 predictions is zero. The average of these 10,000 predictions, however, is 0.0003 incidents. 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.

Conversely, oil outflow is best compared using the median (50th percentile) and 95th percentile, but *not* the average. The problem with averages when comparing oil outflow is that rare, extreme events can significantly skew the result and make it misleading.[5] Consider the example where each year for 9 years, there are 100 gallons of oil outflow. Then, in the 10th year, a ship breaks up and spills 33 million gallons of oil. The average of the 10-year sample is 3.3 million gallons/year, whereas the median is 100 gallons and better reflects what

[5] Number of potential incidents and spills are resistant to the problem of skewed averages because they are not susceptible to maximum values that are orders of magnitude greater than their median values.

happened most (9 out of 10) years. Similarly, the 95th percentile oil outflow indicates an extreme scenario; in this example, the 95th percentile is 16.5 million gallons. The average is a poor indicator of both the "typical" year and the "extreme" year. For this reason, both the 50th and 95th percentiles are given for outflow volumes in place of the average.

It follows that care must be taken when choosing the statistics for measuring risk. The median (50th percentile) and 95th percentile are presented to highlight two scenarios ("typical" and "extreme") that are meant to give the reader a general understanding of risk. However, depending on how the data will be used, median and 95th percentile may not be the most appropriate percentiles. For this reason, the probability distributions for major results (e.g. predicted number of incidents)[6] are also presented graphically, allowing the reader to determine the incremental risk at *any* percentile.[7] This underscores the power of the probability distribution: every probability percentile is presented in a single illustration.

Analysis Cases

Potential risks posed by new traffic associated with the proposed terminal are studied by forecasting and comparing three vessel traffic cases (Figure ES-5). Firstly, traffic existing during and prior to 2010 was forecast to 2019. Secondly, additional sources of vessel traffic were identified. These additional sources of vessel traffic in 2019 were classified as either baseline or cumulative. Identified sources and the classification logic are captured in the flowchart, Figure ES-4. Representative risk statistics from cumulative probability distributions were generated for each case.

Case A (Baseline)	Case B (GPT)	Case C (Cumulative)
• Existing vessel traffic forecast to 2019 • Additional traffic from port expansions or new ports completed since 2010 or currently under construction and completed by 2019	• Case A traffic • Gateway Pacific Terminal vessel traffic	• Case B traffic • Projects expected to take place in the study area in the near future

Figure ES-5 Forecast analysis and traffic components

Analysis Scenarios

Total potential contaminant (oil and bulk cargo) outflow for a given year was determined by summing all the individual spills that occur in that year. Determination of the quantity and volume of individual spills was accomplished by breaking the system into scenarios that represented each potential occurrence of oil and bulk outflow, and sampling each scenario to

[6] Highly specific results, such as predicted spill volume by incident type and subarea, are presented in tabular format only.

[7] It is suggested that when investigating rare results (e.g. the 95th percentile), 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.

determine if that scenario results in any spills of oil cargo, dry bulk cargo, bunker fuel, or some combination thereof. Scenarios are defined by six (6) vessel types, four (4) activity types, six (6) incident types, and seven (7) locations. Tugs pushing tank barges are included within the tug vessel type. The project scenarios taxonomy is summarized in Table ES-3 and yields 1,008 scenarios for each traffic volume case (6 vessel types x 4 activity types x 6 incident types x 7 locations = 1,008).

Table ES-3 Project scenario parameters

Vessel Type	Activity Type	Incident Type	Location
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. Cargo Transfer Error	4. Haro Strait and Boundary Pass
5. Tug		5. Bunker Error	5. Cherry Point
6. Passenger or Fishing Vessel		6. Other Non-Impact	6. Saddlebag
			7. Guemes Channel and Fidalgo Bay

Total vessel time in the study area is captured by including four activity types. Twenty-four hours spent in the study area in one of the activity types is counted as a "vessel-traffic day." These twenty-four hours are not necessarily continuous hours by one vessel. Multiple vessels of a particular vessel type spending any length of time in a particular activity within a single subarea all contribute to the vessel traffic days by that particular vessel type, activity type, and location. In this report, traffic is defined in units of "vessel traffic day," and vessel traffic days are further defined with respect to vessel type, activity type, and location. Annual average vessel traffic days from 1995-2010 by subarea and vessel type, for all activity types, are shown in Table ES-4.

Table ES-4 Average annual vessel traffic days by subarea and vessel type, for all activity types, 1995–2010

Vessel Type	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tankers	277	838	20	583	316	74	613	2,723
Bulkers	760	416	211	58	22	3	204	1,674
Cargo Ships	642	404	126	17	160	3	107	1,459
Tank Barges	88	295	29	383	99	62	409	1,364
Tugs	362	1,045	119	912	432	376	1,152	4,398
Passenger & Fishing	428	1,194	303	2,977	3,297	36	323	8,558
Total	2,556	4,193	808	4,930	4,326	555	2,808	20,175

Note: Data from 1995-2005 are historical estimates.

Traffic Forecast

A traffic analysis and forecast was performed in order to understand existing traffic, the change in traffic from other terminal developments, and the traffic associated with the proposed GPT. To paint a comprehensive picture of future traffic volumes, volumes of study area vessel traffic in 2019 were forecast for different traffic cases. This traffic analysis and forecast was critical to the VTARAS because the number of vessel traffic days is the only input that varies between the three forecast cases in Figure ES-5. All other inputs and algorithms are the same between the three forecast cases.

Table ES-5 Analysis cases' annual average vessel traffic days by analysis case and subarea, for all vessel types and activity types

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Case A	2,692	4,079	877	4,025	3,218	550	2,796	18,237
Case B	3,004	5,184	889	4,165	3,420	666	3,715	21,043
Case C	3,154	5,360	1,038	4,127	3,413	662	3,845	21,599

Vessel traffic days by subarea are given for the three analysis cases in Table ES-5 and Figure ES-6, for all vessel types and activity types: underway, maneuvering, at dock, and at anchor. The Strait of Juan de Fuca East, Guemes Channel, Saddlebag, and Cherry Point subareas include anchorages. The Case C traffic will add 566 total vessel traffic days or 2.6% over the Case B traffic in 2019. Case C adds 348 tanker vessel calls to the Kinder Morgan terminal at Port Metro Vancouver. These vessels only transit through the study area, adding vessel traffic

days underway through the Strait of Juan de Fuca, Haro-Strait, Boundary Pass, and the Cherry Point subarea. GPT-based vessel traffic will add 2,805 vessel traffic days or 15% over the baseline forecast vessel traffic in 2019. The GPT-based vessel numbers include GPT bulkers, assist tugboats, and vessels to support the projected increase in bunkering. Vessel traffic days added by these vessel types and by subarea are given and compared to the baseline vessel traffic days in Table ES-6. The greatest increase in traffic is in the Cherry Point subarea where the proposed GPT project would be located (33%).

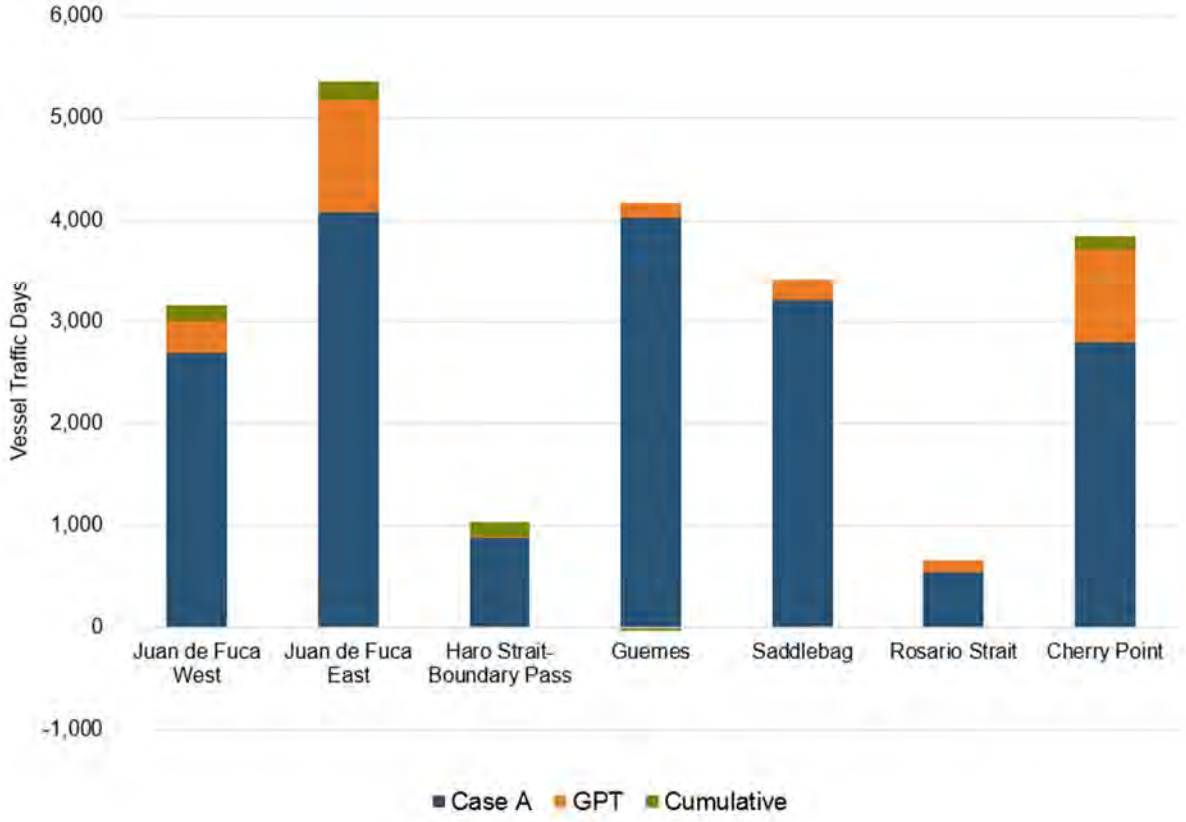

Figure ES-6 Analysis cases' vessel traffic days by analysis case and subarea, for all vessel types and activity types, 2019

Note: Case B = Case A + GPT
Case C = Case A + GPT + Cumulative
Activity types are underway, maneuvering, at dock, and at anchor.

Table ES-6 Baseline and GPT vessel traffic days by subarea, for all activity types, 2019

		Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Case A	Total	2,692	4,079	877	4,025	3,218	550	2,796	18,237
GPT	Tank Barge	0	83	0	62	0	7	0	152
	Bulker	312	898	12	8	101	76	681	2,089
	Tug	0	123	0	70	101	33	238	565
	Total GPT	312	1,105	12	140	203	116	919	2,805
Change with GPT		12%	27%	1%	3%	6%	21%	33%	15%

Risk Forecast

Vessel traffic days are input to a Monte Carlo Analysis to predict a range and probability distribution for:

(1) Annual number of potential incidents.

(2) Annual number of potential spills.

(3) Annual potential oil outflow.

(4) Annual potential dry bulk outflow.

Total annual potential spills throughout the system for each traffic case are output as cumulative distribution functions, Figure ES-7. Average predictions are also reported for annual number of potential incidents and average number of potential spills. For the cumulative traffic case (Case C), the simulation predicts that there is a 95% likelihood that the number of total annual potential spills will be less than or equal to 21. It predicts that there is a 50% likelihood that the number of total annual potential spills will be less than or equal to 14. The average predicted number of total annual potential spills is 13.93. In Case A, the average predicted annual number of spills is 10.62, and in Case B, the average predicted annual number of spills is 13.37. The difference of 2.75 spills is a 26% increase, attributable to the additional GPT traffic. The subarea with the greatest increase in average predicted annual number of spills is Strait of Juan de Fuca East, which increases by 1.37 spills (60%). Increases in each subarea are given in Table ES-7. A majority of the 2.75 additional spills due to GPT are spills due to other non-impact incidents, which increase by 1.86 (33%). In terms of percentage increase, the greatest increase in spills is due to collisions, which increase by 0.33 spills (175%). Increases due to each incident type are given in Table ES-8.

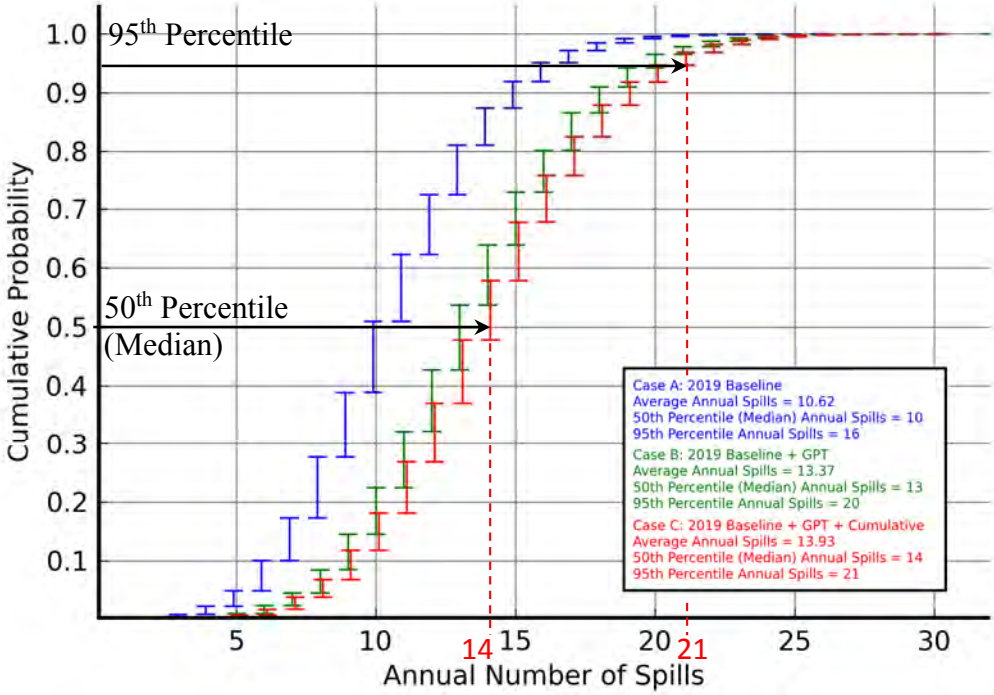

Figure ES-7 **Cumulative distribution function of total annual number of potential spills for all incident types in all subareas. Annual number of potential spills for Cases A and C offset by +/- 0.1 for visual purposes only. Averages presented in legend for comparison**

Table ES-7 Average annual number of potential spills per subarea for all incident types

	Case A	Case B	Case C	Incremental Change	
Subarea	**Baseline**	**Baseline +GPT**	**Baseline +GPT +Cumulative**	**(B - A) / A**	**(C - A) / A**
Strait of Juan de Fuca West	0.97	1.03	1.23	6%	27%
Strait of Juan de Fuca East	2.27	3.64	3.75	60%	65%
Haro Strait and Boundary Pass	0.17	0.17	0.20	0%	18%
Guemes Channel and Fidalgo Bay	2.70	2.84	2.84	5%	5%
Saddlebag	1.50	1.68	1.67	12%	11%
Rosario Strait	0.10	0.10	0.10	0%	0%
Cherry Point	2.92	3.91	4.14	34%	42%
All Subareas	10.62	13.37	13.93	26%	31%

Table ES-8 Average annual number of potential spills per incident type for all subareas

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change (B - A)/A	(C - A)/A
Collision	0.19	0.52	0.55	175%	188%
Grounding	0.13	0.22	0.23	76%	85%
Allision	0.23	0.56	0.56	147%	148%
Transfer Error	1.56	1.64	1.63	5%	5%
Bunker Error	2.91	2.95	2.92	2%	0%
Other Non-Impact	5.61	7.47	8.04	33%	43%
All Incident Types	10.62	13.37	13.93	26%	31%

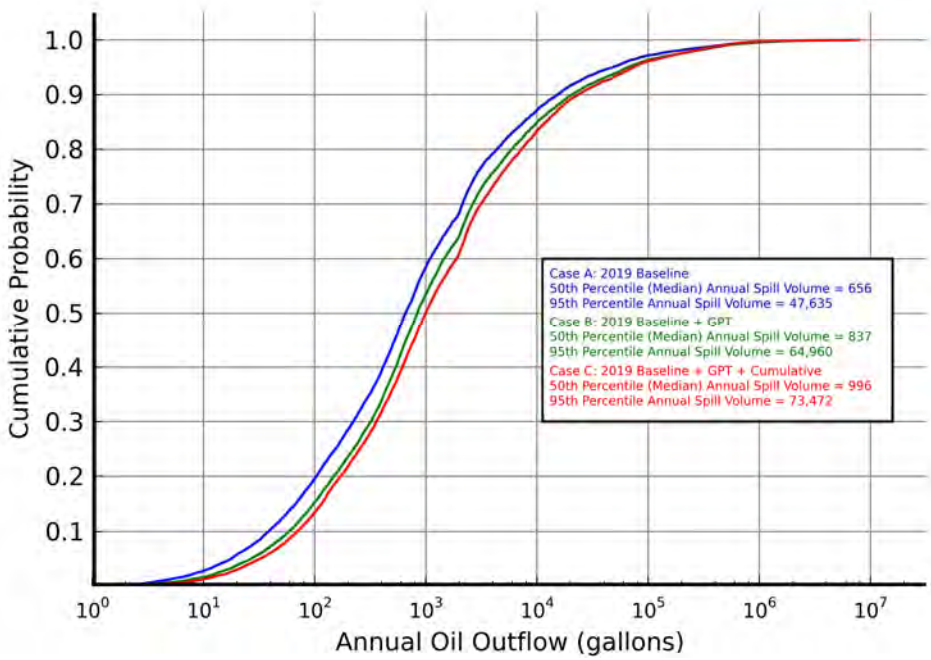

Figure ES-8 Predicted cumulative distribution function of total annual volume of potential oil outflow for all subareas

Total annual potential oil outflow throughout the system for each traffic case are output as cumulative distribution functions, Figure ES-**8**. The simulation results predict that in Case A, the median potential oil outflow is 656 gallons, and in Case B, the median potential oil outflow is 837 gallons. The difference of 181 gallons is a 28% increase, attributable to the additional traffic from GPT. The addition of cumulative traffic in Case C further increases the median total annual potential oil outflow by another 19% to 996 gallons.

Monte Carlo analysis results confirm that the magnitude of the increase in total annual potential oil and dry bulk outflow is predicted to be proportional to the quantity and size of the vessel traffic introduced into the system by GPT, which are Panamax and Capesize bulk carriers, assist tugboats and tank barge-towing tugboats, and tank barges. The contaminant

outflow model predicts a 26% increase in the average number of potential spills and a 28% increase in the median potential oil outflow throughout the study area in 2019.

The outflow contaminant model predicts an increase in median total annual reported dry bulk cargo outflow from zero to 7,376 cubic feet with the addition of GPT. As discussed in Appendix E, dry bulk spills are rarely reported. Potential dry bulk outflow due to unreported spills and dry cargo sweeping will hypothetically result in a further increase in total annual potential dry bulk outflow proportional to the increase in the number and size of bulkers with the addition of GPT.

Select Vessel Traffic Impacts to the Lummi Nation

The section titled 'Select Vessel Traffic Impacts to the Lummi Nation' of the Vessel Traffic and Risk Assessment Study presents select additional impacts of the GPT on the Lummi Nation's fishing and cultural resources. These select impacts include: ballast water discharges and the associated risk of introducing nonnative invasive species (discussed in Section 2, Vessel Traffic Infrastructure and Operations), increased vessel wake impacts on cultural resources, interference with tribal fishing sites and fishing gear, increased risk of collision with tribal fishing vessels, and increased risk of environmental damage due to oil and cargo spills (discussed in Section 3, Vessel Traffic Analysis). It is beyond the scope of this study to address all potential effects of the proposed GPT upon the Lummi Nations fishing and cultural resources.

Lummi fishers currently spend approximately one-third of their time in the Cherry Point subarea during various fishing activities.

In 2013, the Washington State Department of Fish and Wildlife (WDFW) estimated that 6,996,112 cubic meters of ballast water were released into Puget Sound by all marine vessels. Because nearly all of the vessels currently calling on the two existing petroleum oil refineries and the aluminum smelter in the Cherry Point subarea import either crude oil or raw materials for aluminum smelting, very little of the estimated ballast water discharges for all of Puget Sound currently occurs in the Cherry Point subarea. The ballast water discharges related to GPT calling vessels are projected to be 13,900,000 cubic meters (or nearly 3.7 billion gallons) per year that the terminal operates at full capacity, 487 vessel calls. This volume projected for 2019 will nearly triple the total 2013 ballast water discharges in all of Puget Sound. Nearly all ballast water discharges from GPT calling vessels will be within the Cherry Point subarea.

Historically, untreated ballast water discharges have been implicated as a vector for introducing non-indigenous and possibly invasive species. To meet the 2013 Coast Guard regulations (Reference 129), bulk carriers calling at the proposed GPT will require refitting with ballast water treatment systems at their first dry-docking after 1 January 2016. Assuming a five-year dry docking schedule, this fleet would complete its refitting by 31 December 2020.

In the interim period, regulations require all vessels without a ballast water treatment system to perform open-ocean ballast water exchange if the vessel captain determines that the exchange can be safely performed.

Ballast water treatment systems technology and implementation is developing rapidly and current data supporting its efficacy is limited. As the ballast water treatment industry matures, more data will become available supporting the best approach for ballast water treatment.

Additional studies, beyond the scope of the VTARAS, should be undertaken, if not already being done, to assess the impact of ballast water discharges on fishing activities.

Traffic Impact on Cultural Resources

An evaluation of the wake waves of GPT-calling vessels was used to assess the impacts of increased vessel traffic on traditional cultural properties and underwater archaeology. This analysis was focused on the shoreline at locations where traditional cultural properties and underwater archaeological artifacts exist. Vessel wakes were estimated for the two types of GPT-calling vessels that will operate in the vicinity of Lummi cultural resources: bulkers and tugs.

This analysis finds that tugboat wakes have a larger wave height and more energy flux than bulker wakes. Nevertheless, tugboat wakes are considerably smaller than an annual maximum storm wave as follows:

- Height: 13% of an annual maximum storm wave.
- Energy Density: 2% of an annual maximum storm wave.
- Energy Flux: 1% of an annual maximum storm wave.

This difference between small tugboat wakes and large annual storm waves is maintained even when aggregated over an entire year. When the total wave energy from a year of waves and storms and the total wake wave energy from GPT-bound vessels were estimated, it was found that the cumulative energy from the assist tugs and GPT-calling bulkers transiting past Lummi Island is equal to 24% of the cumulative energy from wind-generated waves. Total energy seen at the shoreline would increase by 24% with the additional vessel traffic attributable to the proposed GPT operating at full capacity in 2019.

Traffic Impact on Tribal Fishing

Siting of the wharf and trestle at the proposed GPT and the potential increased anchorage use by bulkers will interfere with Lummi access to fishing sites. A comparison of Lummi fishing times and locations with expected GPT vessel transits was used to quantify the potential disruption to Lummi fishing practices posed by GPT. The goal was to measure the time and area that Lummis fish (referred to as water-day-areas), measure the time and area that passing vessels disrupt this fishing activity (also formulated in vessel-day-areas), and compare the magnitude of the disruption with and without GPT-calling vessels. In general, the unit of vessel-day-area is the product of vessel days on the water and the area occupied. The analysis predicts that GPT would increase the Lummi fishing disruption by 76% in the Cherry Point subarea and 19% in the Saddlebag subarea, compared to baseline vessel traffic in 2019. The difference in vessel-day-area in Cherry Point increases from 26 to 45 between Cases A and B. The difference in vessel-day-area in Saddlebag increases from 130 to 155 between Cases A and B. The analysis shows that the Juan de Fuca East subarea will see the greatest relative increase in disruption of 83% over Case A due to the time and area occupied by GPT vessels at anchor and associated bunkering activity. However, the actual increase in disruption to Lummi fishing cannot be quantified as the Lummi U& A does not encompass all of this subarea.

A secondary aspect of disruption is the potential loss of Lummi fishing gear due to GPT vessel traffic. In 2008, the Lummi Natural Resources Department estimated that each Lummi fisher

loses between 40 and 50 crab traps or pots each year. If gear loss changes proportionately with traffic changes, then in 2019 Baseline, fishers will expect to lose an additional three pots in either Juan de Fuca East or in Haro Strait-Boundary Pass. However, in Guemes Channel, Saddlebag, Rosario Strait, and Cherry Point—where rail projects are expected to lower the volume of vessel transits—fishers may actually see a decrease in gear loss. With the addition of GPT in 2019, gear loss per Lummi fisher is expected to increase between one and fifteen pots depending on which subarea the fisher is fishing in. The number of lost pots is predicted to increase by thirteen pots in Juan de Fuca East, one pot in Guemes Channel, nine pots in Rosario Strait, or nearly fifteen pots in Cherry Point. Impacts to gear such as long-lines and marker buoys are not included in this analysis, as historical loss volumes were unavailable. The variety of gear types and fishing practices used by the Lummi mean that the pot-loss estimate and the surface area disruption measured in this analysis does not fully capture GPT-related disruption.

Risk of Collision with Lummi Fishing Vessels

Incident records from collisions involving deep draft traffic, tugs, and fishing vessels from 1995 through 2010 (16 years) within the study area were studied in an attempt to quantify the potential likelihood of a collision between a GPT-calling vessel and a Lummi fishing vessel. Incidents were recorded by the United States Coast Guard (USCG) and/or the Washington State Department of Ecology. Only the larger of the vessels involved in a collision is usually recorded. The other vessel involved in the incident is not always recorded; however, none of the past collisions recorded were between deep draft vessels and fishing vessels.

Since there are no collision data from which to determine a collision incident rate, a conservative assumption is made that one (1) collision occurs every 17 years, or 0.1192 collisions per 10,000 vessel traffic days. At this rate, the GPT-based traffic is expected to add 0.0104 collisions in 2019, which amounts to a 16.7% increase over the baseline traffic without GPT. Consequences of a potential collision, such as cargo loss or fatality, are not studied in this assessment.

Risk Reduction Options

The VTARAS closed with an exploration of potential risk mitigation measures, termed Risk Reduction Options (RROs). The RROs were identified during a brainstorming session by a group of GPT study participants. The group considered the broader context of future risk in the study area beyond the potential risks posed by new traffic. Although the list of 49 RROs is neither prioritized nor exhaustive, it provides key points for discussion and consideration. This list is offered as a starting point for future efforts which may develop recommendations for risk mitigation. Just for illustration, the list of RROs includes:

- Near-miss reporting system.
- Vessel Traffic Management: Phase vessel arrivals.
- Manning: Add a 2nd officer on the bridge (west of Port Angeles).
- At-dock transfer: Limit other operations ongoing (e.g., bunker, internal fuel transfer).
- Offloading all untreated ballast water to onshore treatment facility.

Section 1 Introduction

1.1 Proposed Gateway Pacific Terminal

The proposed GPT is to be located at Cherry Point in Washington State, see Figure 1. The GPT would be a multi-modal dry bulk commodities terminal. The proposed terminal has three deep-water berths along a wharf connected to the shore by the trestle, see Figure 2. Berths 1 and 2 service open storage commodities, such as coal, while Berth 3 is equipped for other, covered dry bulk commodities. Figure 1 also shows the boundary of the nearby Lummi Reservation. The purpose of this study is to assess potential risks posed by new bulk carrier traffic and other associated vessel traffic that the proposed terminal would bring to the northern part of Puget Sound. Associated vessel traffic are assist tugs and tugs with tank barges. Existing and forecasted traffic levels are considered for the study area, which includes the designated Puget Sound vessel transit lanes in the Strait of Juan de Fuca, Rosario Strait and Haro Strait, the maneuvering area near the proposed GPT at Cherry Point, the local anchorage areas, and the transit routes for tugs assisting GPT traffic. The terminal operators estimate this future bulk carrier traffic at 487 total annual visits bound for GPT at full build-out. Of the total vessel calls, it is projected that there would be 318 Panamax and 169 Capesize vessels (Reference 44).

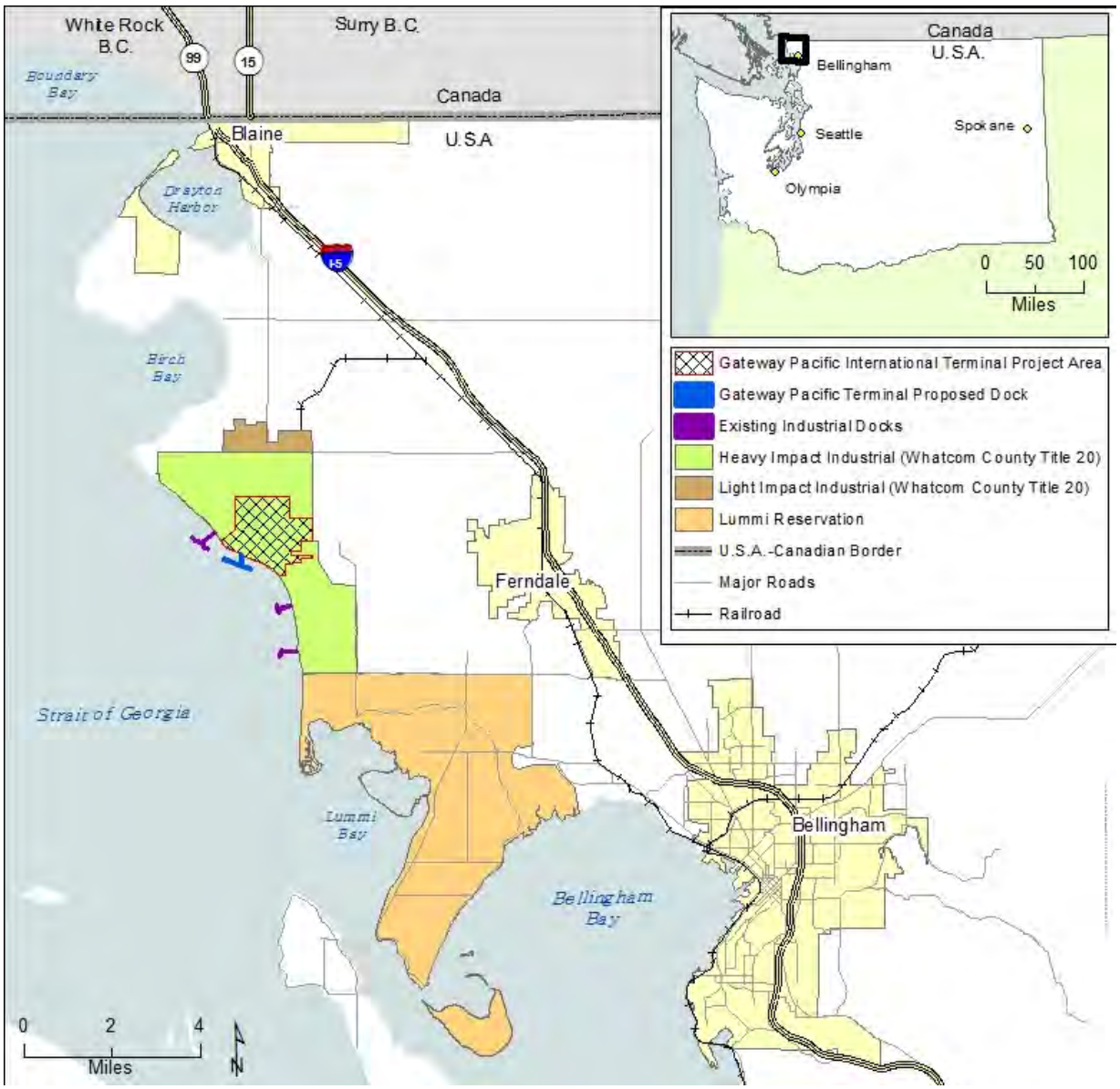

Figure 1 Location of the proposed GPT, Reference 94
Note: Docks not shown to scale

Figure 2 Proposed GPT layout, Reference 50

1.2 Scope of This Study

New traffic associated with the proposed GPT will affect the existing regional traffic. The VTARAS predicts and analyzes the risks associated with this change in traffic. These risks include potential interactions between GPT-calling vessels and another vessel, potential incidents involving a single vessel, and impacts to regional fishing activities. The VTARAS focuses on the traffic associated with the proposed GPT; it is not within the scope of the VTARAS to evaluate the general risks of any and all potential future vessel movements in the region.

Generally, the purpose of the VTARAS is to assess potential risks posed by new traffic brought by the proposed terminal to the northern part of Puget Sound. Specifically, the study addresses three questions:

(1) What will be the demands on anchorages, bunkering volumes, ballast water management, vessel traffic management, and pilots in the study area?

(2) What is the incremental impact of the proposed GPT and of the anticipated cumulative[8] projects on potential incidents and spills from marine traffic?

(3) What are some of the impacts of the proposed GPT on the Lummi Nation's fishing and cultural resources?

The new traffic investigated by the VTARAS falls into three categories: GPT-calling bulkers, GPT-calling assist tugs, and tugs and tank barges supporting GPT vessel bunkering. The main approach of the VTARAS is the quantitative and statistical analysis of three forecast vessel traffic volumes:

- Case A – 2019 Baseline Vessel Traffic.
- Case B – 2019 Baseline traffic plus vessel traffic attributable to the operation of GPT at full capacity.
- Case C – 2019 Baseline traffic plus GPT plus vessel traffic from cumulative projects expected in the study area after 2019.

Representative risk statistics are calculated for the purpose of finding the incremental, relative change from Case A to Case B and Case C.

Geographically, the study focuses on the vessel transit lanes and local maneuvering area associated with the proposed GPT. Vessel transit lanes are designated by the US Coast Guard. Commercial vessels of the size and type calling at the proposed GPT are required to operate within these lanes prior to mooring, maneuvering, or locally anchoring near GPT. Thus, the study focuses on vessel movements in these vessel transit lanes, as well as in local maneuvering, mooring, and anchorage areas. The following section details the study area.

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[8] Consideration of cumulative effects was not included in the original 1970 NEPA Statute. The statute did however establish the Council on Environmental Quality (CEQ) which developed the regulations we follow today. Cumulative effects are defined by the CEQ as "an impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR §1508.7). These include both the direct and indirect effects of a project, which are separately defined.

1.3 The Study Area

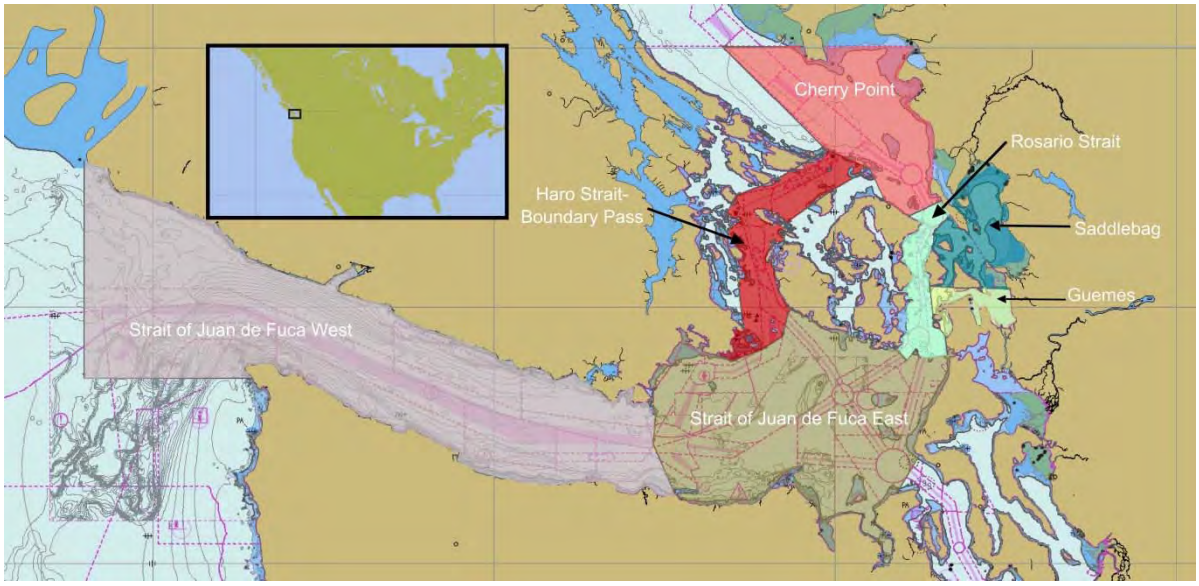

Figure 3 Study area and subareas

1.3.1 The Strait of Juan de Fuca

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 international boundary is a line equidistant to either shore. The US and Canada have a shared navigational right to the waterway. The entrance of the strait lies between Cape Flattery, Washington (48°23´43″N, 124°44´11″W) to the south, and Carmanah Point, BC (48°36´38″N, 124°45´00″W) to the north. The strait is an important waterway that connects the Pacific Ocean to passages in Puget Sound and BC as well as Southeast Alaska via the Inside Passage (the waterway between Vancouver Island to the west and the BC mainland to the east).

Traffic through this area includes both domestic and foreign vessels, serving a number of industries including lumber, fishing, rail, grain, cruise, oil, coal, and containerized cargo. In addition, both the United States and Canadian militaries have bases in the region and use several areas for training and testing weapons. The area is used by tribal fishers for commercial, ceremonial and subsistence harvest purposes, as well as by tribal and non-tribal commercial and recreational fishers. The strait is about 12 nm wide from the mouth to 50 nm east at Race Rocks, where it widens to almost 16 nm for the next 30 nm east to the boundary of Whidbey Island. The strait is deep to near the shoreline as a rule, with very few outlying dangers except near the islands.

1.3.2 Haro Strait and Boundary Pass

For the purposes of this study, Haro Strait is defined as the waters north of a line between Discovery Island, 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 Moresby

Island to Turn Point on Stuart Island, where it then turns into Boundary Pass and eventually 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 it is mainly used by vessels transiting to and from Vancouver BC or traveling to Alaska through the Inside Passage. The combination of Haro Straight (beginning at Discovery Island) and Boundary Pass (ending at East Point abeam Patos Island where the passage opens into the Strait of Georgia) is 30 nm long and straddles the international boundary for its extent. Depths in this area range from 160 fathoms (960 feet) at the deepest, to 20 fathoms (120 feet) in the shoals.

1.3.3 Cherry Point

Cherry Point is the location of the proposed GPT, and is also one of eight primary anchorage area locations in the study area. For the purposes of this study, the Cherry Point subarea includes the southern waters of the Strait of Georgia, from Orcas Island in the south, north to the Canadian border, including Boundary Bay.

A bight with no off-lying dangers runs between Cherry Point and Sandy Point, which lies 4.5 miles to the southeast of Cherry Point. The bight contains the piers of two large oil refineries and an aluminum smelter (Reference 122).

1.3.4 Rosario Strait

Rosario Strait is the easternmost channel leading from the Strait of Juan de Fuca to the Strait of Georgia. Its widest point is 5 nm between Davidson Rock and Deception Island, its narrowest 1.5 nm between Blakely Island and Strawberry Island. The depths range between 13 fathoms (78 feet) in the south end to 53 fathoms (318 feet) in the north end, with an average depth of approximately 30 fathoms (180 feet).

Rosario Strait is regularly used by tankers calling on 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 Haro Strait (Reference 122).

1.3.5 Saddlebag / Guemes Channel and Fidalgo Bay

The Saddlebag subarea includes the waters of Bellingham Bay, Samish Bay, and Bellingham Channel between Cypress Island and Guemes Island.

Guemes Channel is bordered on the north by Guemes Island and on the south by Fidalgo Island. The channel stretches from Rosario Strait in the west to Padilla Bay in the east. The three-mile channel has a width of 0.5 miles at its narrowest point, with depths from 8 to 18 fathoms (48-108 feet) (Reference 122).

1.4 Vessel Characteristics

There are two sizes of vessels expected to call at the proposed GPT facility at Cherry Point. The vessel types are known as Capesize and Panamax. The defining characteristics of these vessels are summarized in Table 1. Panamax vessels are the largest vessels capable of transiting the Panama Canal. Panamax vessels' length and width are limited by the canal dimensions. Capesize vessels are so named because they are too big for the Panama or Suez canals and thus voyage via Cape Horn or the Cape of Good Hope (Reference 80). The proposed GPT will have capacity for vessels up to 250,000 DWT, and smaller Handymax sized vessels may also call at the terminal (Reference 50).

Table 1 Vessel definitions

Vessel Type	Deadweight Tonnes (Reference 114)	Draft	Length	Width
Capesize	160,000-180,000	approx.17 m	(none specified)	(none specified)
Panamax	65,000-80,000	(none specified)	≤ 275 m	≤ 32.3 m

Both of these vessel types currently call at the Port of Vancouver and the Westshore Terminal, which are located in British Columbia (BC), Canada. The typical and maximum sizes of Panamax and Capesize vessels reported at the Port of Vancouver and Westshore Terminal are reported in Table 2.

Table 2 Vessels observed at BC destinations

Vessel	Draft	Length	Width
Typical Capesize	18.6 m	287 m	50 m
Maximum Capesize	18.6 m	300 m	50 m
Typical Panamax	14.0 m	224 m	32 m
Maximum Panamax	14.6 m	229 m	32 m

The prudent speed for transit conditions on all routes for bulk ships is generally 10-17 kts. Container ship speed is approximately 20 kts. An escorted loaded tank vessel speed is approximately 10 kts, and is limited by escort tug capabilities or tug speed.

1.5 Peer Review Plan

A Peer Review Plan was developed with members of the GPT VTARAS Work Group concurrently with beginning this study. The group was comprised of representatives from the Washington Department of Ecology, Pacific International Terminals, and the Lummi Nation. The peer review plan was developed to solicit feedback and obtain consensus from the GPT VTARAS Work Group. Glosten proposed the following peer review plan to deliver interim working documents, to receive comments on them, and then incorporate feedback into revisions. All interim working documents went through this peer review process with the GPT VTARAS Work Group.

The study deliverables were divided into eighteen separate working documents, and the eighteen documents were organized into three groups. Drafts of interim working documents were distributed to all representatives of the GPT VTARAS Work Group for review.

Comments were then collected from each GPT VTARAS Work Group representative, and consolidated. The GPT VTARAS Work Group convened for each group of documents and again a fourth time, for the compiled Draft Final.

During these meetings, the GPT VTARAS Work Group representatives' comments were each reviewed within the context of the interim working document. Discussions were held to clarify issues, and generally consensus among the group was reached. Comments were then included, excluded, or determined to require additional analysis.

Section 2 Vessel Traffic Infrastructure and Operations

2.1 Introduction

This section of the VTARAS focuses on the operational parameters of GPT calling vessels and includes both existing operations and projected operations out to 2019 when the proposed GPT is operating at full capacity. At full capacity, the annual volume of 487 deep draft vessels, the required assist tugs, and bunkering vessels will increase the vessel traffic within the study area. This section aims to answer what the existing infrastructure and operations are, and what the increased demands on this system will be. Each of the sub-sections in this section defines the existing operating environment and/or the anticipated 2019 operating environment. This section addresses:

- The extent of the vessel traffic study area;
- Vessel routing to the proposed GPT;
- Vessel traffic management;
- Anchorage areas along the approaches;
- Anticipated additional bunkering demand of GPT calling vessels and assist tugboats; and,
- Ballast water management for GPT-calling vessels.

This section blends both qualitative and quantitative analysis to inform the reader and to develop conclusions.

Section 2.2 of this report addresses the probable routing of GPT traffic using information from interviews with marine pilots familiar with the study area.

Section 2.3 describes existing vessel traffic management in the study area, through an overview of the relevant traffic regulations in place. It also offers alternatives for managing vessel traffic.

Section 2.4 identifies anchorage areas in the study area and presents historical anchorage usage. This section then forecasts anchorage usage to 2019 and compares remaining anchorage availability with anchorage demand from GPT-calling bulkers in 2019. Average daily anchorage availability reported reflects an even distribution of anchorage usage through the year, though in practice anchorage usage varies day to day.

Section 2.5 estimates the change in demand for bunker fuel in the study area due to GPT - calling bulkers and assist tugs potentially bunkering in the study area, using current fueling locations and representative bulker and tug fuel usage data.

Section 2.6 describes the risks associated with ballast water discharge and the anticipated incremental increase in ballast water discharge from GPT calling vessels. This section then describes both current and future regulatory environments.

Section 2.7 relates to concerns that the operation of the proposed terminal will adversely affect the spawning habitat of the Cherry Point herring stock. This section evaluates the feasibility

of the alternative GPT operating procedures suggested in the 1999 Settlement Agreement as part of a herring monitoring program.

In general, the conclusions of the Vessel Traffic Infrastructure and Operations Section are as follows:

- Additional pilots may be required to support the increased deep draft vessel traffic.
- Based on the 2019 forecast of average annual usage, available anchorage spaces will be sufficient to handle the queuing vessel traffic, but the anchorages will have a higher utilization rate.
- The 2019 GPT traffic will significantly increase the demand for bunker fuel. Due to variability and uncertainty in consumption rates and bunkering location, a range is calculated. GPT-calling bulkers and assist tugs are forecast to bunker between 2,185,000 and 4,337,000 bbl within the study area in 2019. This volume represents an increase of 122% to 243% over the 2011 level.
- The 2019 GPT-calling bulkers nearly triple the volumes of ballast water discharged within Puget Sound. Discharge from GPT-calling bulkers will be concentrated at the proposed terminal, within the Cherry Point subarea. Assuming they are adequately and reliably enforced, existing and evolving ballast water regulations should mitigate the impact of the ballast water discharged at GPT.

2.2 Vessel Traffic Routing Study

2.2.1 Introduction

As part of the Vessel Traffic and Risk Assessment, a study was conducted to determine the most probable routing of vessels calling on the proposed GPT from the Pacific Ocean. There are two options for the passage of vessels between the ocean and Cherry Point, with different implications based on vessel traffic regulation and international boundaries. In addition to identifying the most likely vessel route, this study also investigated the likely use of temporary moorages for GPT-calling vessels, and other factors that might influence vessel routing and traffic in the study area. Most probable routing was prepared for two proposed wharf alignments as shown in Figure 4. These routings are incorporated into the Vessel Traffic Analysis, Section 3.2.

Representatives from the Puget Sound Pilots (PSP) and the British Columbia Coast Pilots (BCCP) organizations were interviewed for the study, for their expertise in vessel traffic routing in the study area. Pilotage is required by Canadian law in Haro Strait and Boundary Pass for vessels over 350 gross tons that are not pleasure craft, and for every pleasure craft over 500 gross tons (Reference 93). Under 46 USC§8502 & 46 CFR§15.812, pilotage in US waters is compulsory for all foreign vessels and US vessels engaged in foreign trade. If a vessel is bound for a Canadian port, a Canadian pilot (BCCP) will pilot the ship for the entirety of the passage. The Canadian pilot boarding area is by Victoria (Reference 122). If the vessel is bound for a US port, a US pilot (PSP) will pilot the ship for the entirety of the passage. The US pilot boarding area is at Buoy “PA” by Port Angeles, south of Race Rocks. When a ship is transiting between a Canadian port and a US port in either direction, pilot boarding and disembarking location depends on the departure and arrival port.

The use of a state pilot is optional for US vessels engaged in the coastwise trade with a federally licensed pilot on board such as the vessel master, if they have the requisite pilotage endorsement for the route used (Reference 9).

When interviewed in the fall of 2012, PSP representatives stated that the most probable routing for vessels from the Pacific Ocean calling on the proposed terminal at Cherry Point would be through the Straits of Juan de Fuca and Rosario Strait. Also according to the PSP representatives, past vessel traffic in the area was greater than that of the current level plus the potential increase of GPT vessel traffic. Historical data confirm this (Appendix A). Appendix A shows that overall traffic volumes generally decrease from 1995 to 2010 (Appendix A, Figure 18). The hindcast traffic volumes in the mid-1990s are within a percentage of the forecast traffic volumes with the potential increase of GPT vessel traffic (Appendix A, Table 9). During this past period, Rosario Strait was the most used route to the Cherry Point area. Additionally, the PSP estimated that current traffic docking at Cherry Point uses the Rosario Strait route 95% of the time and the second route option, through Haro Strait and Boundary Pass, the remaining 5%. Vessel Traffic System (VTS) data support this estimate with a traffic split of 94% for Rosario Strait and 6% for Haro Strait-Boundary Pass (Reference 75).

According to both the PSP and the BCCP representatives, the primary effect of traffic increases at GPT would be increased operational demands for pilotage that could result in the need for additional pilots in Washington waters. The Washington State Pilotage Commission regulations would determine the resulting number of pilots, as they implement limitations on the number of hours that pilots may work.

PSP representatives did not foresee that either of the proposed GPT wharf alignments would affect route selection. However, the pilots did express concerns about wharf placement related to berthing considerations.

2.2.2 Methods

Members of the PSP and BCCP organizations were interviewed during late August and early September 2012 as part of the information gathering effort for this study. A questionnaire was provided to the president of the BCCP and distributed to the BCCP pilots whom the president thought best represented the BCCP organization. The BCCP president then shared the summarized responses during a follow up phone interview. A copy of the pilot questionnaire is included for Reference in this report, Appendix G.

A total of nine PSP pilots were interviewed using the questionnaire. The PSP pilot selection was based upon their experience and the relevance of their assigned routes. Efforts were made to interview pilots that used both Haro and Rosario approaches to Cherry Point.

The pilots advised on many aspects to consider related to bulk carrier traffic routing in the study area. The interview responses are summarized in the following sections based on considerations for tug escort, traffic, weather, operations, berthing, anchorage, and wharf placement.

2.2.3 Pilot Response Summaries

2.2.3.1 Escort and Assist Tug Considerations

Escort Tugs

Escort tug experience is varied for each group of pilots. In British Columbia, while tug escorts are not compulsory for bulk carrier vessels, they are requested by pilots for sluggish handling ships and/or when there is a strong current. BCCP representatives indicated that they would request a tug escort when there are strong tides at Eastpoint and there are loaded ships out of Vancouver going to bunker; however, as an option, they could wait for slack tide.

For the members of the PSP, current regulations or requirements do not require escort for any ship other than a loaded tanker. PSP would only request a tug escort when the following conditions exist: mechanical or hardware deficiency, a *Captain of the Port Order*, and/or an applicable regulation. Current US regulations require loaded tankers to be escorted eastward of a line drawn from Discovery Island to Dungeness Spit including the East Strait of Juan De Fuca (1.5 nm west of Buoy "R"), Rosario Strait, Haro Strait, and Boundary Pass to the destination terminal.

The type of tug the PSP representatives most often request for escort is a tractor tug capable of a minimum of 13 knots. Additionally, escort tugs must have an aggregate shaft horsepower of at least 5% of the escorted vessel's deadweight, per Washington State code, Reference 111. The number of tugs required to escort a given vessel increases with vessel size. The safe working load (SWL) of the deck fittings also dictates the number of tugs that can be used. The lower the SWL of the fittings, the more tugs would be needed to safely distribute the forces needed to escort the ship. More tugs can be used to compensate for the lack of adequate deck fittings.

BCCP representatives request and are experienced in using purpose-built Z-drive tugs for escort assistance. These are similar to tractor tugs in that both are omnidirectional. The number of tugs used in BCCP's escort is again based on the bollard rating of the ship's fittings and the bollard pull of the tugs.

Assist Tugs

Assist tugs are used by vessels for maneuvering in and out of anchorages and berths. Assist tugs intercept and are dismissed from the ship at the following points:

- For inbound berthing assist tugs meeting the arriving ship:
  - In Puget Sound; 1 nm to 3 nm from the berth, depending on the weather conditions.
  - In British Columbia; 0.3 nm to 0.5 nm from the berth.
- When outbound from the dock, tugs are dismissed:
  - In Puget Sound; when the vessel is clear of the berth, underway, and under power with sufficient headway to maneuver.
  - In British Columbia; 0.1 nm to 0.3 nm from the berth.

In the PSP representatives' experience, the appropriate number of tugs to assist any vessel in safe maneuvering to or from a berth or anchorage is two to four tugs depending on the type

and bollard pull of the tug (conventional or tractor), weather, and ship's draft. Tractor tugs are preferred for docking assistance. Purpose-built Z-drive tugs, also called Azimuthing Stern Drive (ASD) tugs, are requested by the BCCP representatives for docking assistance to or from berth or anchorage. If a ship is laden or partially laden when approaching the dock, the pilots may ask the tugs to intercept the ship earlier to help with speed control. Upon departure in Puget Sound, the vessel's cargo load does not change the timing of a tug's dismissal; however, BCCP may consider the vessel's cargo load when determining where the tugs are dismissed.

2.2.3.2 Traffic Considerations

Currently, PSP make approximately 7,600 pilot assignments per year. At the time this study was conducted, the traffic level was handled by 54 Puget Sound Pilots. In past years, annual pilot assignments have been as high as 8,600 per year, requiring 58 pilots. The Washington State Pilot Commission designates the number of pilots required based on shipping levels (Reference 22).

There is not an exact one-to-one relationship between PSP vessel visits and vessel port calls. In some instances, the PSP may visit a vessel on a single round-trip more than once. In addition, some vessel traffic does not use the services of the PSP.

If the proposed GPT were operating at predicted full capacity, the increase in vessel traffic would be approximately just over forty additional vessels per month (Reference 114). Inbound and outbound transits would add a minimum of 974 additional annual assignments above the pilots' 2011 total assignments, which represents a 12.8% increase above their current utilization. Trips to anchorage or other moves could add assignments as well. The Washington State Pilots Commission may require additional pilots to support the predicted GPT traffic.

The pilots reported that this increase in traffic would require their increased coordination with Seattle and Victoria VTS, and increased coordination between PSP and BCCP as well. For instance, on the Haro Strait/Boundary Pass route, the vessel will pass through both US and Canadian waters. Pilotage for Haro Strait/Boundary Pass and Rosario Strait is shared by PSP and BCCP.

<u>Communications</u>

When transiting Haro Strait/Boundary Pass, PSP exchange information with BCCP via VHF communications on Channels 11, 13, 5a, 16, and 17. The Canada/US Cooperative Vessel Traffic Service (CVTS) information is shared in accordance with the CVTS manual (Reference 34). More information about VTS and CVTS is detailed in Section 2.2.2.3. The BCCP representatives expressed interest in working with the PSP to establish common practices and protocols.

<u>Rosario Strait</u>

The PSP representatives estimated that existing traffic docking at Cherry Point uses the Rosario Strait route 95% of the time and the Haro Strait-Boundary Pass route the remaining 5%. VTS data support this estimate with a traffic split of 94% for Rosario and 6% for Haro Strait Boundary Pass (Reference 74).

PSP members also said that Rosario Strait is the primary route for ships bound for a US port in the study area; however, PSP will use Haro Strait/Boundary Pass if there is conflicting traffic in Rosario Strait.

Rosario Strait is generally a one-way zone for vessels over 40,000 DWT, which includes all bulkers that would be calling at GPT.

Per 33 CFR §161.55 (c), the following additional requirements are applicable in the Rosario Strait and Guemes Channel VTS Special Areas:

> *(1) A vessel engaged in towing shall not impede the passage of a vessel of 40,000 dead weight tons or more.*
> *(2) A vessel of less than 40,000 deadweight tons is exempt from the provision set forth in § 161.13(b)(1) of this part.*
> *(3) A vessel of less than 100 meters in length is exempt from the provisions set forth in § 161.13(b)(3) of this part. Approval will not be granted for:*
>
> > *(i) A vessel of 100 meters or more in length to meet or overtake; or cross or operate within 2,000 yards (except when crossing astern) of a vessel of 40,000 dead weight tons or more; or*
> > *(ii) A vessel of 40,000 dead weight tons or more to meet or overtake; or cross or operate within 2,000 yards (except when crossing astern) of a vessel of 100 meters or more in length.* (Reference 5)

A 15-minute notification to Seattle VTS is required before entering or getting underway within the Rosario Strait Special Operating Area (SOA). US Coast Guard (USCG) approval must be granted to enter the Rosario Strait/Guemes Channel SOA (Reference 92).

Haro Strait/Boundary Pass

Haro Strait/Boundary Pass is typically used by traffic transiting to or from Canada. Generally, there is two-way traffic in Haro Strait except near Turn Point, where the SOA (Reference 92) requires vessels of more than 100 m to maintain a minimum distance of 0.5 nm of separation between vessels while maintaining a distance of 3 cables (approximately 560 m) off Turn Point.

In Haro Strait, advance notice is given via a call to Canadian VTS at East Point, to Gowlland Point southbound and Danger Shoal northbound. There is also a check in/out point to either Seattle Traffic or Victoria Traffic when abeam Race Rocks. All VTS participants approaching the Turn Point SOA are expected to make safe passing arrangements with other VTS participants prior to entering the vicinity. Additionally, a southbound ship will swing wide and pass on a reciprocal course of a northbound ship.

Strait of Georgia

The Strait of Georgia is also used for Canadian traffic along with Haro Strait/Boundary Pass, as well as by US vessels transiting to or from Alaska via the Inside Passage.

The Strait of Georgia has dedicated traffic lanes. Currently, transit speed in the Strait of Georgia is set at “prudent speed” (e.g., bulk ships at 10-17 kts and container ships at 20 kts). An escorted loaded tank vessel speed is approximately 10 kts, and is limited by tug capabilities or tug speed.

2.2.3.3 Weather Considerations

Anecdotal feedback from pilots assured that wind, weather, and currents are taken into account in their daily operations. The responses in this subsection are not incorporated into the quantitative vessel traffic model presented in Section 3.

Both groups of pilots stated that the frequency of operational changes due to weather and environmental factors was low or infrequent. They did not have enough data to give more detail on the frequency of weather-based changes. Only extreme weather conditions exceeding 35 kts wind and 5 foot seas (or approximately 1.5 m seas) would lead to operational changes.

The weather and environmental factors with the greatest impact upon PSP's operations are strong winds from the Northwest combined with wind-generated seas and maximum currents. These conditions necessitate the pilot conducting an on-scene assessment of the vessel's operating condition. There are no restrictions on vessel transits in severe weather; however, berthing facilities will have limiting conditions for docking and undocking, as determined by the dock master.

The BCCP reported that winds and currents greatly influence decision-making regarding operations. Of particular concern are wind speed and direction when the vessel is in ballast and current speed and direction when the vessel is laden.

Operations for pilot boarding are not changed during inclement weather since the ship can make a sufficient lee for the pilot boat so that the pilot can board the ship.

During times of poor visibility, transit speed is reduced. Arrivals and departures are adjusted accordingly, based on berth facility procedures.

The Puget Sound Harbor Safety Committee (HSC) *Standards of Care for Anchoring* (Reference 105) requirements apply for Puget Sound anchorages during inclement weather. For all weather conditions and situations, the HSC Standards of Care (SOC) and Captain of the Port (COTP) directives apply.

Seasonal effects to vessel traffic can influence the speed of the transit. Summer brings increases in yacht traffic and whale watching at Turn Point and Danger Shoal in Haro Strait. Late summer includes increases in fog and fishing traffic. The time between October and March sees increases in wind events. Some terminals have weather parameters that prevent ships from docking in rough weather, which generally occur with over 35 kts of wind and 5 foot seas (or approximately 1.5 m seas). The pilots stated that occasionally operations are affected by commercial fishing and naval traffic in Puget Sound; however, this statement was not detailed further.

2.2.3.4 Operational Considerations

Depth issues for transiting Rosario Strait and Haro Strait/Boundary Pass were not discussed with the pilots. In the Strait of Georgia and the Vancouver area, the controlling depth (or shallowest point of the passage) is generally 60 feet (18.3 m). There are some deeper areas and shallower shoals in the transit of both routes, but they are off the optimal track line. Puget Sound HSC SOC requires that, when underway, minimum clearance under a vessel shall be 3 feet (approximately 0.9 m) or 10% of draft, whichever is greater.

The frequency of mechanical (engine) failure during transits of the areas in question has been low according to the PSP's knowledge. Reporting of such failures is a USCG (Form 2692) report requirement, and records of such incidents are kept on file by the USCG. The ports of refuge and anchorages along transit routes for the pilotage waters between Port Angeles and the proposed GPT in case of a disability are Port Angeles, Anacortes, Vendovi Island, Bellingham Bay, and Cherry Point.

Additional vessel movements are conducted specifically for bunkering in Port Angeles, Anacortes, Vendovi Island, March Point, and Bellingham Bay. Bunkering for vessels calling at the Cherry Point terminals typically happens at Port Angeles, Anacortes, Vendovi Island, and Bellingham Bay, and directly from fuel barges at some oil terminals. Bunkering is conducted using the Puget Sound HSC *Bunkering Operations Guide* (Reference 29). All vessels will be prohibited from bunkering while docked at the proposed GPT.

Ballast water transfers are subject to international, national, and state regulatory regimes (Reference 129). More information on ballast water management can be found in Section 2.6, Ballast Water Management.

2.2.3.5 Berthing Considerations

It was assumed that berthing operations at the proposed GPT would be very similar to those at other existing berthing sites near Cherry Point. During October through March, strong westerly winds could limit docking and undocking. Weather limits for berth procedures in the area are those mentioned above, over 35 kt winds and abeam or quartering over 5 foot (1.5 m) sea (Section 2.2.3.3). The preferred direction of berthing and departure in these conditions consists of a method where the ships move opposite both the wind and current. If the wind and current are opposing, the ship will generally move opposite the current. The alignment of the terminal wharf in relation to prevailing currents can have considerable impact on berthing operations, as further discussed in Section 2.2.3.7. During inclement weather, the pilots' operational options for berthing or departure include using the anchor or requesting additional tugs. In addition, the pilot may remain on board the ship after it is docked in inclement weather in case a departure is necessary.

2.2.3.6 Anchorage Considerations

When selecting an anchorage for a ship calling at a terminal, the following considerations are taken into account: proximity to the berth, vessel draft, bunkering needs, laden condition, holding ground, weather, and traffic. In addition to the above, factors such as logistics for pilot transportation, crew launch service, stores, and safety may be used in selection of a preferred anchorage area.

Generally, anchorage spaces are available in most weather conditions. Table 3 in Section 2.4.2 lists the anchorage areas and number of spaces available in the study area. The Puget Sound HSC sets the Standards of Care (SOC) for anchoring in the *Harbor Safety Plan* (Reference 105). It is the responsibility of the pilot and vessel master to determine the maximum wind and sea conditions for anchoring, in conjunction with the USCG COTP and VTS. Anchoring generally never occurs in winds over 45 kts.

Considerations when shifting between the anchorage and the berth during the loading process include pilot transportation to and from the berth and the vessel's handling with consideration to draft, trim, and weather conditions.

According to the BCCP, congestion at anchorage areas is an issue when calling at the Westshore Terminal. The arriving vessels are eager to anchor and to tender the notice of readiness to the terminals so that they can go on demurrage. This urgency to anchor can cause anchorage congestion. Although it is not anticipated that the GPT traffic would use Canadian anchorages, causes of anchorage congestion are an important consideration.

According to the pilot responses, the increase in traffic that would be caused by the proposed GPT could saturate the anchorages in the area, depending on ship schedules and cargo availability. Currently, vessels calling at US docks never use anchorages in Canada, as the Canadian anchorage is used for ships calling on Canadian berths in the area. If a US ship used this anchorage (English Bay), they would be required to clear Customs and Immigration in both Canada (when arriving) and the US (when docking). Further anchorage considerations are discussed in Section 2.4 Anchorages.

2.2.3.7 Wharf Alignment Considerations

The alternative alignment for the wharf is an alignment discussed by the state agencies. It has been included in the study for assessment purposes only. PIT does not propose this alignment as part of the proposed Gateway Pacific Project. The two alternative proposed pier locations are close to each other and differ mainly in their alignments by about 20 degrees (Figure 4). Per discussions with the PSP, the vessel route to either alternative would be identical except for the final approach and berthing.

The pilots did say they would be concerned about the berth azimuth in relation to the expected environmental forces if the proposed GPT were operating at the projected full capacity. Particular attention was expressed about current velocities and alignment with current direction. The PSP expressed interest in being involved in full-mission simulator analysis of the terminal docks to confirm favorable alignment and model approach to the berth strategies.

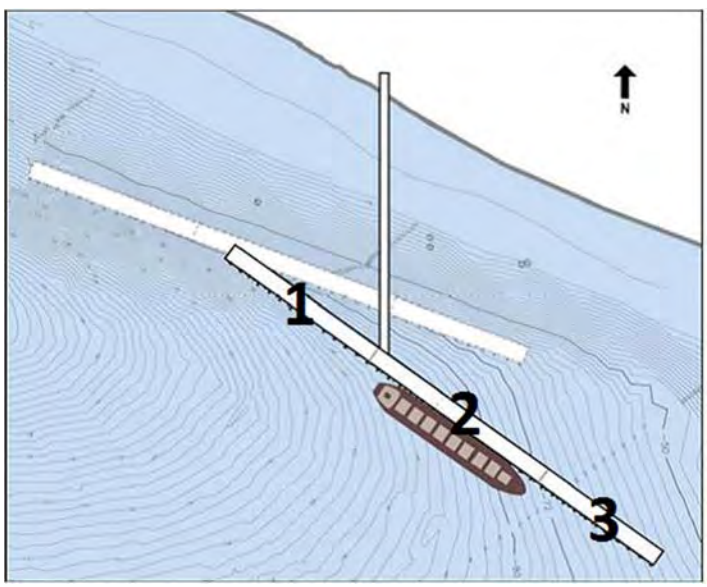

Figure 4 Second wharf alignment; Berths 1-3 labeled

2.3 Traffic Management Approaches

2.3.1 Introduction

This section presents information and regulations detailing the current traffic separation and management schemes in the study area. This information comes from Washington State, US Federal, and Canadian government publications. Information found on the United States Coast Guard District 13 and Puget Sound VTS web sites, United States Coast Pilot No. 7, and Canadian Sailing Directions PAC 201 are combined with information from National Oceanic and Atmospheric Administration (NOAA) Nautical Charts for the area.

The study considers alternative traffic control and risk mitigation measures that have the potential to reduce the impact of increased traffic resulting from the proposed GPT. Information obtained from prior studies for tanker risk mitigation and methods used by other ports are also considered when discussing alternatives. Alternatives of mandatory tug escorts, voluntary speed reductions, standby response tugs, area transit plans, complements to the existing traffic separation scheme, and supplemental aids to navigation are addressed in Section 2.3.3.

In Section 3, vessel traffic is forecast to 2019. That forecast assumes that the current traffic separation and management schemes in the study area will remain in effect. Additional traffic in 2019 is assumed to comply with the current regulations. As such, the escort tugs are added to the traffic model along with additional tankers. Similarly, escort tugs are removed with tanker traffic that is forecast to be displaced by other transportation modes. Tug escort, Section 2.3.2.3, is the only management approach discussed in this section which is explicitly modelled in the Vessel Traffic Analysis, Section 3.

2.3.2 The Traffic System

The vessel traffic system in Puget Sound is responsible for the safe flow of shipping approaching and within the Strait of Juan de Fuca and Puget Sound. The three primary elements of the traffic system are the traffic separation scheme (TSS), the vessel traffic services (VTSs), and the Coast Guard Navigation Rules. The TSS assists ships to pass one another at a safe distance. The VTSs are located to accommodate shipping in the adjacent waters of Canada and the United States. VTS communicates with vessels and assists in tracking their progress within the study area. Lastly, the USCG Navigation Rules (Reference 86) per the *Convention on the International Regulations for Preventing Collisions at Sea* (COLREG. Reference 39) and the *Canada Shipping Act* (Reference 33) spell out the manner in which vessels interact with one another in both good and restricted visibility conditions.

Other elements of the traffic system include:

- Special Operating Area (SOA): An area or zone established to enhance order and predictability, ensure the efficient and safe movement of goods and services, and to reduce the risk of accidents with respect to vessels transiting certain waterways or channels.
- Traffic Lane: An area within defined limits in which one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary.

- Separation Zone or Line: A zone or line separating traffic lanes in which ships are proceeding in opposite or nearly opposite directions; or separating a traffic lane from the adjacent sea area; or separating traffic lanes designated for particular classes of ship proceeding in the same direction.
- Roundabout: A separation point or circular separation zone and a circular traffic lane within defined limits.
- Inshore Traffic Zone: A designated area between the landward boundary of a TSS and the adjacent coast.
- Recommended Route: A route of undefined width for the convenience of ships in transit that is often marked by centerline buoys.
- Deep-Water Route: A route within defined limits that has been accurately surveyed for clearance of sea bottom and submerged articles.
- Precautionary Area: An area within defined limits where ships must navigate with particular caution and within which the direction of flow of traffic may be recommended.
- Area to be Avoided: An area within defined limits in which either navigation is particularly hazardous, or should be avoided by all ships, or by certain classes of ships (Reference 120).

2.3.2.1 Traffic Separation Schemes

The International Maritime Organization, as part of SOLAS (Safety of Life at Sea) Chapter V, was established as the only international body with the responsibility for developing guidelines, criteria, and regulations for ships' routing systems, including traffic separation schemes (Reference 120). COLREG Rule 10 governs the behavior of vessels operating in and around the TSS and applies on all the waters of the Strait of Juan de Fuca, Haro Strait, Rosario Strait, and Strait of Georgia (Reference 39). The Ports and Waterways Safety Act (33 USC§1221-1232) grants the US Coast Guard the authority to establish traffic separation schemes where necessary, to provide safe access for vessels proceeding to or from US ports. Similar authority is granted to the Canadian Coast Guard by Transport Canada.

A TSS is used to regulate the traffic in busy, confined waterways or around capes. Within a TSS, it is normal to have at least one traffic-lane in each main direction, as well as turning points, deep-water lanes, and separation zones between the main traffic lanes. The direction of travel in each traffic lane is indicated by arrows on the chart. The body of water between two opposite lanes is a separation zone, and travel within them in US waters is generally prohibited. In Canadian waters, vessels engaged in fishing may depart from certain provisions of Rule 10 of COLREG (Reference 39) and fish in any direction in a traffic lane.

The following paragraphs discuss the Canadian and US traffic lanes from the Strait of Juan De Fuca Traffic Lane Separation Lighted Buoy "J" (48°29´36.50″N, 125°00´00″W) to the proposed GPT located at Cherry Point, Washington, (48°51´29.97″N, 122°44´13.01″W) utilizing Haro, Georgia, and Rosario Strait.

The Strait of Juan de Fuca Traffic Scheme consists of six sets of traffic lanes: Strait of Juan de Fuca, Port Angeles, Victoria Approach, Port Angeles to Rosario, Rosario to Strait of Georgia,

and Haro Strait to Strait of Georgia. Each set consists of an inbound and outbound lane, with a separation zone 0.5 to 2.5 nm in width (Figure 5).

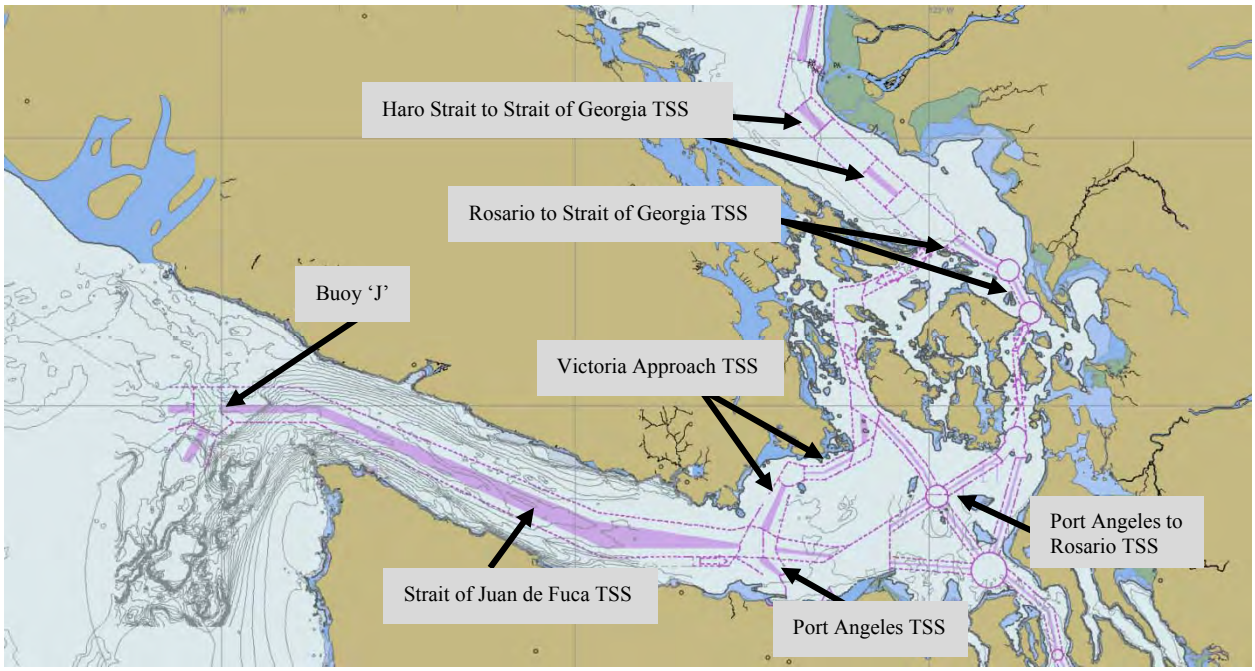

Figure 5 Established traffic separation schemes (TSS') in the study area

Two additional vessel traffic lanes are used by vessels arriving to and departing from the Strait of Juan de Fuca from the west, at sea: the western approach and the southwestern approach off the Washington coast at Swiftsure Bank. The convergence of these two approaches is marked by a lighted yellow buoy, Buoy "J."

There are two precautionary areas in the Strait of Juan de Fuca: one west-northwest of Cape Flattery, and the other between Port Angeles in the south and Race Rocks to the north. Each precautionary area is marked by lighted yellow buoys. Both buoys marking the precautionary areas are equipped with a radar transponder known as a RACON (RAdio beaCON). When illuminated by the ship's radar, this RACON flashes back to the radar display with the Morse code letters indicating the buoys' designation.

The purpose of the precautionary areas and buoys is to:

- Assist in the separation of inbound and outbound vessels transiting the Strait of Juan de Fuca.
- Eliminate, as much as possible, the cross vessel traffic that occurs between the entrance to the Strait of Juan de Fuca at Cape Flattery, the pilot stations at Port Angeles, the southern lanes from Seattle, and the northern lanes to Victoria, BC.

As stated in 33 CFR§167.1330, the Haro Strait and Strait of Georgia TSS consists of inbound and outbound traffic lanes with separation zones, which continues east from the Victoria Approach segment of Strait of Juan de Fuca TSS to Victoria, BC, then through Haro Strait, Boundary Pass, and the Strait of Georgia, to Vancouver, BC.

Two abbreviated TSSs, consisting of inbound and outbound traffic separation lanes with separation zones, connect the Haro Strait and Strait of Georgia TSSs with the Puget Sound

Traffic Service. One TSS leads northwest from the precautionary area east of Hein Bank into Haro Strait, and the other leads northwest from the precautionary area south of Alden Bank into the Strait of Georgia (Reference 7). These TSSs have also been adopted by the IMO (Figure 5).

2.3.2.2 Vessel Traffic Services and Vessel Movement Reporting Systems

Traffic is handled jointly by the Vessel Traffic Service Puget Sound and the Victoria Marine Communications and Traffic Services (MCTS) under the Canada/US Cooperative Traffic Service (CVTS). The level of participation with the vessel traffic service depends on different vessel parameters. A Vessel Movement Reporting System (VMRS) is used to monitor and track vessel movements.

<u>Cooperative Vessel Traffic Service (CVTS)</u>

In 1979 by formal agreement, the Canadian and the United States Coast Guards established the CVTS for the Strait of Juan de Fuca region. The purpose of the CVTS is to provide for the safe and efficient movement of vessel traffic while minimizing the risk of pollution by preventing collisions and groundings and the environmental damage that would follow. Responsibilities for the region are as follows:

- Tofino Traffic provides VTS for the offshore approaches to the Strait of Juan de Fuca and along the Washington State coastline from 48°00´N, 127°00´W, or within 50 nm of Vancouver Island. All vessels 20 meters or greater, including tug and tows, must contact Tofino Traffic.
- Seattle Traffic provides Puget Sound VTS for both the Canadian and US waters of Juan de Fuca Strait.
- Victoria Traffic provides VTS, known as MCTS, for both Canadian and US waters of Haro Strait, Boundary Passage, and the lower Georgia Strait (Reference 34, Figure 6).

33 CFR§161 (Reference 5), defined which vessels are required to participate in the VTS in US navigable waters of the Salish Sea, and further defined whether full participation, passive participation, or minimal participation with the VTS Puget Sound or the Canadian MCTS is required. In its 2*013 VTS User Manual* (Reference 134), the VTS Puget Sound stated that full participation is required for the following:

- Power driven vessels of 40 m (~131 feet) or longer in length.
- Every towing vessel of 8 m (~26 feet) or greater in length, while navigating (engaged in towing).
- Every vessel certificated to carry 50 or more passengers for hire, when engaged in trade (includes dead heading for passengers).

These vessels form the Vessel Movement Reporting System User Class, and are required to participate in VMRS.

Passive participation with VTS Puget Sound is required, per the *2013 VTS User's Manual*, by vessels who meet any or all of the following requirements:

- Power-driven vessel of 20 m or greater in length, while navigating.

- Every vessel of 100 gross tons or more carrying one or more passengers for hire, while navigating.
- A dredge or floating plant.

The *User's Manual* also stated that minimal participation with the VTS is required by any vessel not meeting the above criteria, which includes every type of water craft, including nondisplacement craft, and seaplanes per the USCG's Navigation Rule 3, that can be used or is capable of being used as transportation on the water.

Vessels that are required to participate in the VTS must report their vessel name when they get under way or when they enter the VTS area, enter the Strait of Juan de Fuca at 124°00´W, or when directed to do so by Seattle Traffic VTS. The vessel must also provide its name and position, and must check out of the system when it arrives at its destination or when it leaves the VTS area.

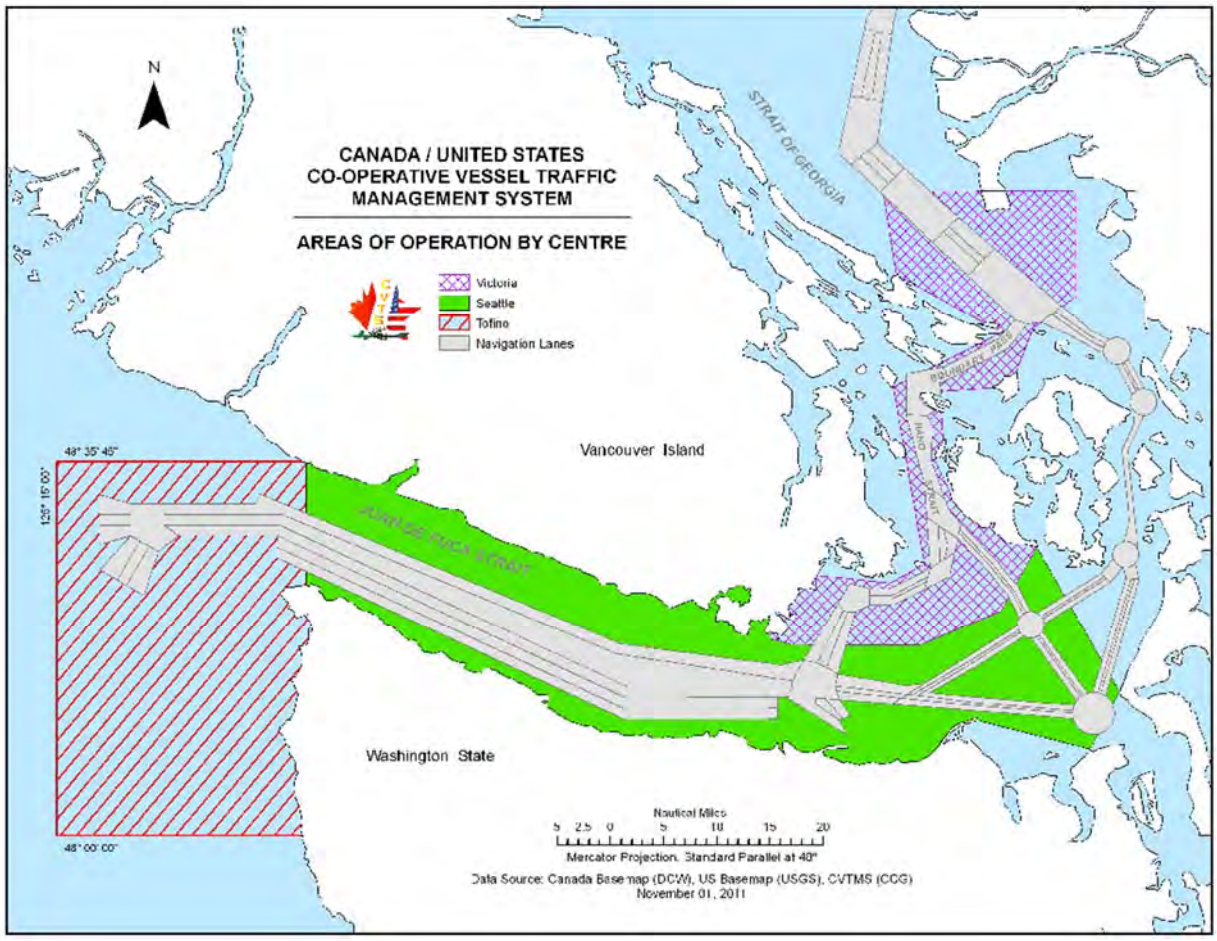

Figure 6 CVTS areas

Puget Sound Vessel Traffic Service (VTS)

Puget Sound Vessel Traffic Service, also known as Seattle Traffic, is operated by the US Coast Guard – Sector Puget Sound. It was established for the Strait of Juan de Fuca east of Port Angeles, Rosario Strait, Admiralty Inlet, Puget Sound, and the navigable waters adjacent to these areas. The Puget Sound VTS consists of three components, which include the TSS, the

Vessel Movement Reporting System (VMRS), and surveillance system. The VMRS is based upon a VHF-FM communications network, which is monitored continuously by the Coast Guard Vessel Traffic Center in Seattle. The surveillance system includes:

- A network of 12 strategically located radar stations from Cape Flattery, through Rosario Strait in the San Juan Islands, to Tacoma.
- An automatic identification system (AIS).
- A closed circuit television (CCTV).

The Puget Sound VTS center processes information received from vessels and disseminates navigational safety information to vessels participating in the service.

Victoria Marine Communications and Traffic Services (MCTS)

Victoria's VTS system is operated by certified Marine Communication and Traffic Officers (MCTSOs), who monitor the movement of vessels using VHF radio and direction-finding equipment, AIS tracking computers, and surveillance radar. Victoria Marine Communications and Traffic Services (MCTS) provides VTS to vessels operating in Haro Strait and the Strait of Georgia, and north to 49°00´N (Figure 6). VTS Victoria provides a means of exchanging information between ships and the shore-based MCTS Center. Under the CVTS, MCTS is the Vessel Traffic Service for vessels transiting Haro Strait, Boundary Passage, and the lower Georgia Strait, and vessels entering these waters must participate in the VTS to their required level.

Vessel Movement Reporting System (VMRS)

A Vessel Movement Reporting System (VMRS) is a system used to monitor and track vessel movements in a VTS or VMRS area. This tracking is accomplished by requiring that vessels provide information under established procedures set forth in the CFR (Reference 5), or as directed by the VTS Center. To avoid imposing an undue reporting burden or unduly congesting radiotelephone frequencies, reports are limited to information that is essential to achieve the objectives of the VMRS. These reports are consolidated into three reports; a sailing plan, position report, and final report (Reference 5).

2.3.2.3 Escort and Tethering

Escort and tethering procedures are set forth by the Puget Sound Harbor Safety Committee (April 2012) for all tank vessels as defined in the Federal OPA 90 tanker escort requirements as per 33 CFR §168 (single hull tankers over 5,000 GRT) (Reference 8); and State of Washington RCW 88.16.190 and WAC 363-116-500 (for all oil tankers 40,000 DWT and over) (References 111 and 135). The Federal rule establishes that each laden single hull tanker must be escorted by at least two escort vessels and the State rule allows one tug if that tug meets the horsepower to tonnage ratio requirement in those navigable waters of the United States and Washington State 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. This area includes all the navigable waters of the United States within Haro Strait, Boundary Pass, Rosario Strait, the Strait of Georgia, Puget Sound, and Hood Canal, as well as those portions of the Strait of Juan de Fuca east of the New Dungeness-Discovery Island line (Reference 8). Speed restrictions apply when is ship is under escort: "Must not exceed a speed beyond which the escort vessels can reasonably be expected to safely bring the tanker under control within

the navigational limits of the waterway, taking into consideration ambient sea and weather conditions, surrounding vessel traffic, hazards, and other factors that may reduce the available sea room," (Reference 8). Other procedures of the Puget Sound Harbor Safety Committee require that laden tankers tether the escort tugs: between Saddlebag and Huckleberry Islands; in the vicinity of Viti Rocks; and in Guemes Channel from Shannon Point to Cap Sante, Boundary Pass, Haro, and Rosario Strait. Figure 7 shows the portion of the study area, shaded in red, where this rule applies.

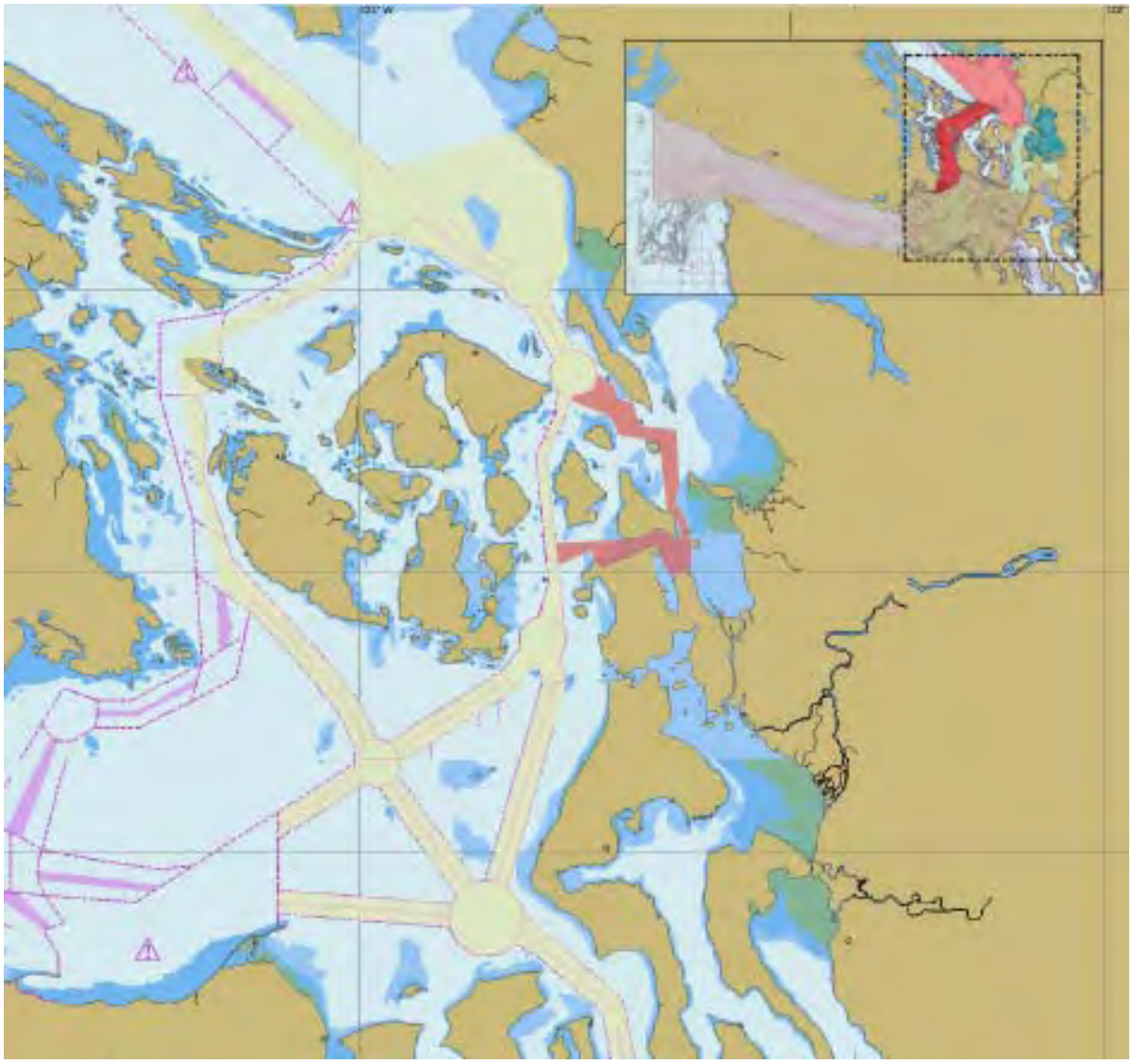

Figure 7 Shipping lanes and general areas where tanker escort is required (yellow and red) and area where tethered escort is practiced (red)

2.3.2.4 Special Areas

There are two special areas within the study area. One is a Special Operating Area at Turn Point (Figure 8), and one is a Special Area through Guemes Channel and Rosario Strait

(Figure 9). These areas each have their own regulatory designations, dictating special practices for certain vessels navigating the areas.

Turn Point

Turn Point is at the northwest extremity of Stuart Island and is the junction of two waterways, which are Boundary Pass to the northeast and Haro Strait to the south. In accordance with the CVTS agreement between the US and Canada, and in cooperation with industry and the BCCP, the Turn Point Special Operating Area (SOA) was established. The SOA was intended to enhance order and predictability, to maintain efficient and safe movement of goods and services, and to further reduce the risk of incidents between both commercial and recreational vessels with respect to vessels transiting the boundary waters of Haro Strait and Boundary Passage in the vicinity of Turn Point. This is of specific concern at the intersection of Haro Strait and Boundary Pass near Turn Point Light (48°41´20″N, 123°14´15″W) (Figure 8).

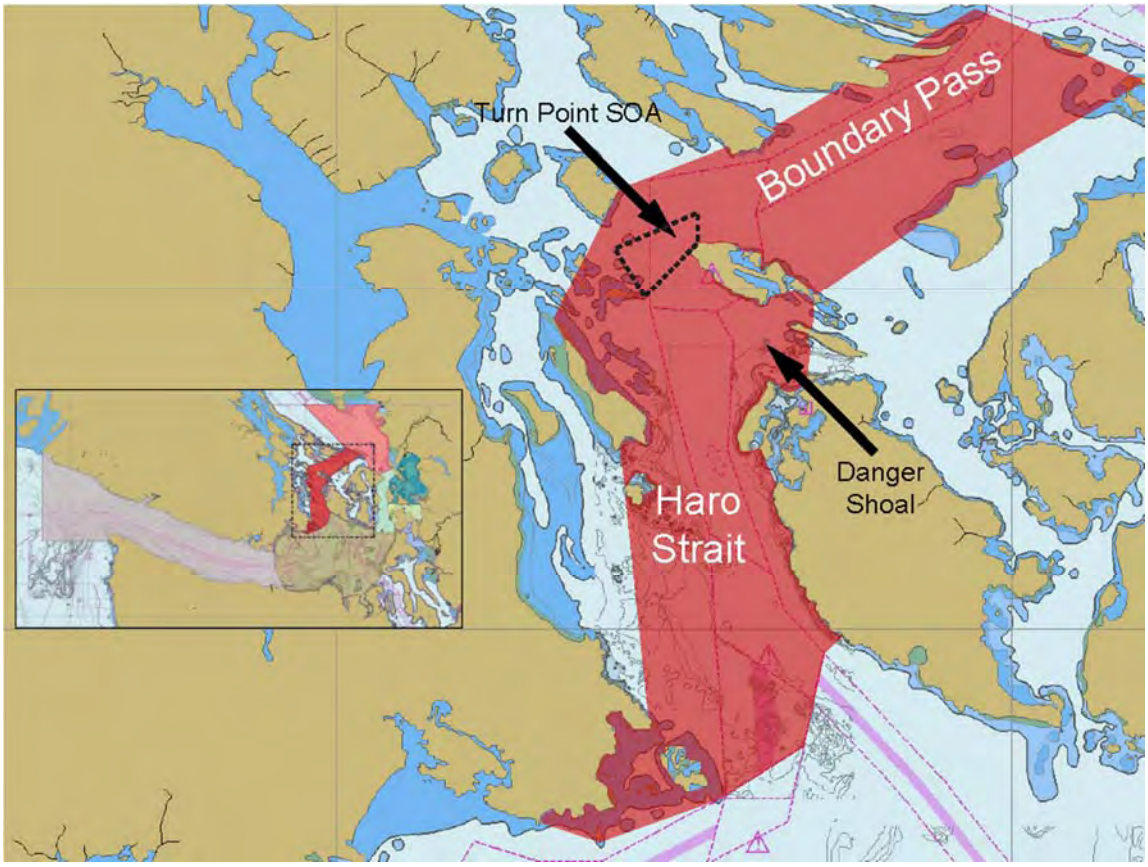

Figure 8 Haro Strait, Boundary Pass, and Turn Point

The SOA consists of those Canadian and United States waters contained within an area connected by the following coordinates: 48°41.324´N, 123°14.245´W (Turn Point Light), 48°42.400´N, 123°13.967´W, 48°41.087´N, 123°17.631´W (Arachne Reef Light), and 48°39.732´N, 123°16.438´W (Tom Point Light). The passage is approximately 1 nm wide in the vicinity of Turn Point and requires a vessel to make a turn of 85° to transit the next segment.

The Turn Point SOA applies to participating vessels of 100 meters (328 feet) or longer that operate within or approach the Turn Point SOA, southbound for Haro Strait and northbound for Boundary Pass or Swanson Channel. These vessels should make best efforts not to enter the Turn Point SOA when another VTS participant of 100 meters (328 feet) or more in length is already located in the area, unless (Reference 122):

> *"1. when following astern a minimum 0.5 nm (5 cables) separation is maintained with the vessel ahead,*
>
> *2. when overtaking in the SOA with the concurrence of MCTS Victoria that there is no opposing traffic and a CPA (closest point of approach) of at least 0.5 nm (5 cables) is maintained,*
>
> *3. if outbound from Boundary Pass and meeting an inbound vessel from Haro Strait already in the SOA, enter only after the outbound vessel is past the vector heading of the inbound vessel engaged in the turn and maintain at least a 0.5 nm (5 cables) CPA,*
>
> *4. if inbound from Haro Strait and meeting an outbound vessel from Boundary Pass already in the SOA, enter only after the outbound vessel has crossed a bearing line between Turn Point and Arachne Reef and maintain at least a 0.5 nm (5 cables) CPA."*

The Turn Point SOA has additional sailing requirements:

> *"All vessels should maintain a distance of at least 0.3 nautical mile off Turn Point. Special circumstances are considered to exist when more than two vessels, greater than 328 feet or more, are interacting around the SOA at the same time."*
>
> *"All 100 meter vessels in a special circumstance should maintain a CPA of at least 0.5 nautical mile, and continue to maintain a distance of 0.3 nautical mile off Turn Point"* (Reference 134).
>
> *"All VTS participants will verbally communicate with Victoria Traffic on VHF-FM Channel 11 when 3.0 nautical miles from Turn Point. VTS participants are expected to make safe arrangements with other VTS participants within or near the SOA."* (Reference 122).

Rosario Strait and Guemes Channel VTS Special Areas

The Rosario Strait VTS Special Area consists of those waters bounded to the south by the center of Precautionary Area "RB", which is a circular area of 2,500 yards radius centered at 48°26′24″N, 122°45′12″W; and to the north by the center of Precautionary Area "C", which is a circular area of 2,500 yards radius centered at 48°40′34″ N, 122°42′44″ W; Lighted Buoy "C" (Figure 9, Reference 6).

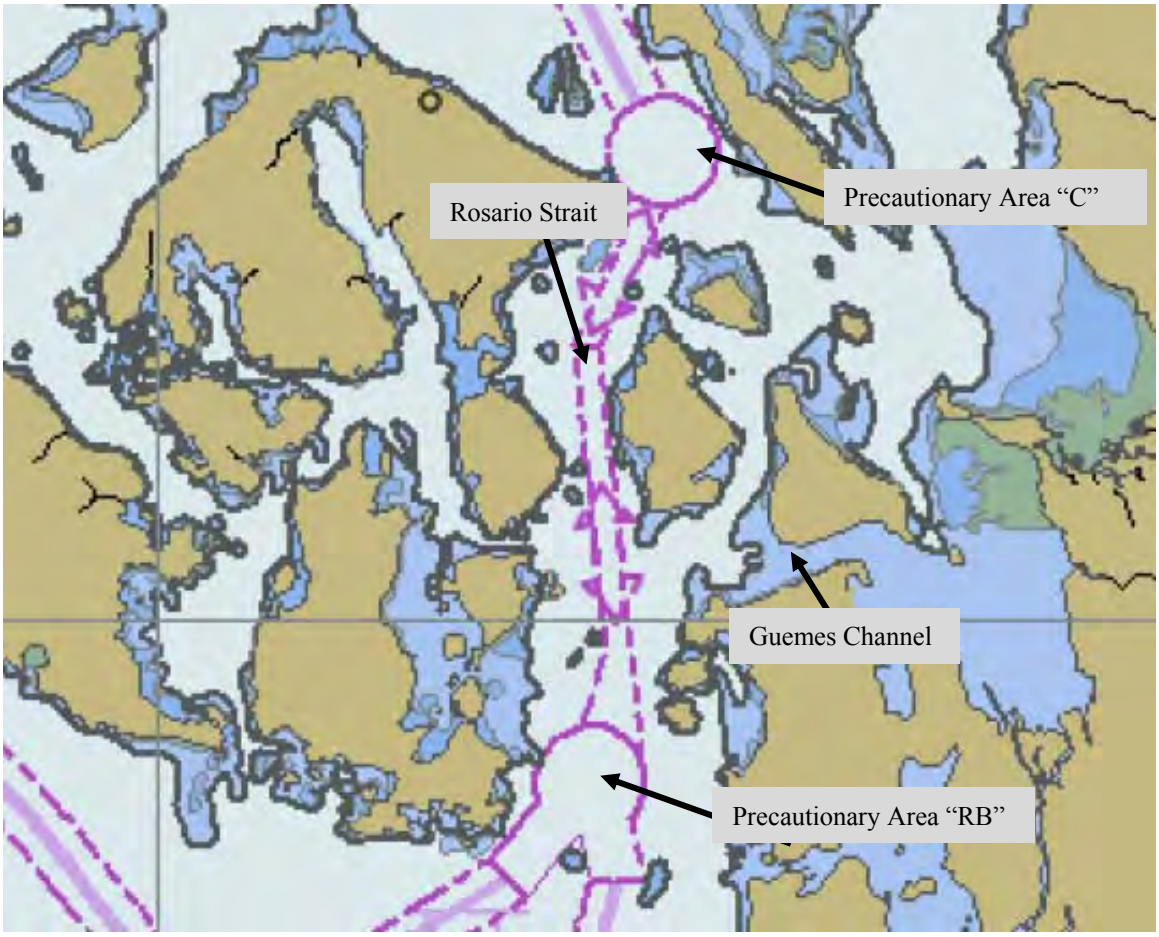

Figure 9 Rosario Strait and Guemes Channel

The Guemes Channel VTS Special Area consists of those waters bounded to the west by Shannon Point on Fidalgo Island and to the east by Southeast Point on Guemes Island (Figure 9).

Rosario Strait and Guemes Channel share the following additional VTS Special Area Operating Requirements per 33 CFR §161.55 (Reference 4):

> *"(1) A vessel engaged in towing shall not impede the passage of a vessel of 40,000 dead weight tons or more.*
>
> *(2) A vessel of less than 40,000 dead weight tons is exempt from the provision set forth in §33 CFR §161.13(b)(1).*
>
> *(3) A vessel of less than 100 meters (328 feet) in length is exempt from the provisions set forth in §33 CFR §161.13(b)(3). Approval will not be granted for:*
>
> > *(i) A vessel of 100 meters or more in length to meet or overtake; or cross or operate within 2,000 yards (except when crossing astern) of a vessel of 40,000 dead weight tons or more; or*
> >
> > *(ii) A vessel of 40,000 dead weight tons or more to meet or overtake; or cross or operate within 2,000 yards (except when crossing astern) of a vessel of 328 feet or more in length."*

Additionally, the following operating requirements apply within a VTS Special Area (Reference 5):

> *"(a) A VTS User shall, if towing astern, do so with as short a hawser as safety and good seamanship permits.*
>
> *(b) A VMRS User shall:*
>
> *(1) Not enter or get underway in the area without prior approval of the VTS;*
>
> *(2) Not enter a VTS Special Area if a hazardous vessel operating condition or circumstance exists;*
>
> *(3) Not meet, cross, or overtake any other VMRS User in the area without prior approval of the VTS; and*
>
> *(4) Before meeting, crossing, or overtaking any other VMRS User in the area, communicate on the designated vessel bridge-to-bridge radiotelephone frequency, intended navigation movements, and any other information necessary in order to make safe passing arrangements. This requirement does not relieve a vessel of any duty prescribed by the International Regulations for Prevention of Collisions at Sea, 1972 (72 COLREGS) or the Inland Navigation Rules."*

2.3.3 Alternatives for Vessel Traffic Management

This section outlines alternatives for vessel traffic management. Vessel traffic management techniques can be varied in approach. Voluntarily adopting operating practices used by other forms of shipping could help minimize the burden of regulatory, international, state, and local approvals, and reduce the impact to other shipping concerns utilizing the same waterways. For example, vessels can choose to adopt voluntary speed reduction, like the Port of Long Beach program. Alternatively, the introduction of innovative methods not currently approved or practiced could offer some advantages to improving the safety of the transit, but could be burdensome in the regulatory approval process and alter current traffic patterns. In the long term, these might prove challenging for acceptance by other shipping and regulatory concerns. Alternatives in this section are based on current measures in place rather than completely new solutions, with the aim of providing minimally burdensome additional vessel traffic management techniques.

Applicability to any or all categories of vessel traffic, including traffic specific to the Gateway Pacific Project, was considered in developing the traffic management alternatives. How each alternative could be applied to a specific vessel, all vessels in a particular area, or by all vessels in the study area factored into a relative ranking.

The following alternative management schemes have been ranked in terms of their potential effectiveness. For the purposes of this section, effectiveness is defined as: the inferred likelihood that a particular scheme could prevent a collision, allision, or grounding, in the event of a vessel propulsion, steering or control system failure, or a situation where two vessels have approached so closely that collision can no longer be avoided by one ship acting alone (i.e. *in extremis*). Effectiveness is evaluated without consideration to cost. This list of

alternatives and evaluation of effectiveness is purely qualitative, based on Glosten's own expertise, and is not intended to imply that systems currently in place for vessel traffic management are somehow deficient or ineffective.

The alternative management schemes are further expanded on below and are ranked by their expected effectiveness from highest to lowest as follows:

1. Mandatory Tug Escort
2. Voluntary Speed Reduction
3. Standby Rescue/Response Tugs
4. Area Transit Plans
5. Complements to the Existing Traffic Separation Scheme
6. Supplemental Aids to Navigation

Whereas these alternatives focus on vessel traffic management, separate risk reduction options (RROs) were developed with a broader application. These RROs have applicability to one or more of six stages of a risk event, whereas the alternative management schemes all address the basic or root cause stage of an event (see stage descriptions in Section 5). RROs identified include applicability to: vessel traffic management; anchorage management; vessel servicing; training; crewing; on-board technology; data collection of risk assessment, emergency notification and risk communication; vetting and inspection; spill containment and cleanup; standard operational procedures for vessels, mooring, and oil transfers; ballast water systems and operations; and standby, rescue, escort, and assist tugs. RROs were developed in discussion with members of Glosten's technical staff, as well as representatives of the Lummi Nation, the Department of Ecology, and PIT. The process and results from the RRO discussion group are listed in Section 5.

Neither the RROs nor the vessel traffic management alternatives are considered exhaustive or fully developed. It is acknowledged that any mandatory action would need to be implemented through regulatory action involving multiple agencies of the federal, state, and local government. Even for voluntary measures, the feasibility or likelihood of gaining support from government, the international shipping community, or other interest groups is not factored into the assessment. The following discussion of the six alternative management schemes focuses on their potential effectiveness.

2.3.3.1 Mandatory Tug Escort

Although tankers are required to have a tug escort in some parts of the study area, there are no regulations in place mandating tug escorts for bulk ships. Washington law currently requires oil tankers entering Puget Sound to have one tug escort with a minimum horsepower equivalent to 5% of the deadweight tonnage of the vessel the tug is escorting. In theory, a single escort tug could act as scout, close escort, or tethered tug to aid bulkers and potentially may increase the safety of vessel traffic. BCCP sometimes call tug escorts for slow bulkers or those traveling under adverse weather conditions (Section 2.2.3.1). Tug escort for smaller vessels would be less useful, and the tug itself could pose additional risk. It is believed that mandatory tug escorts for vessels Panamax and larger in Puget Sound could increase marine safety.

Tug escorts may help a distressed vessel by applying corrective forces to the sides or rear of the vessel. Assistance to a distressed vessel may involve either pushing directly against the vessel, or using a tethered line to pull the vessel. In routine escort circumstances where the escorted vessel is not in distress, tugs are sometimes tethered to the escorted vessel to improve response time in restricted areas.

Glosten believes mandatory tug escort is the most effective alternative management scheme because the tug is dedicated to a particular vessel for the duration of the inbound or outbound transit, essentially acting as a completely redundant power plant. The tug stays in close proximity to the ship and is able to provide assistance in the ways described above almost immediately. This is the only management scheme that enables the immediate application of braking power in the event of a loss of propulsion or other condition that renders the ship unable to maneuver. Of the five alternatives investigated in this study, this would have the greatest operational expense.

2.3.3.2 Voluntary Speed Reduction

It is important to note that VTS and USCG Sector 13 do not dictate or actively manage the speeds of commercial vessels in Puget Sound. While VTS works to facilitate safe, efficient, and reliable marine transportation, they do so by providing information to mariners. Vessel speeds are governed by USCG Navigation Rules Rule 6, *Safe Speed*, which states (Reference 86):

"Every vessel shall at all times proceed at a safe speed to that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions."

For a variety of reasons, many of which are characterized in the subsections of Rule 6, the notion of mandatory speed limits for commercial vessels is a contentious topic. In certain areas however (e.g. the Port of Los Angeles/Port of Long Beach vicinity), voluntary speed reduction programs have been developed and have seen near 100% rates of compliance by vessel operators (See Port of Long Beach *Green Flag Incentive Program* Operator Compliance Report, Reference 54). Reduced vessel speed could be incorporated with just-in-time arrival management, discussed in Section 2.4.5.4.

Employing a simple, voluntary speed reduction program in Haro Strait, Boundary Pass, and Rosario Strait would allow additional time for pilots and/or masters to assess navigational situations and conditions, and to take countering action to prevent an incident, or reduce the impact of a casualty, if encountered. It would also reduce the stopping time/distance of a ship in the event of a propulsion or steering system failure, and allow additional time for assistance to arrive. Reducing vessel speed would also give ships' bridge teams more time to develop situational awareness. For these reasons, voluntary speed reduction is considered to be a highly effective management practice, second only to having a dedicated escort tug for the duration of the inbound or outbound transit from Port Angeles.

2.3.3.3 Standby Rescue/Response Tugs

A strategically positioned Emergency Response Towing Vessel (ERTV) or "rescue tug" has been stationed in Neah Bay, Washington during the winter months since 1999, and year-round

since 2008. The intent of the ERTV is to serve as a safety net to prevent disabled ships and barges from grounding off Washington's outer coast or the Western Strait of Juan de Fuca.

The use of similar ERTVs in Haro Strait and/or Rosario Strait is another potential management scheme for traffic risk mitigation in the eastern portion of the study area. One or more ERTVs could be stationed in Haro Strait and/or Rosario Strait to respond to disabled vessels on those routes, including vessels bound to and from GPT. However, due to the comparatively narrow geography surrounding these waterways, there is limited sea room (i.e. time) for ERTV response in the event of propulsion, steering, or control system failure. As an example, an ERTV stationed in Anacortes would take 1.5 hours (at 12 knots) to reach a disabled vessel near Buoy "CA" (Figure 10). This does not account for any delays related to "crew up" time, opposing tidal currents, or time required to get a line aboard the stricken vessel. It is likely that in many cases a Tug of Opportunity would be able to respond more quickly than pre-positioned ERTVs, under the existing International Tug of Opportunity System (ITOS).[9] For this reason, this management scheme is considered less effective than voluntary speed reduction, which is more preventative in nature.

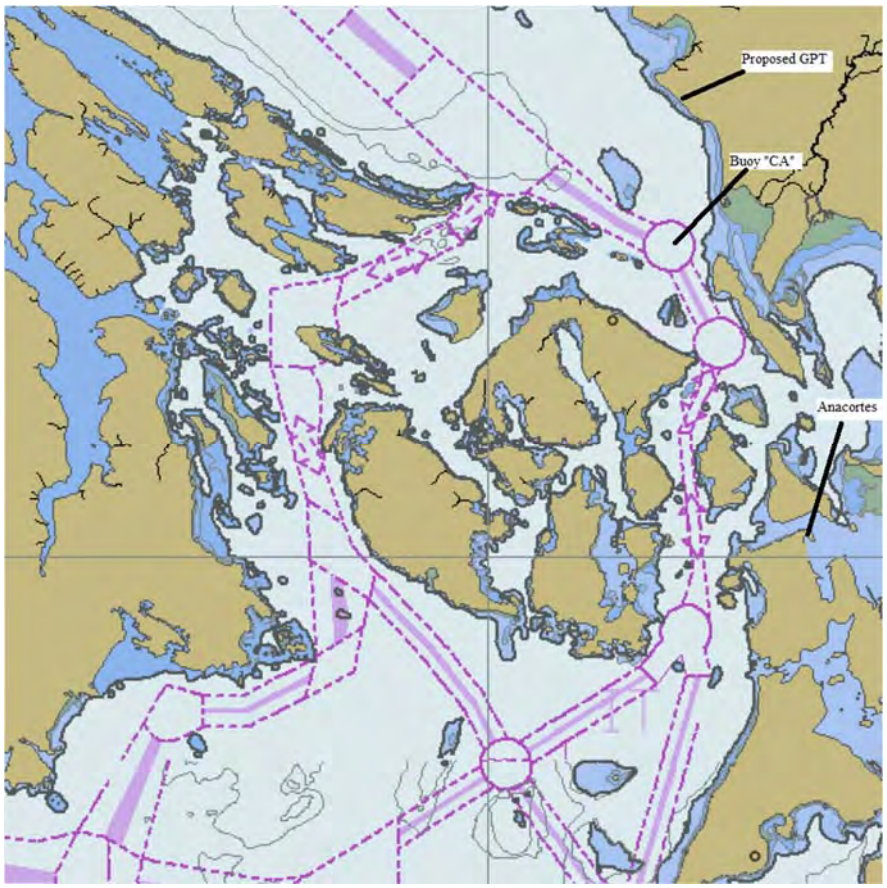

Figure 10 Buoy "CA," Anacortes, and GPT location

[9] International Tug of Opportunity System (ITOS) has been in place in Puget Sound and adjacent waters since 1997. A "Tug of opportunity" is a towing vessel that can be quickly identified to respond to a vessel in distress due to a loss of power or steering (Reference 61).

2.3.3.4 Area Transit Plans

Another potential management scheme is requiring ship masters to develop and submit Preliminary Area Transit (PAT) Plans prior to transiting the eastern portion of the study area.

Among other navigation tools, pilots and ship masters currently rely on AIS data, generally integrated with ARPA radar and electronic chart programs, to navigate safely in high traffic areas. This information helps mariners avoid situations that could introduce risk of collision. Specifically, AIS data can influence decisions relative to vessel speed, course headings, and rates of turn. AIS data also enables bridge teams to plan arrival and departure times to coincide with favorable traffic conditions.

PAT Plans would essentially involve providing VTS with a rudimentary plan for transiting the area using this real-time traffic information. The plans would be reviewed by the pilot upon boarding, and submitted to VTS just prior to departing the terminal (for outbound vessels) or the pilot station (for inbound vessels).

The PAT Plan itself would consist of basic data points such as intended speeds and estimated times of arrival at key waypoints in the TSS. The data would be submitted on a standard form, in a common file format such as Microsoft Excel. VTS would not approve or reject submitted plans, but would use the information to compare a vessel's intended transit with the intended transits of other vessels, thereby enabling VTS to identify potential traffic conflicts well in advance of their development in reality.

Of course, the submitted PAT Plans would not obligate vessels in any way during their transits. The primary objective is to force early awareness of other vessels and encourage proactive planning on the part of the bridge team. The plans would, however, allow VTS to infer the intent of any deviations and verify that vessels are monitoring one another and taking appropriate action in time to avoid risk of collision.

There would be a number of technical challenges associated with implementing this management scheme, including the development of new procedures and, potentially, new software and increased staffing for VTS. Infrequently calling vessels and vessels without internet capability would also present certain challenges. However, once in place, this process would likely enhance marine safety across the eastern portion of the study area. This scheme is preventative in nature only, and is therefore ranked less effective than alternatives that incorporate a response strategy.

2.3.3.5 Complements to the Existing Traffic Separation Scheme

The existing TSS within the study area has evolved over many years to accommodate marine traffic patterns in the region. Considering its history of zero documented ship collisions in Haro or Rosario Strait (see Section 3.3), it now stands as a testament to the value of TSSs in preventing vessel collisions. Nevertheless, some alternative traffic control approaches might be employed to enhance vessel safety in the region and continue this record of accomplishment, even as traffic volumes increase.

Modification of existing routing schemes, such as altering the current traffic lane approaches from Seattle, the Strait of Juan de Fuca, and the Strait of Georgia, would require regulatory approvals from State, Federal, and International interests. Routing changes would need to be investigated for impacts to tribal fishing operations during harvest season. More importantly,

there is little assurance that any modification of the existing TSS would appreciably enhance vessel safety. In fact, substantial changes to the existing TSS could potentially introduce new navigation risks, or create new traffic patterns that have not proven to be manageable over many years, and tens of thousands of ship movements. The establishment of voluntary traffic guidelines or "best practices" in the area approaching GPT and other nearby facilities may be appropriate considering that the proposed GPT project would introduce higher concentrations of large ship traffic to the immediate area.

The goal of this management scheme would be to limit conflicting (e.g. anchored) or opposing traffic in the area between Alden Bank and Neptune Beach/Cherry Point on the mainland. Currently, Puget Sound Pilots berth tankers "starboard side to" at the Phillips 66 refinery at Ferndale and adopt a generally counter-clockwise approach to navigating into and out of berths in this area (See Reference 51 and Figure 11). Adopting a similar practice at the proposed terminal would complement this current traffic pattern. Voluntary use of alternative anchorage areas (i.e. avoiding use of the anchorage area between Alden Bank and Cherry Point) would also reduce risk in this area. Lastly, establishing these "best practices" as a set of written guidelines would encourage, if not ensure compliance from Puget Sound Pilots and vessel operators. Alternatively, the same practices could be incorporated into the Puget Sound Pilots Vessel Guidelines.

While there are compelling reasons to adopt this management scheme, its ability to reduce marine risk is preventative in nature only, and limited to the immediate area around Ferndale/Cherry Point. It is therefore ranked as less effective than alternative management schemes that incorporate a response strategy, and have the potential to reduce risk over the broader study area.

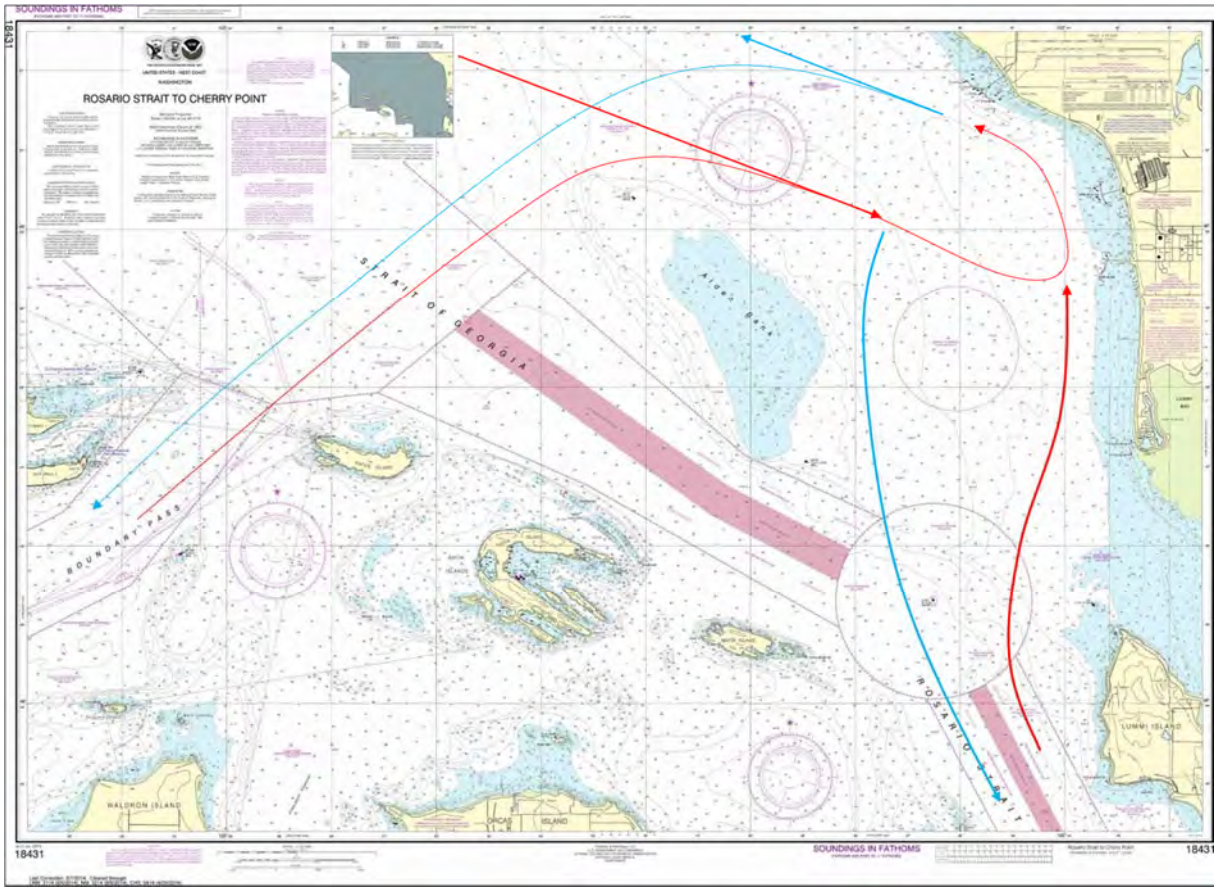

Figure 11 Routing alternative for arrival and departure from GPT

2.3.3.6 Supplemental Aids to Navigation

Haro Strait, Boundary Pass, and Rosario Strait are well-established thoroughfares for marine traffic. As such, they are also well-marked by a system of buoys and fixed aids to navigation that indicate the preferred fairway, prominent points on land, and hazards such as submerged or low-lying rocks. Though the navigational infrastructure in these straits is well developed, the installation of additional aids to navigation may improve marine safety in the area. Some examples of possible new aids to navigation are described below.

Given there are relatively long and strait course headings on both routes, lighted ranges could be installed in key locations to indicate if a ship is travelling on a safe course over ground (COG), or staying within the appropriate traffic lane. Each range would consist of a pair of fixed lights onshore, that, when visually aligned, indicate a preferred line of approach. More specifically, optimal course headings to and from terminals in the Cherry Point area (the proposed GPT, BP, and Phillips 66) and the Southern Strait of Georgia using Rosario Strait could be marked by:

- Range lights placed on Blakely Island and Lummi Island for the leg from Buoy "C" to Lydia Shoal (Figure 12).
- Range lights on Orcas Island for the leg between Lydia Shoal and Cape St. Mary (Figure 12).

- Range lights on Burrows Island for the leg from Cape St. Mary to Davidson Rock (Figure 13).

These ranges would not be consistently visible at certain distances, however, due to changing weather and atmospheric conditions. Their effectiveness, therefore, would be limited.

Another option would be installation of additional traffic separation buoys in mid-channel to divide inbound and outbound traffic. Similar to lighted ranges, these buoys would not be visible in certain weather/sea conditions; however, their presence would be easily detected by radar, making them plainly apparent to the bridge team of a vessel. This enables the buoys to serve their intended purpose in almost any weather or sea condition.

Possible locations for additional buoys, however, may be limited by the geography of the area and the existing traffic separation scheme. Fitting locations such as the Turn Point Special Operating Area, and off Lydia Shoal, are not wide enough to accommodate standard traffic lanes and separation zones, where such buoys are normally installed.

The application process for new navigational aids, public and private, is through the United States Coast Guard and is defined in 33 CFR§66.01-5 (Reference 18). The feasibility for approval and installation of the additional aids to navigation described above has not been evaluated.

Logically, the placement of additional aids to navigation in Haro Strait, Boundary Pass, and Rosario Strait would enhance vessel safety in the area to some extent, but it is not likely to make an appreciable difference, particularly when one considers the capabilities of modern electronic navigation tools onboard most vessels. Additionally, this management scheme is, of course, purely preventative in nature. For these reasons, the installation of supplemental aids to navigation is ranked as less effective than alternative management schemes presented in this section.

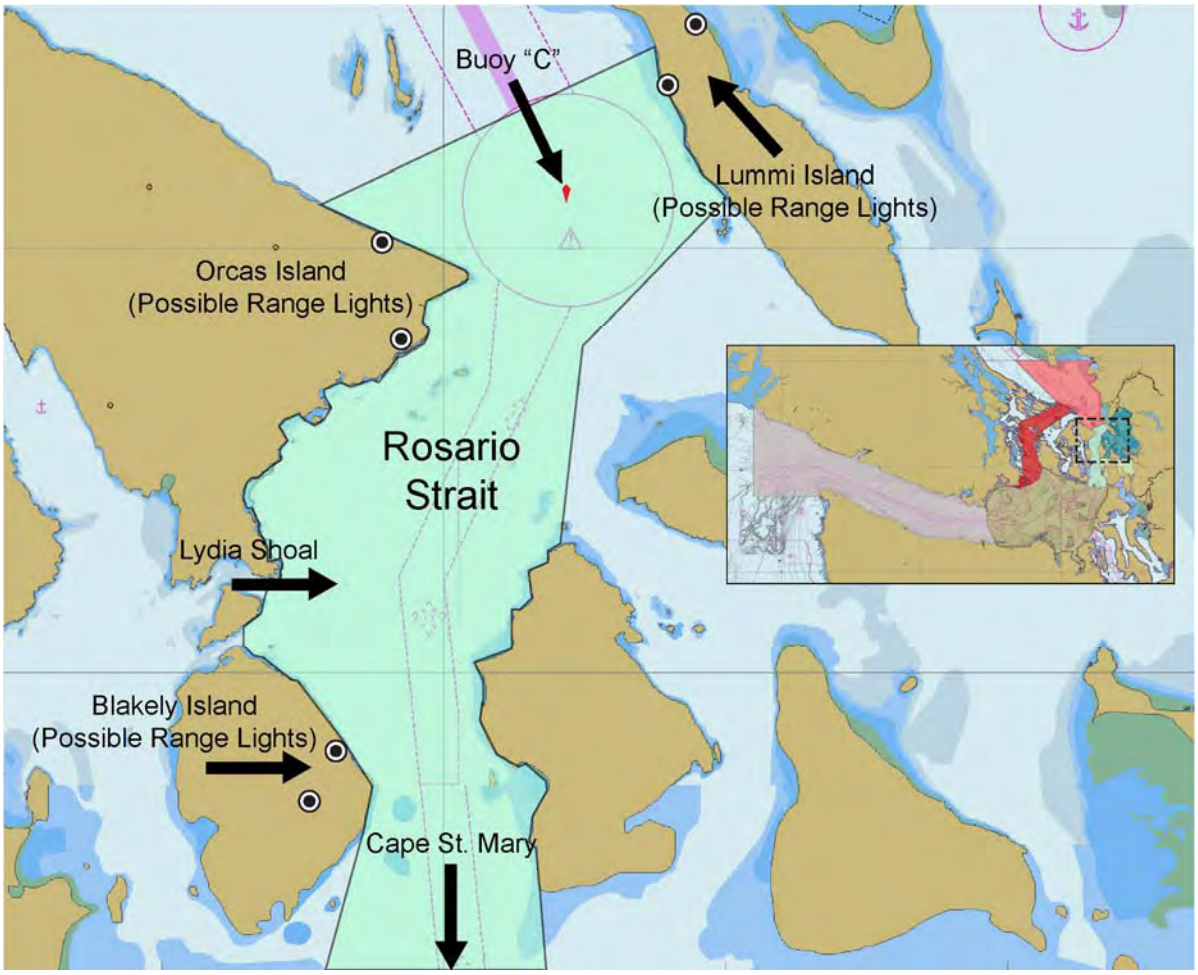

Figure 12 Possible range lights for Northern Rosario Strait. North is up and a key map is provided for scale

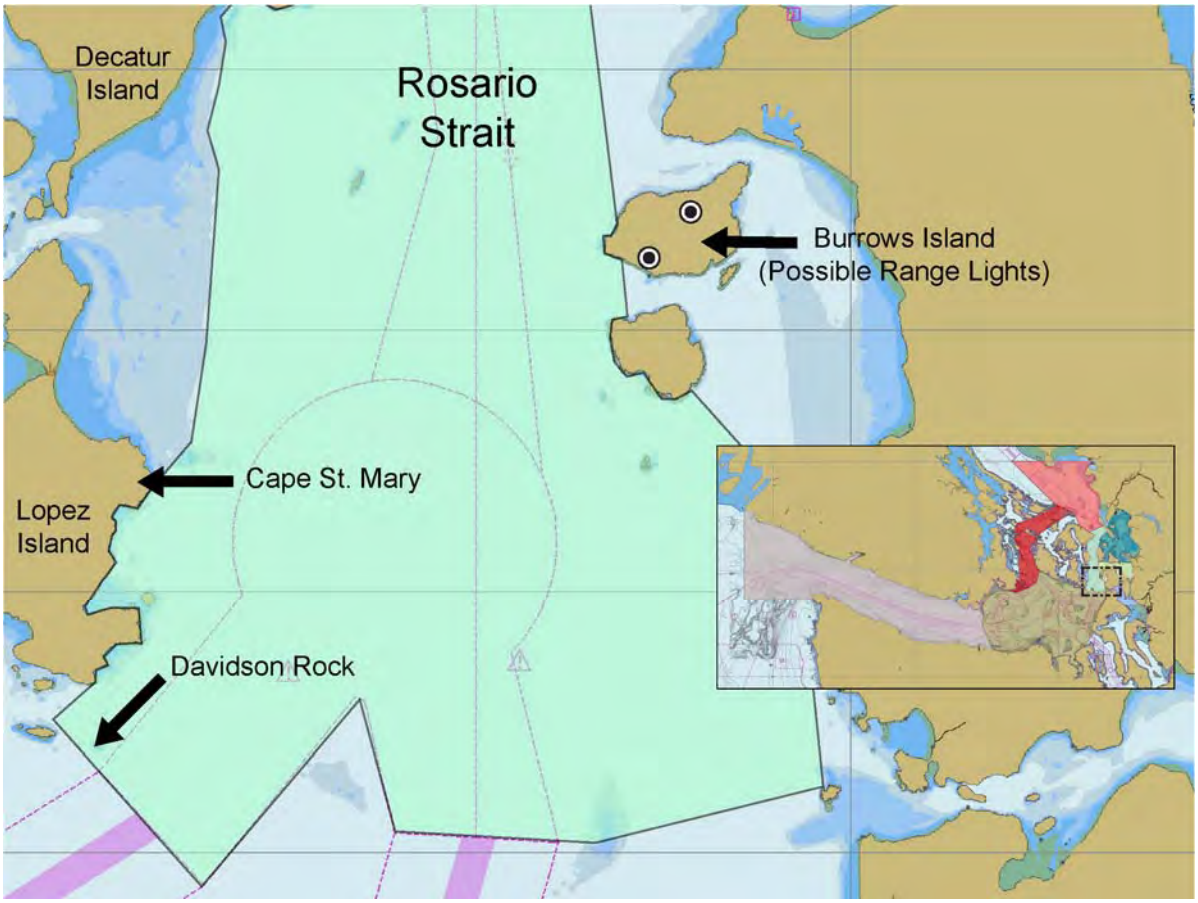

Figure 13 Possible range lights for Southern Rosario Strait. North is up and a key map is provided for scale

2.4 Anchorages

2.4.1 Introduction

This section reviews the existing anchorages in the study area, compares their use, and then analyzes whether they have adequate capacity for GPT-calling traffic at anticipated levels, per Reference 114.

The overview of existing anchorages uses Coast Guard regulations, Harbor Safety Committee guides, local charts, and interviews with area marine pilots to describe the characteristics and suitability of anchorages for bulkers.

The anchorage activity comparison uses historical vessel traffic information provided by the Marine Exchange (MX) of Puget Sound and the US Coast Guard (USCG) Sector Puget Sound to show historical use of anchorages. 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 individual vessel movements from the initial point of detection through all inter-harbor and coastwise shifts, and ultimately departure. MX can generate reports from its database, along with certain reports from 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.

USCG Sector Puget Sound is designated as the Captain of the Port's (COTP) authorized representative. According to applicable regulations, no vessel shall anchor in any of the general anchorage areas examined in this study without prior permission from either the COTP or their 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 (Reference 2), which effectively creates a reservation system. USCG Sector Puget Sound maintains a database of these anchorage reservations; this database is the most accurate and consistent record of activity at North Puget Sound anchorages. This database is used with a high level of confidence for the basis of this study.

The anchorage demand forecast compares the historical anchorage use and corresponding anchorage availability to estimate anchorage demands from future traffic. It estimates future vessel traffic based on several cases, including anticipated GPT traffic as well as other potential area traffic. This forecast uses a queuing model to predict the amount of time future GPT-calling vessels would potentially spend at anchorage, and compares this to the average historical and forecast anchorage availability in the study area.

This analysis concludes that adequate anchorage capacity for GPT traffic will exist in 2019 within the available anchorage areas. A particular anchorage area may occasionally be at capacity, however, which would force a GPT-calling vessel to move to a different anchorage area or to reschedule their arrival time at the proposed GPT.

2.4.2 Background

The eight primary anchorage areas used by vessels in the study area are located at Cherry Point, Bellingham Bay, Vendovi Island (two subareas), Anacortes (three subareas), and Port Angeles (Figure 14). Table 3 lists the Vessel Traffic System abbreviation, maximum capacity, limitation of stay at each anchorage, and radius. These anchorage area characteristics are defined within "Puget Sound Anchorages," Puget Sound Harbor Safety Plan (HSP), written by the Puget Sound Harbor Safety Committee (Reference 102). Their published maximum capacity already takes into account weather limitations, which is one factor that influences anchorage capacity and use. Additional factors affecting maximum anchorage area capacity include whether the vessels are laden or unladen, and the ground-holding properties of the anchorage. No further limitations to capacity were found based on the larger, Capesize vessel size. These factors are discussed in the next subsection, 2.4.3, specific to each anchorage area. Of the eight primary anchorage areas, the maximum capacity for GPT-calling vessels is reduced for two anchorage areas: Bellingham Bay and Cherry Point (see Section 2.4.5). Otherwise, the forecasted anchorage capacity is defined as published by the Puget Sound Harbor Safety Plan.

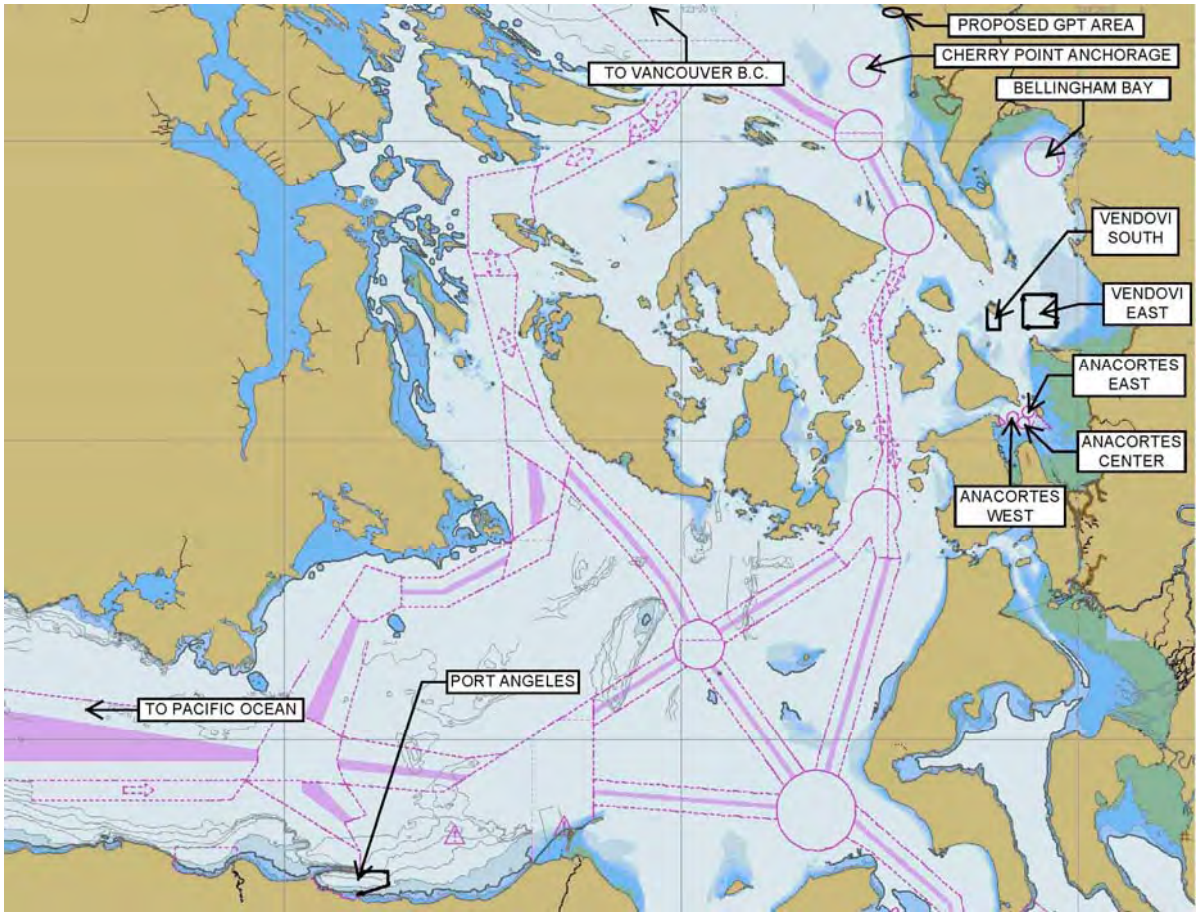

Figure 14 Anchorages in the study area

The USCG has been delegated the authority to establish, administer, and enforce anchorage areas pursuant to 33 CFR §109 and 110. Authority is then re-delegated to the USCG District Commanders under 33 CFR §1.05-1(e)(1) (Reference 99).

In 1976, Puget Sound Area Anchorages rulemaking defined 11 general and explosives-transferring anchorages within the greater Puget Sound area. These areas were described using geographic land bearings and ranges as the boundaries. Designated anchorages include both general and special anchorages and are labeled as anchorages on NOAA charts. A non-designated anchorage is not labeled as an anchorage; however, ships anchoring in a non-designated anchorage must still notify the USCG. The USCG controls reservations in both designated and non- designated anchorages.

On 1 July 2012, changes were made to the anchorage areas in the study area. The regulation reorganized 33 CFR§110.230 by incorporating 33 CFR§110.229, modifying the descriptions of four general anchorages. These changes clarified to the general public the boundaries and requirements of anchorages.

This rule also updated existing anchorages to describe areas using points of latitude and longitude, which, with the advent of GPS, is much more practical and accurate for the mariner. Additionally, the rules corrected outdated boundaries to reflect changes to shoreside infrastructure, safety and security zones, and environmentally sensitive areas. For example, although Port Angeles is one of the busiest anchorage areas in Puget Sound and has been used

as a general anchorage for many years, it was never originally codified in the Code of Federal Regulations. This rulemaking brought the Port Angeles anchorage into line with the other anchorages in Puget Sound. Changes did not affect the study area anchorages in number, size, or position of available anchorages in any way that concerns the proposed GPT shipping.

Table 3 Anchorages in North Puget Sound, Reference 102

General Anchorages	Abbreviation	Number of Vessels Accommodated	Maximum Stay	Radius*
Designated Anchorages				
Cherry Point	CP	1	30 Days	1,620 yards
Bellingham Bay	BB	6	30 Days	2,000 yards
Anacortes West	ANW	1	6 Days	600 yards
Anacortes Central	ANC	1	10 Days	600 yards
Anacortes East	ANW	1	10 Days	600 yards
Non-Designated Anchorages				
Vendovi Island East	VIE	4	10 Days	1,660 yards
Vendovi Island South	VIS	1	10 Days	648 yards
Port Angeles Harbor	PA	5	10 Days	506 yards

*Bellingham Bay anchorage is defined in 33 CFR §110.230 - 2(i). Port Angles anchorage is defined in 33 CFR §110.230 – 14. All anchorages are then divided into swing radii to fit the defined number of ships in the HSP for each anchorage.

2.4.2.1 Anchorage Preferences

In addition to the quantitative data from the anchorage database, qualitative data was provided by the VTS Director, Mark Ashley. Mr. Ashley discussed how anchorage usage and capacity in the study area is managed, and emphasized that many different factors play into where a vessel goes to anchorage. The following notes summarize his feedback (Reference 66).

- Certain anchorage areas are preferred. Preferences stem from:
  - proximity to route,
  - conditions for the deeper draft vessels, and
  - infrastructure and cost for bunkering, if needed.
- As each anchorage area reaches capacity, the VTS typically assigns reservations to the next anchorage area in this order: Port Angeles, Vendovi, Anacortes, and then Bellingham Bay.
- Port Angeles (PA) is the busiest and most requested anchorage area. PA is often requested because it supports bunkering, and is also where pilots depart to meet a vessel en-route east through the Strait of Juan de Fuca (and return to after piloting the outbound voyage). Still, PA only reaches capacity about 10% of the time. When it fills up, VTS then typically sends vessels to Vendovi.
- Vendovi reaches capacity occasionally, usually with only two vessels there. After Vendovi fills up, VTS typically sends vessels to Anacortes.

- Anacortes is generally used by tankers calling at the nearby refineries, but could also be used by bulkers. After Anacortes reaches capacity, VTS typically sends vessels to Bellingham Bay.
- Bellingham Bay can accommodate six vessels, but it has never exceeded three.
- Pilots do not like the Cherry Point anchorage area. It is typically used for short-term queuing only.
- After Port Angeles, Vendovi, Anacortes, and Bellingham Bay, there are still more available anchorage areas for when there is high demand.

2.4.2.2 Anchorage Activities

Mark Ashley also provided feedback on vessel activity at anchorages. The following notes summarize his comments (Reference 66).

- The majority of the times that the vessel goes to anchor, it is because it is waiting for an available berth. However, the vessel traffic system has many "moving parts", and there are assorted reasons why a vessel would go to anchor, in addition to queuing. Reasons for anchoring are listed in rough decreasing order of likelihood:
    1. Queuing.
    2. Bunkering.
    3. Waiting for vessel agent to send the vessel elsewhere.
    4. Lightering.
    5. Repairs. Although typically done at the dock, a repair on the propulsion system may have to be done at anchor before the vessel could head underway to the dock. Repairs could be taken on while waiting for a tug assist.
- Although queuing may be the most likely reason that vessels go to anchor, the VTS would not be able to estimate the amount of queuing time. The VTS does not manage vessel arrival times. That is managed by the vessel, often in coordination with the destination terminal.

2.4.3 Current Anchorage Location and Usage Overview

This section details the eight existing anchorage areas in the study area, and their capacity (in number of ships and days) for GPT-calling vessels. The capacity of an anchorage area for GPT vessels depends on its characteristics. For example, while Bellingham Bay can accommodate six vessels, approximately half of the anchorage area available is less than 10 fathoms (60 feet) in depth. As a result, GPT-bound vessels are likely to use only three of the six available anchorage spots. In addition, the Cherry Point anchorage is only seasonally available due to high winds (Section 2.4.3.1). Over the past two years, Cherry Point has recorded winds of over 19.1 knots for about 25% of the year.[10] Table 4 shows the results of

[10] Winds of 19.1 knots is a data point from a study of escort tugs in Puget Sound conducted by Glosten for the State of Washington (Reference 123). Above that speed, the Pilot might consider the use of another anchorage. Anchorage capacity published by the Puget Sound HSC already account for weather restrictions.

this overview for all of the study area anchorages. Capacity for GPT bulkers is calculated as a product of the number of GPT size vessels an anchorage area can accommodate times the estimated number of days that anchorage area is available for use, considering weather trends. This capacity is therefore given in vessel days.

Table 4 Anchorage capacity for GPT-calling bulkers in North Puget Sound

Study subarea	Anchorages	Total Capacity (number of vessels)	GPT-Calling Bulker Capacity (number)	Capacity for GPT (vessel days per year)	Sub-area Capacity for GPT (vessel-days per year)
Cherry Point	Cherry Point	1	1	274	274
Guemes Channel	Anacortes West	1	1	365	1,095
	Anacortes Central	1	1	365	
	Anacortes East	1	1	365	
Saddle-bag	Bellingham Bay	6	3	1,095	2,920
	Vendovi Island East	4	4	1,460	
	Vendovi Island South	1	1	365	
Juan de Fuca East	Port Angeles Harbor	5	5	1,825	1,825
Total		20	17	6,114	

Adjusting for specific anchorage characteristics, the overall capacity of existing anchorages that could support GPT-bound vessels is 6,114 annual vessel days. The maximum annual utilization of all anchorages during the period of this study (2006-2010) was in 2007 with 1,444 vessel days, or 23.6% utilization. The average annual utilization (2006-2010) was 20%, leaving 80% available. The maximum usage year for each subarea and overall is shown in bold in Table 5.

Table 5 Vessel days at anchor by subarea, Reference 14

Subarea	Capacity (vessel-days per year)	2006	2007	2008	2009	2010
Juan de Fuca East	1,825	545.4	**662.7**	495.9	532.0	437.1
Guemes Channel	1,095	251.3	354.7	282.2	**393.1**	363.0
Saddlebag	2,920	259.3	**407.7**	315.1	473.3	263.8
Cherry Point	274	15.3	**19.0**	14.4	12.8	5.9
Total	6,114	1,071.4	1,444.0	1,107.6	1,411.2	1,069.8

The Juan de Fuca East sub-area includes the Port Angeles anchorage area. It is the busiest anchorage of the study subareas. Port Angeles has an annual capacity of 1,825 vessel days (five sites available for 365 days a year). The maximum utilization of Port Angeles occurred in 2007 with 663 vessel days, or 36% utilization. Cherry Point, which can accommodate only one vessel at a time, is the least active of all of the anchorages and has an average utilization of 5%. The maximum utilization of Cherry Point was in 2007 at 19 vessel days.

The following sections detail the specific characteristics of each anchorage area. They are divided into study subareas. Figure 15 shows the study area divided into subareas. Neither the Rosario Strait nor Haro Strait/Boundary Pass subareas contain any anchorages. Each section below describes the relevant anchorage areas within the particular subarea, including both physical conditions and their current patterns of use.

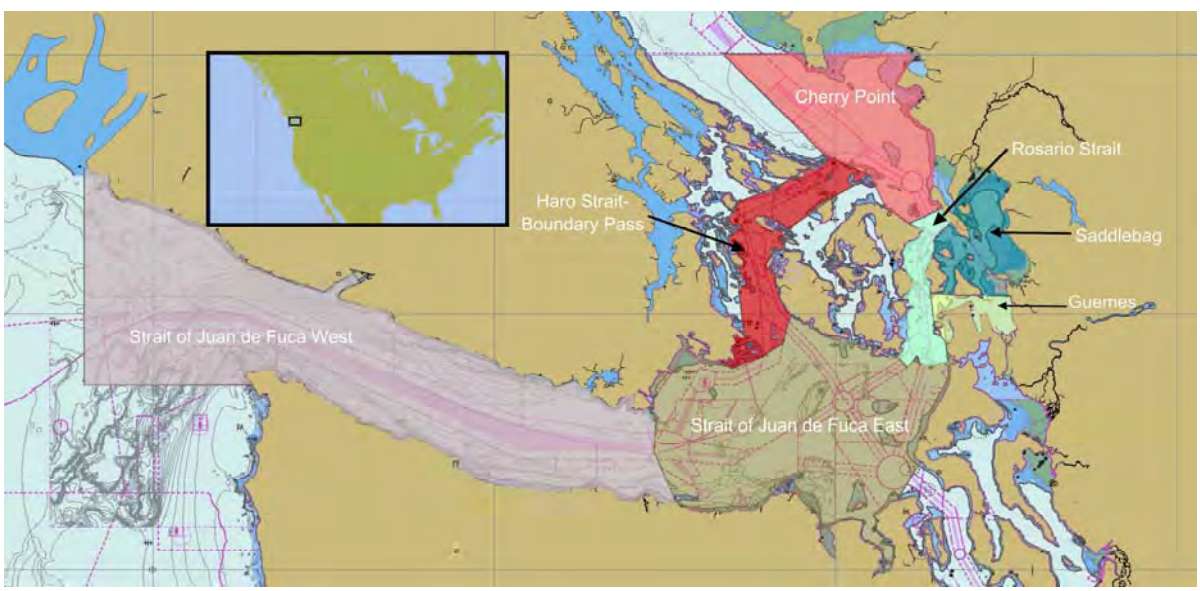

Figure 15 Study subareas. North is up and a key map is provided for scale

To calculate the number of vessels each anchorage area could accommodate, the following characteristics were used:

- Capesize ship: 984 feet LOA × 164 feet B × 61 feet D – (Largest ship to call at Westshore Terminal, BC, Canada per BCCP).
- Anchor Chain Scope: Five times the depth of water.
- Freeboard: 20 feet.
- Maximum swing radius (yards) is calculated using Equation 2-1:

$$Maximum\,swing\ radius = \frac{LOA_{(ft)} + \left[\left(Scope_{(ft)}\right)^2 - \left(WaterDepth_{(ft)} + Freeboard_{(ft)}\right)^2\right]^{1/2}}{3} \qquad 2\text{-}1$$

For instance, the swing radius for the Cherry Point general anchorage in Section 2.4.3.1 was calculated using the following values:

- LOA = 984 feet.
- Water depth = 174 feet (29 fathoms).
- Scope = 870 feet (174 feet × 5).
- Depth = 50 feet.
- Freeboard = 20 feet.

$$Maximum\ \ swing\ \ radius = \frac{984 + \left[870^2 - (174 + 20)^2\right]^{1/2}}{3} =\sim 610\ \ yds. \qquad 2\text{-}2$$

2.4.3.1 Cherry Point Subarea

<u>Cherry Point General Anchorage</u>

General statistics:

- Anchorage capacity and radius: One at 1,620 yards.
- Water depth: 29 fathoms (174 feet).
- Maximum ship swing radius: 610 yards.

Cherry Point general anchorage is managed by Vessel Traffic Service (VTS) Puget Sound on behalf of Sector Puget Sound and the COTP Puget Sound. The Cherry Point general anchorage encompasses waters within a circular area with a radius of 1620 yards, 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 by USCG regulation.

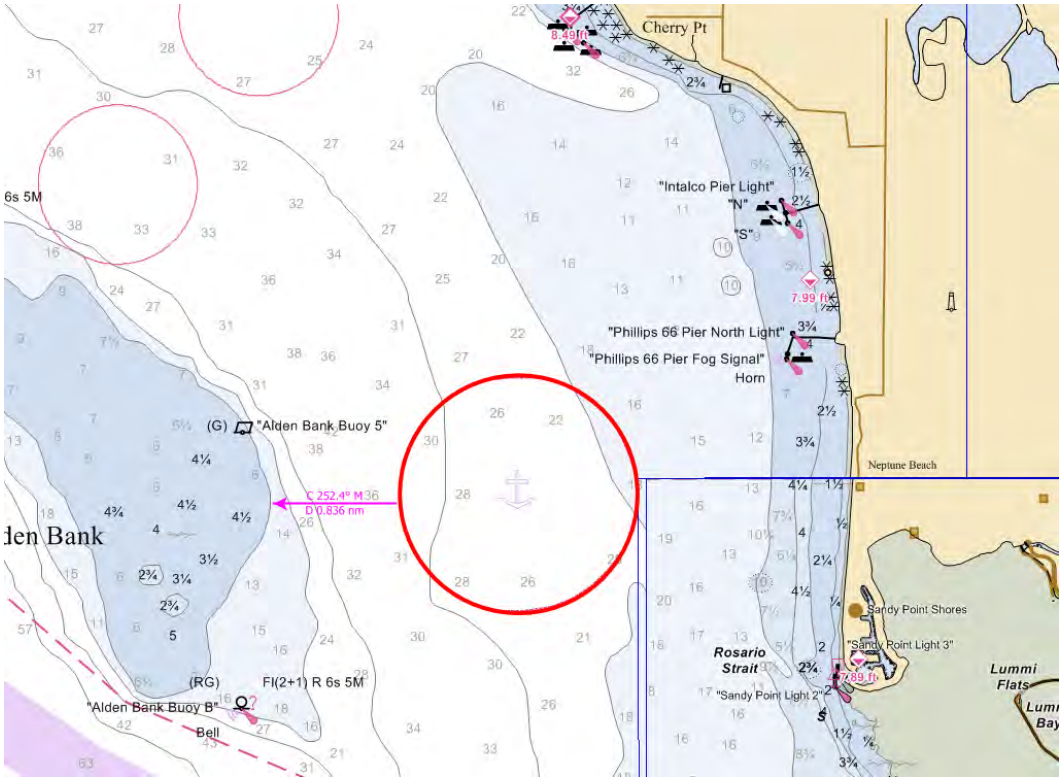

Figure 16 Cherry Point general anchorage

Alden Bank lays directly to the west and Neptune Beach to the east at a distance of .9 nm from the western and eastern outer edge of the anchorage area, leaving an uncomplicated approach solely in the Strait of Georgia from the northerly or southerly directions. The anchorage bottom consists of primarily mud, sand, and shells, and offers a fair holding ground in good weather. According to representatives from the Puget Sound Pilots, it is unsuitable in higher wind and current speeds, making it unusable a significant amount of the available time during the months from October to March.

The anchorage is exposed to all wind and seas except from the east-northeasterly quadrant. In the open waters of Georgia Strait, winds are usually either northwesterlies (17.6% of the time) or southeasterlies (32.5% 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, or about 23 meters per second (Figure 17). This wind combined with a 0.7-knot flood and 1.1-knot ebb current makes the anchorage generally undesirable for use during this period. Laden condition, duration of stay, wind, temperature and sea forecasts, tug availability, the ship's ability to deploy a second anchor, and readily available propulsion all are considerations when deciding to utilize the anchorage during less favorable conditions.

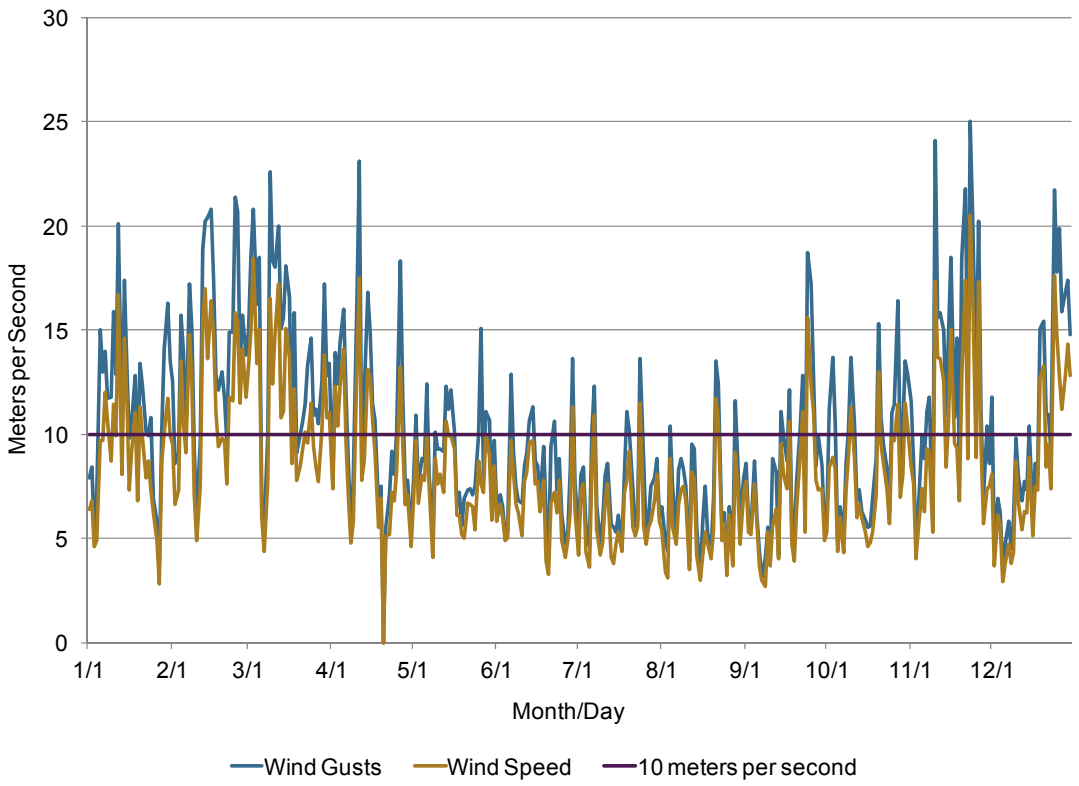

Figure 17 Daily wind speed at Cherry Point, 2011, Reference 57

The Cherry Point anchorage area is suited for use from May-September following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (Reference 102). In summer months, winds in Rosario and Haro Straits are usually southwesterlies. Summer breezes are variable. Gales are uncommon particularly in mid-summer, when storm activity diminishes (Reference 122).

The two types of vessels currently anchoring at Cherry Point are tankers and bulk vessels (Figure 18). 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.

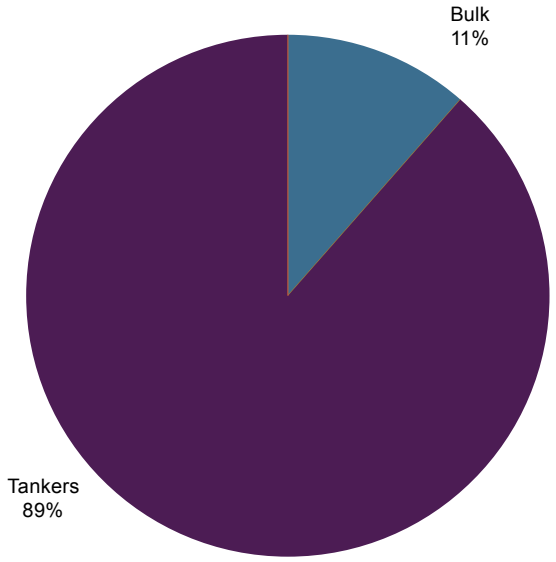

Figure 18 Use of Cherry Point anchorage area by vessel type, 2006-2010, Reference 14 and 75

From 2006–2010, annual vessel days at the Cherry Point anchorage area declined from a high of 19 in 2007 to a low of 6 in 2010. During the same period there was a drop in vessel calls to Cherry Point and Ferndale docks; calls declined from a high of 530 in 2007 to a low of 460 in 2010 (Figure 19).

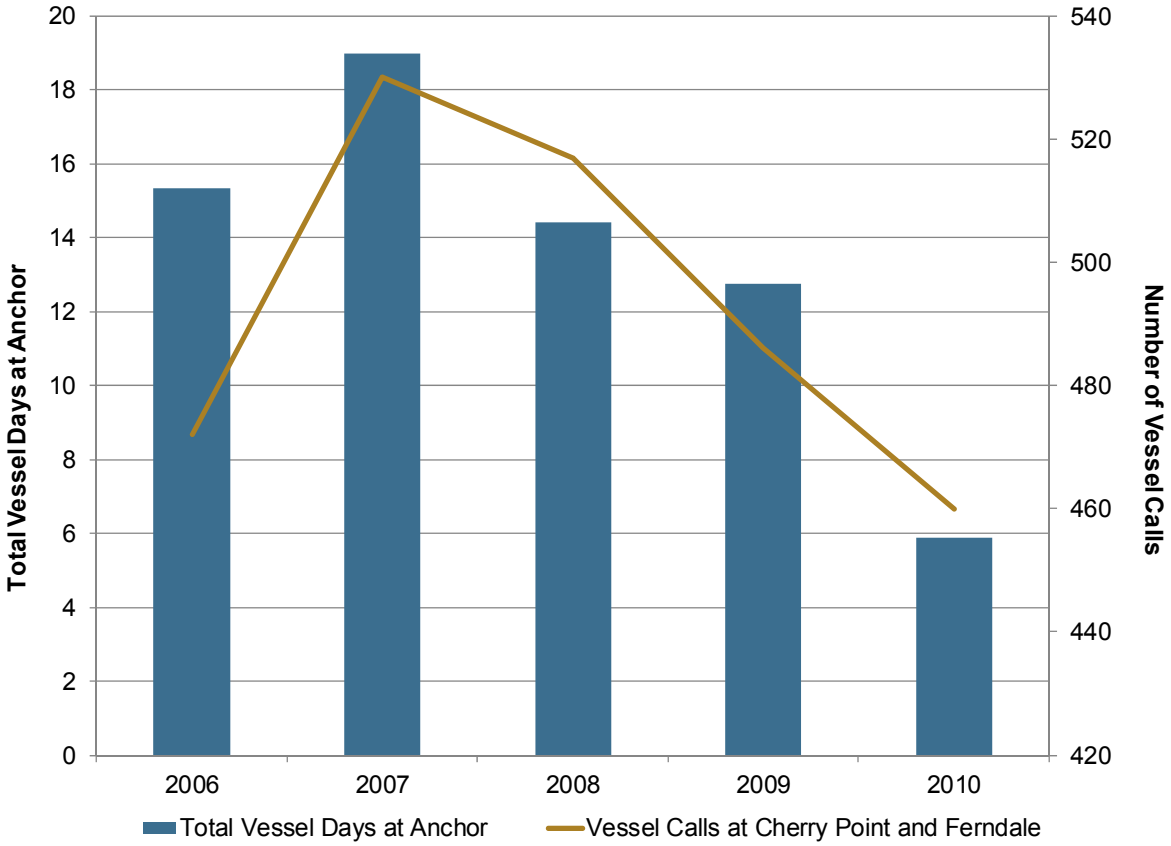

Figure 19 Vessel days at anchor and vessel calls, Cherry Point subarea, 2006-2010, Reference 14 and 75

Figure 20 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 vessel days) over the course of a year. The Cherry Point anchorage area is rarely used; many of the vessels calling docks in Cherry Point anchor outside of the Cherry Point subarea.

The number of monthly reservations at the Cherry Point anchorage peaks in November. July and December are typically months of low reservation counts. November is also the peak month for vessel time at anchor. The lowest months for vessel anchorage time are October and December, which each have an average of half of one vessel day over the five years included in this analysis.

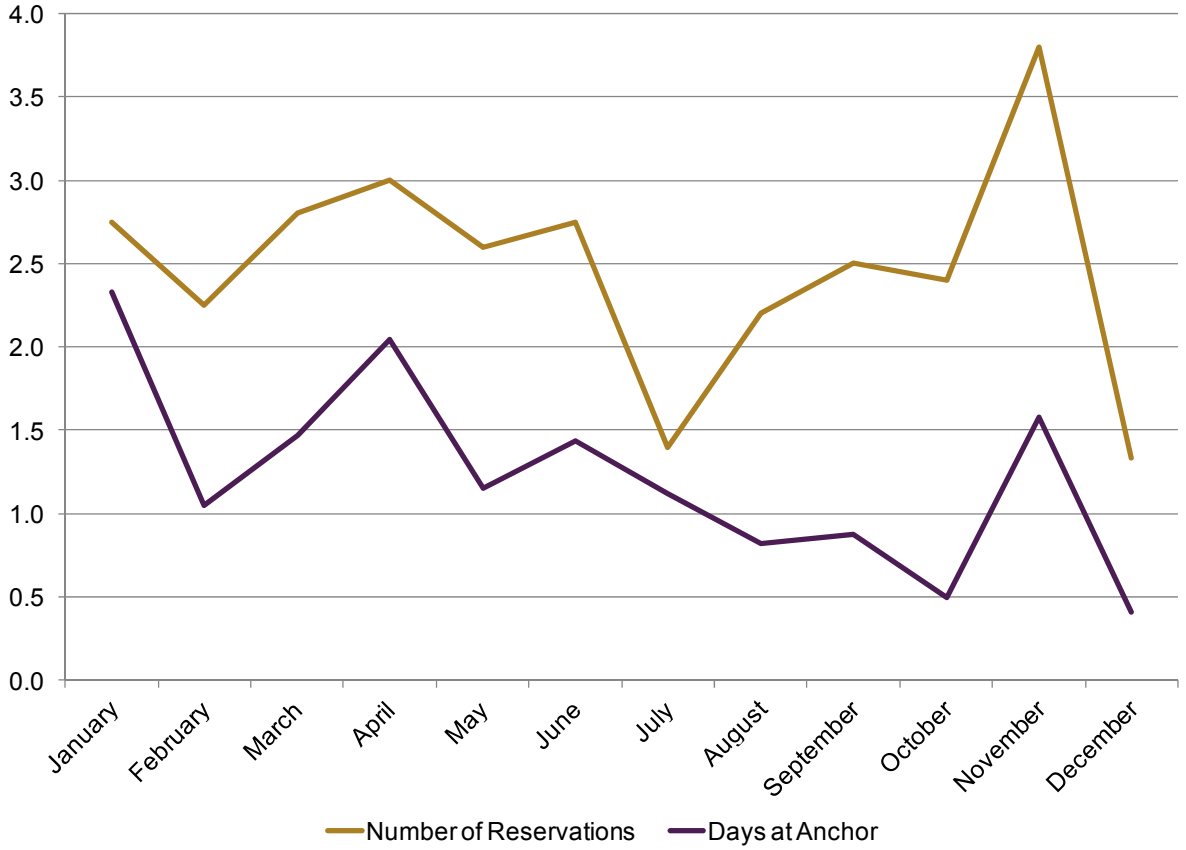

Figure 20 Average number of reservations and vessel days at Cherry Point anchorage, by month, 2006 – 2010, Reference 14

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 that call in the winter. This is consistent with the noted winds in the winter months (October through March) which 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 vessel days were spent at anchor. The Cherry Point anchorage can accommodate only one vessel at a time; assuming there are 365 vessel days available for use, Cherry Point anchorage is used only 3.6% of the time. However, it should be noted that total

possible anchor time and actual available time differ significantly for Cherry Point. According to NOAA records, maximum wind speeds (not including gusts) at Cherry Point were in excess of 19.5 knots for 93 days in 2011, or 25% of the year. Adjusting for this factor increases actual use of the anchorage to 5% between 2006 and 2010 (13.5 vessel days divided by 274 available days). Within our VTARAS model, the Cherry Point Bay anchorage capacity is limited to 274 days per year, due to the likelihood of high winds.

2.4.3.2 Saddlebag Subarea

Bellingham Bay and Vendovi Island[11] are the two anchorage areas located within the Saddlebag subarea. They are managed by VTS Puget Sound on behalf of Sector Puget Sound and the COTP Puget Sound. The Saddlebag anchorage areas are used almost exclusively by tanker vessels (Figure 21). Vendovi Island is used by crude and product tankers while Bellingham Bay is used by Articulated Tug-Barges (ATBs), which typically require a shallower anchoring depth.

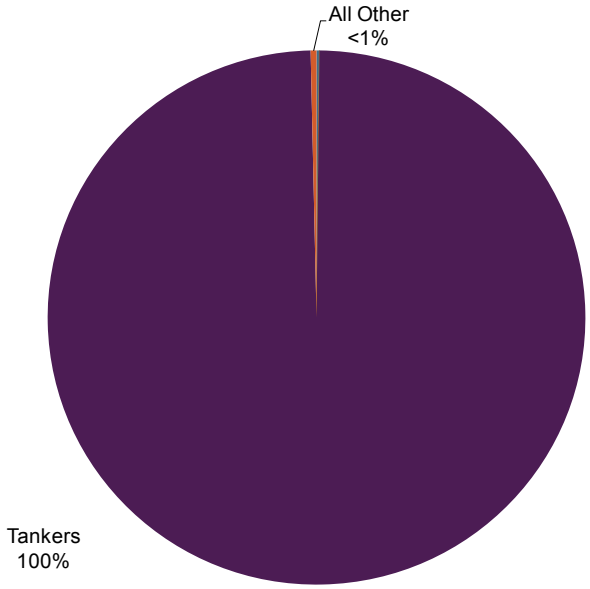

Figure 21 Use of Saddlebag anchorage areas (Vendovi and Bellingham Bay) by vessel type, 2006–2010, Reference 14 and 75

Bellingham Bay is the largest anchorage area 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 area is shallower than most, ranging in depth from 6 to 15 fathoms (36 - 90 feet). In addition, the anchorage's thin mud layer over hard pan bottom makes it unsuitable for holding ground during unfavorable weather from the south. Vendovi Island, which can accommodate up to five vessels at a time, has greater depths ranging from 8 to 35 fathoms (48 - 210 feet). The benefits of using the Vendovi Island anchorage area are confirmed by the USCG database; Bellingham Bay accounts for only 2% of all days at anchor in Saddlebag over the five-year period. Vendovi Island accounts for the remaining 98% (Figure 22).

[11] Vendovi Island East and Vendovi Island South are separate anchorage areas, however, the USCG database does not distinguish between the two; consequently we look at them collectively as 'Vendovi Island'.

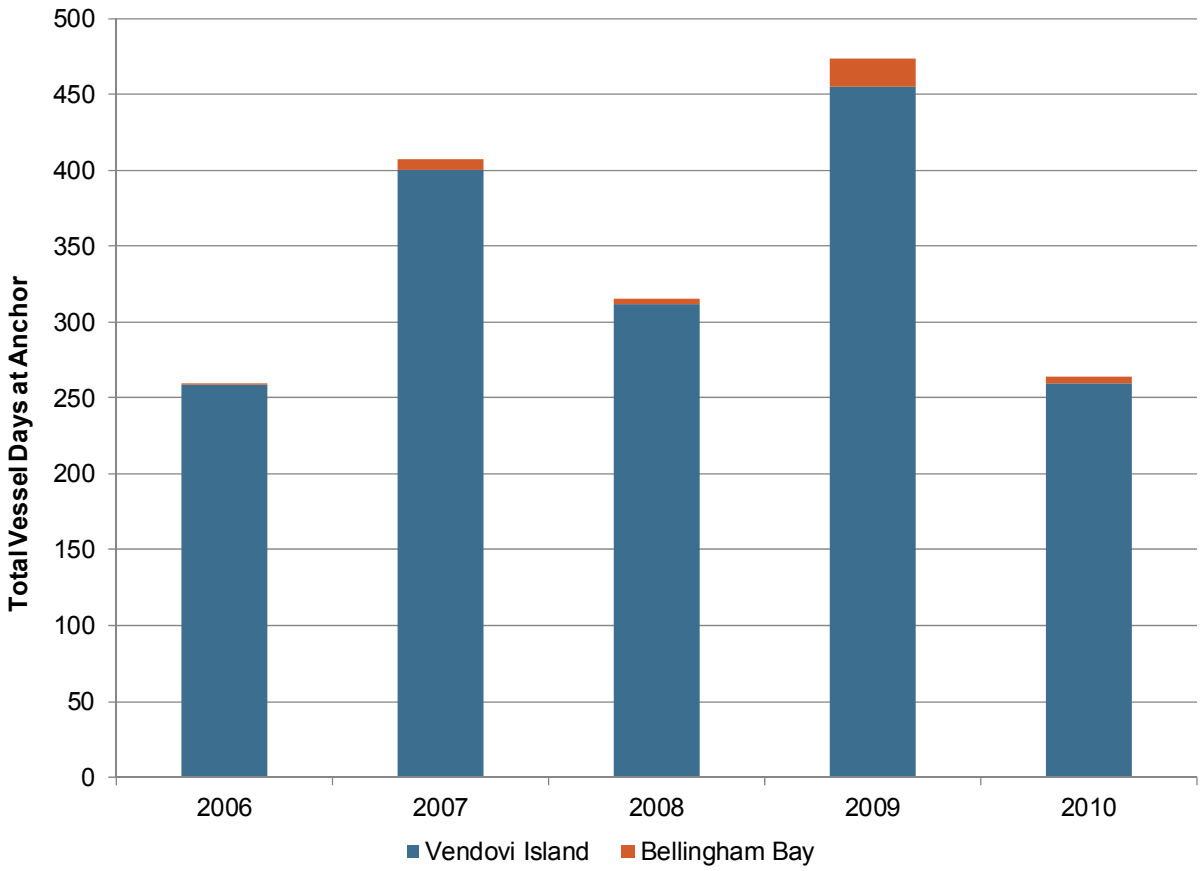

Figure 22 Vessel days at anchor for all vessel types, Saddlebag anchorage areas, 2006 – 2010, Reference 14

The predominant weather pattern for most of the year in this area is southerly winds occurring 40% of the time, with speeds of 20 knots or less about 50% of the time. The strongest winds occur during the winter months (December to March) when southerly winds above 20 knots occur 13% of the time.

Reservations at the Saddlebag anchorages remain consistent throughout the year, averaging between 6 and 10 each month. Vessel days at anchor show greater variation, with peaks in the spring and fall accompanied by dips in the winter and summer (Figure 23). 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.

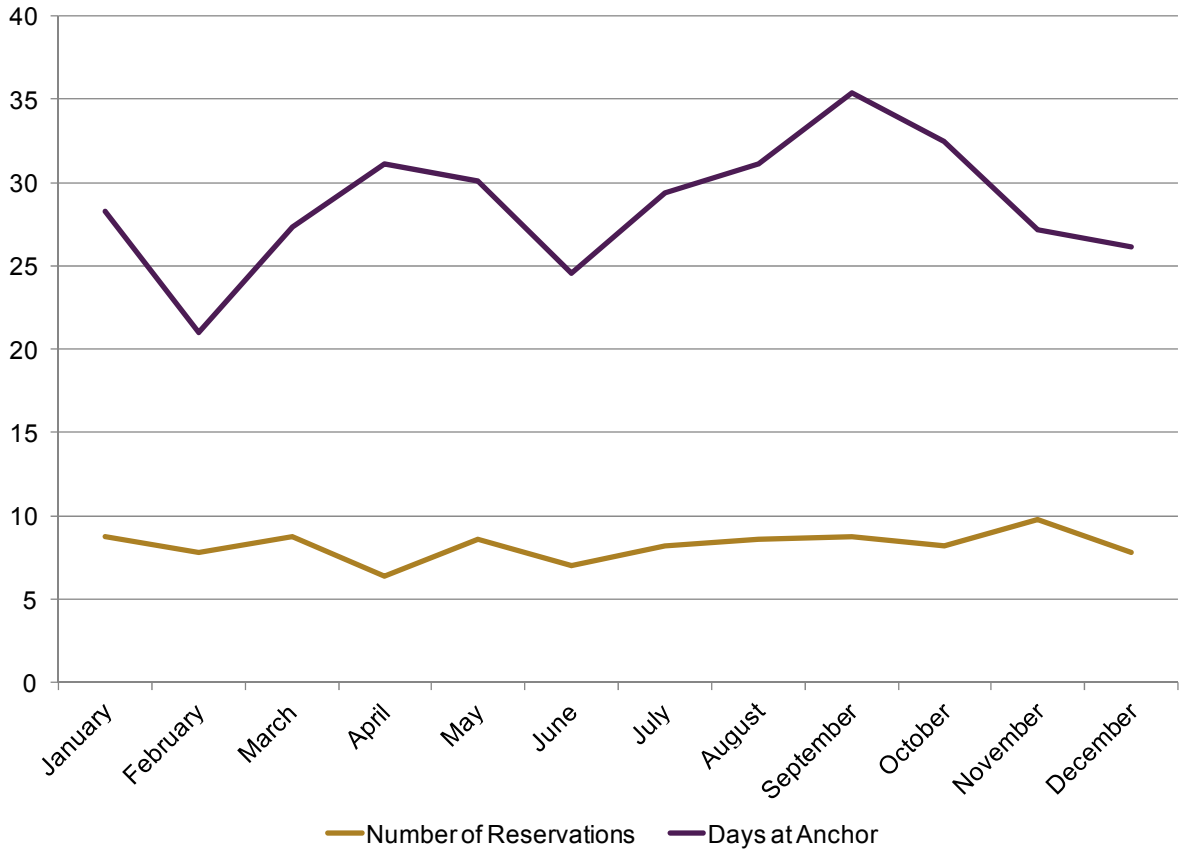

Figure 23 Average number of reservations and vessel days at Saddlebag anchorage areas, by month, Reference 14

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. Bellingham Bay is not suitable for most deep-draft vessels anchoring in the study area and is rarely used. Average annual anchorage usage at Bellingham Bay is 7 days. Practically all of its capacity remains available. Average annual usage at the other Saddlebag anchorages at Vendovi Island is 377 days. Assuming that Vendovi Island anchorages are accessible 365 days a year, then its total capacity is 1,825 days a year (Table 4), and its average annual anchorage use is approximately 18%.

The Bellingham Bay General Anchorage

General statistics:

- Anchorage capacity and radius: Six (6) at 2,000 yds (total.)
- Water depth: 10 fathoms (60 feet) or less in the northern half, 11-14 fathoms (66-84 feet) in the southern half.
- Maximum ship swing radius: 439 yards.

Bellingham Bay anchorage encompasses waters of Bellingham Bay within a circular area having its center at 48°44'15", 122°32'25" (Figure 24). The Bellingham Bay general anchorage is capable of accommodating up to six ships for a period of 30 days. The anchorage lies in the north end of Bellingham Bay directly west from the town of Bellingham, WA.

Depths in the northern half of the circle range from 10 fathoms (60 feet) in the center to 5 fathoms (30 feet) at the outer confines of the defined anchorage. Traveling northward, the depth continues to shallow into flats at 350 yards, where it becomes a lee shore. Because of the shallow depth and lee shore, the north side of the anchorage is not feasible for use by GPT ships. The depths of the southern half of the anchorage range from 10 fathoms (60 feet) in the center to 14 fathoms (84 feet) in the southern quadrant, 13 fathoms (78 feet) in the southwest and 11 – 12 fathoms (66-72 feet) in the southeast. Using a calculated swing radius for a Capesize ship of 439 yards, three Capesize ships could comfortably anchor in the southern half. It is conceivable up to five ships could anchor along the outer border of the southern half of the anchorage in good weather, as the distances between the ships would be reduced. Historically, there have not been more than three ships at Bellingham Bay at any one time; practically, not all six spots at Bellingham Bay would be booked at once (Reference 66). Within our VTARAS model, the Bellingham Bay anchorage capacity is limited to three, due to the combination of relatively shallow depth, poor holding ground, and exposure.

Bellingham Bay is open to the south and thus allows winds from the south 10 miles of open water fetch into Bellingham Bay anchorage. Although the GPT ships' headings would be southerly for the most part, making access to the anchorage uncomplicated, use of this anchorage would add an additional 6 miles of transit to the proposed terminal over the use of Vendovi East or South anchorages.

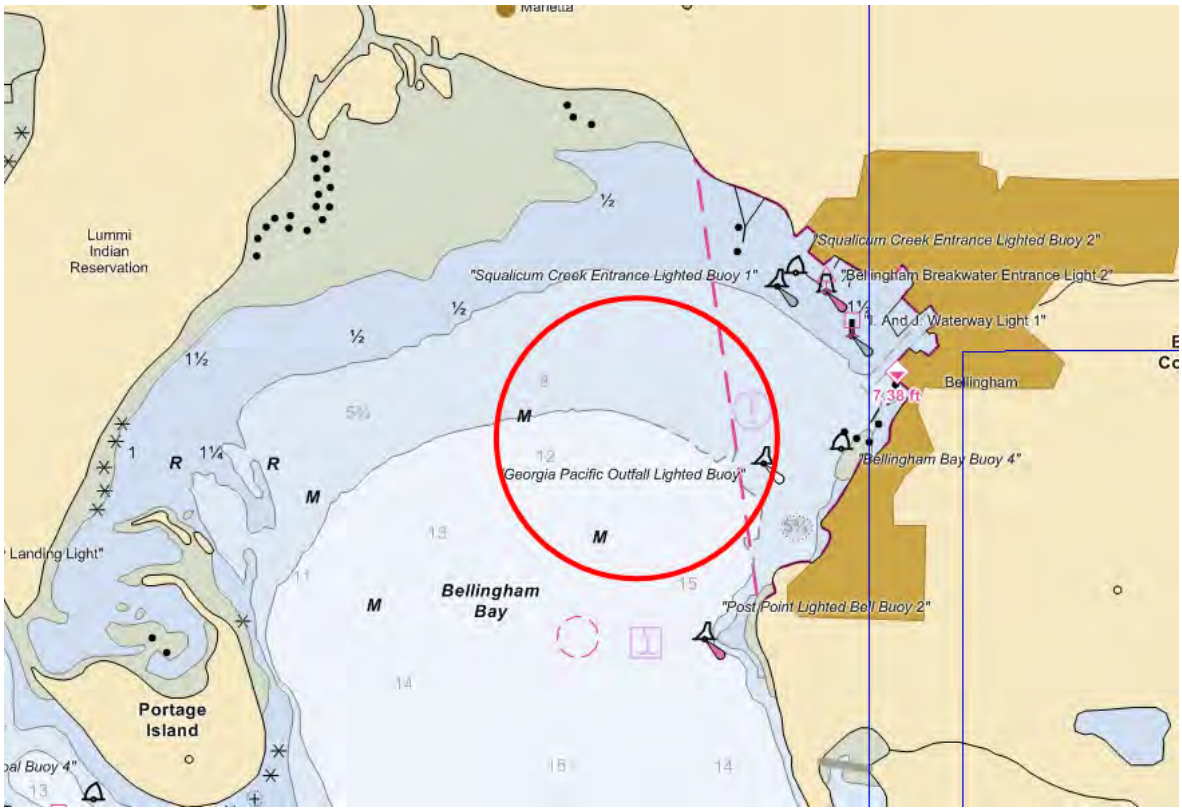

Figure 24 Bellingham Bay anchorage area (depths shown in fathoms)

The Vendovi Island South Non Designated Anchorage

General statistics:

- Anchorage capacity and radius: One (1) at 648 yards.
- Water depth: 20 fathoms (120 feet).
- Maximum ship swing radius: 522 yards.

Vendovi Island South anchorage lays directly adjacent and south of Vendovi Island. It is as wide as the island and extends into the waterway about half the distance to Jack Island (1,519 yards) (Figure 25).

The anchorage 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.

Approach to this anchorage may be made by vessels transiting from the north between Lummi and Sinclair Islands, from the southwest using Bellingham Channel between Guemes and Sinclair Islands and from the southeast using Guemes Channel and Padilla Bay. When transiting from Rosario Strait the Bellingham Channel would offer the shortest route to the anchorage. The southern anchorage area is better protected from south winds than Bellingham Bay, by the nearby landmasses of Guemes and Samish Islands, Cypress and Sinclair Islands, and the hills in the town of Blanchard. Additionally, it is out of the way of vessels transiting Bellingham and Padilla Bays. The bottom is a mix of pebbles and shells and offers good holding ground for ships.

The depths in the anchorage range from 35 fathoms (210 feet) in the north near the island, to 16 fathoms (96 feet) at the southern end. The anchorage offers a maximum radius of 648 yards, giving a Capesize ship sufficient margin when anchoring at 18 – 20 fathoms (108-120 feet).

The anchorage is suited for year-round use following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (Reference 102).

The Vendovi Island East General Anchorage

General statistics:

- Anchorage capacity and radius: Four (4) at 1,660 yards.
- Water depth: 15 fathoms (90 feet, average).
- Maximum ship swing radius: 473 yards.

The Vendovi East anchorage 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.

Vendovi Island East anchorage can accommodate four ships for up to 10 days by USCG regulation. The anchorage lays 1.17 nm east of Vendovi Island and just west of Samish Bay. The anchorage is generally protected by land mass in all but the northern quadrant where almost 10 miles of fetch from Bellingham Bay exists. The percentage of winds from that quadrant average up to 10 knots 6% of the winter months and up to 20 knots 3% of the winter

months. The bottom consists of primarily mud with some mud and shells in the southwest half and offers suitable holding ground for anchoring.

Depths in the anchorage range between 8 fathoms (48 feet) in the northeast to 23 fathoms (138 feet) in the southwest. The suitable holding bottom combined with limited exposure to unprotected high winds and proximity to Cherry Point make the Vendovi anchorage one of the more favorable anchorages for tankers and potential GPT bulk carriers.

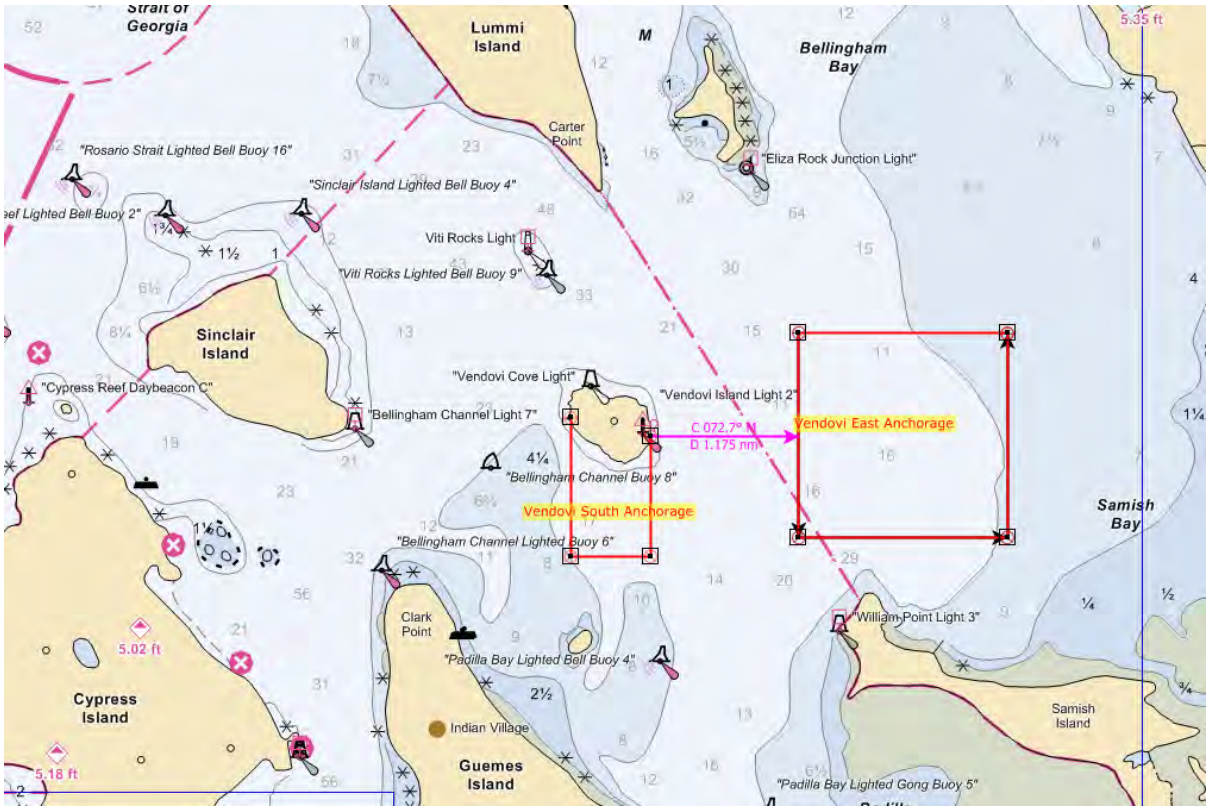

Figure 25 Vendovi Island anchorage areas

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% recorded their last port of call as Cherry Point or Ferndale, and 74% 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.

2.4.3.3 Guemes Channel Subarea

Guemes Channel anchorages are comprised of Anacortes East, Anacortes Center, and Anacortes West. The Coast Guard established these three general anchorages on 2 June 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 6 to 10 days. They are managed by VTS Puget Sound on behalf of Sector Puget Sound and the COTP Puget Sound. The Guemes Channel anchorages' use is dominated by tankers waiting for cargo operations at the Anacortes and March Point refineries, which would pose difficulty in obtaining availability for Capesize bulker vessels calling at GPT. Occasional bulk and general cargo vessels also make use of these anchorages (Figure 26).

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. They can be approached from Guemes Channel and Padilla Bay. The anchorages are suited for year around use following the Anchoring Standards of Care established in the *Puget Sound Harbor Safety Plan* (April 2012) [Reference 105]. The holding ground in these anchorages consists mainly of a combination of sand with some shells; the bottom is more than adequate for an anchorage of this type.

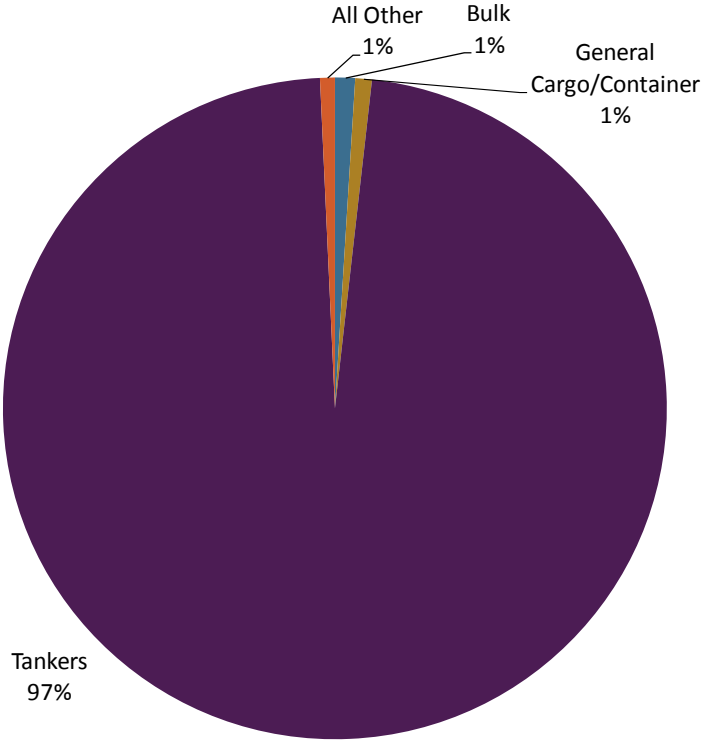

Figure 26 Use of Guemes Channel anchorage areas by vessel type, 2006-2010, Reference 14 and 75

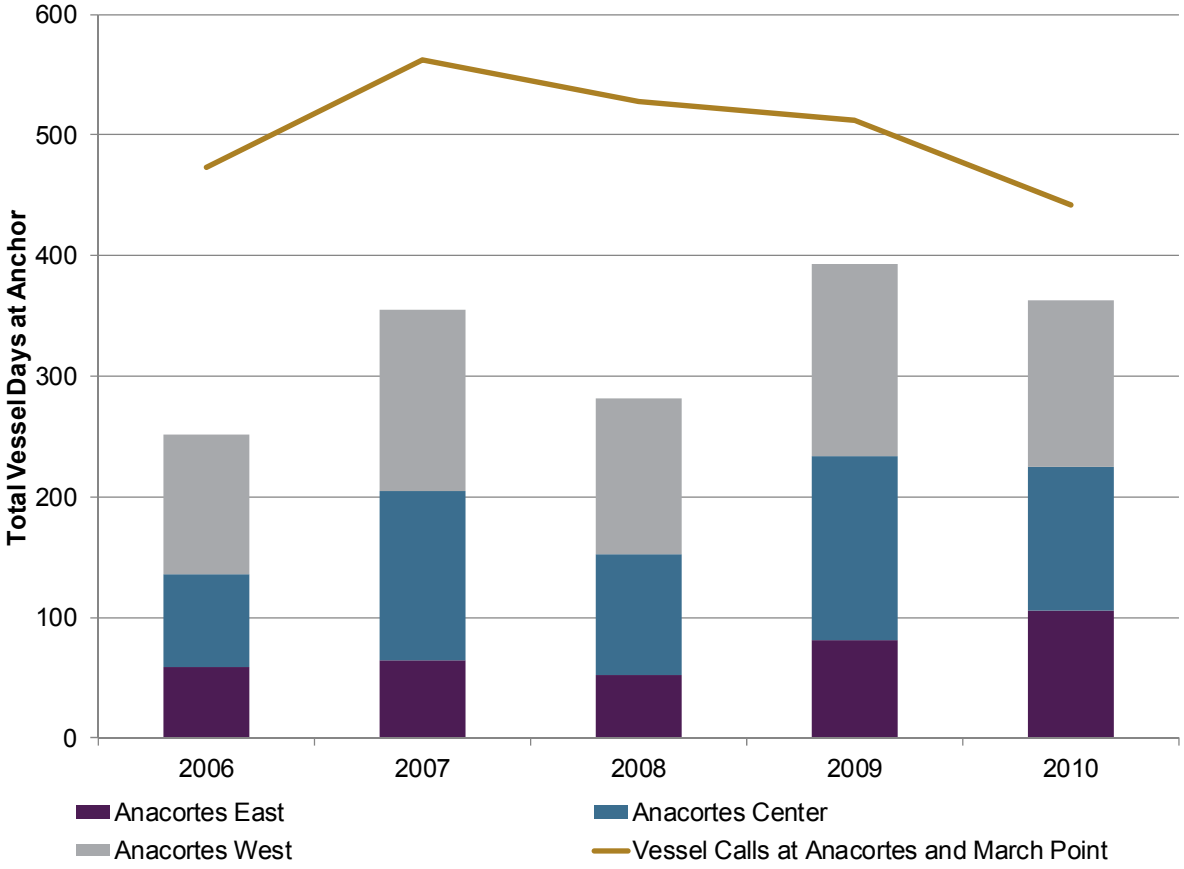

Figure 27 Vessel days at anchor and vessel calls for all vessel types, Guemes Channel subarea, 2006-2010, Reference 14 and 75

Annual vessel days at anchor in Guemes Channel fluctuated between a low of 250 in 2006 to a high of nearly 400 in 2009 (Figure 27).

On a monthly basis, reservations at the Anacortes anchorages remain between 14 and 18. However, days at anchor by the month demonstrate greater volatility, spiking nearly every other month (Figure 28), and ranging from 19 days to 35 days.

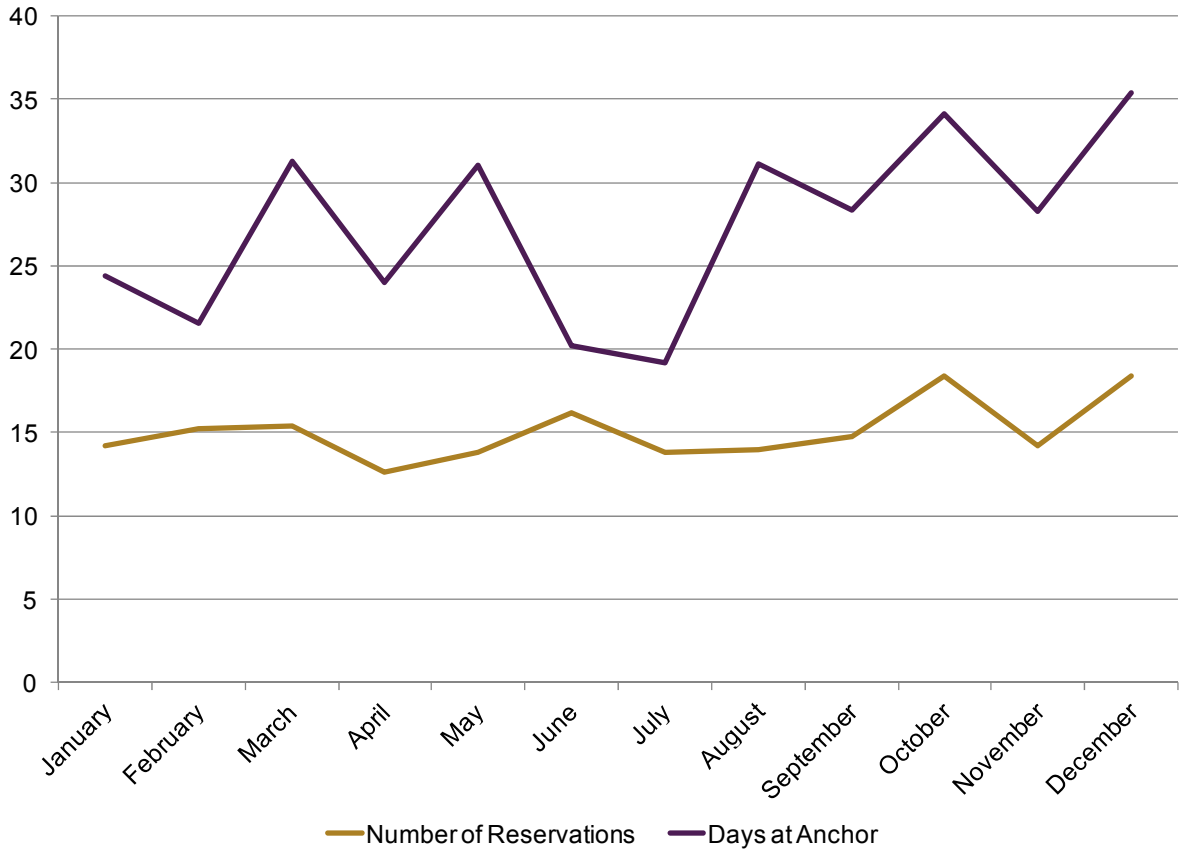

Figure 28 Average number of reservations and vessel days at Guemes Channel anchorage areas for all vessel types, Reference 14

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

Annual vessel days at anchor in Guemes Channel are similar to vessel days at Saddlebag anchorages. However, it should be noted that nearly twice the number of reservations are made in Guemes.

Anacortes East General Anchorage

General statistics:

- Anchorage capacity and radius: One (1) at 600 yards.
- Water depth: 38 fathoms (228 feet).
- Maximum GPT ship swing radius: 699 yards.

Anacortes East general anchorage 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 anchorage area is the least protected of the three Anacortes anchorages in the winter months from northerly winds, but is well protected from southerlies. The depths of this anchorage range from 27 fathoms (162 feet) to 44 fathoms (264 feet) with the greatest depth in the western quadrant. The eastern border of the anchorage lies 150 yards west of Hat Island. The 600-yard radius is sufficient to

allow a Capesize ship room to swing in most wind and current conditions, but at maximum swing in a storm, this anchorage would have insufficient swing radius for a Capesize vessel. The smaller Panamax vessels could be accommodated. Although potentially limited by high winds, the anchorage capacity at Anacortes East is not reduced from the published capacity within our VTARAS model.

Anacortes Center General Anchorage

General statistics:

- Anchorage capacity and radius: One (1) at 600 yards.
- Water depth: 15 fathoms (90 feet).
- Maximum ship swing radius: 473 yards.

Anacortes Center general anchorage 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. Because the area is southeast of Guemes Island, it is well protected from both southerly and northerly winds in the winter months. The depths of this anchorage area range from 9 fathoms (54 feet) in the south to 17 fathoms (102 feet) to the north. Nine fathoms is too shallow for a Capesize vessel but is adequate for a Panamax vessel. Although the anchorage is deep enough on the northern side, the maximum swing radius of the vessel (473 yards.) compared with the relatively small total anchorage size (600 yards.) suggests that overall this anchorage may not be deep enough for a Capesize vessel. Within our VTARAS model, the anchorage capacity at Anacortes Center is not reduced from the published capacity.

Anacortes West General Anchorage

General statistics:

- Anchorage capacity and radius: One (1) at 600 yards.
- Depth of water: 9 fathoms (54 feet).
- Maximum ship swing radius: 414 yards.

Anacortes West general anchorage 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. Because the area is southeast of Guemes Island, it is well protected from both southerly and northerly winds in the winter months. This anchorage area is also likely too shallow for a Capesize vessel. Although potentially limited by shallow depth, the anchorage capacity at Anacortes West is not reduced from the published capacity within our VTARAS model.

The assumption to maintain the published anchorage capacity within the VTARAS model at Anacortes East, Center, and West did not affect the model results. The total predicted number of vessel traffic days at anchor for GPT-calling bulkers were distributed to anchorages following VTS feedback on pilot preference and USCG management. Anchorages were filled in a cascading sequence in the study area, in order of preference: Port Angeles, Vendovi, Anacortes, and Bellingham Bay. There was sufficient capacity at Port Angeles and Vendovi to accommodate the total predicted number of vessel traffic days at anchor for GPT. As a result, the Juan de Fuca East and Saddlebag subareas are the only ones with vessel traffic days at anchor for vessel traffic associated with the proposed GPT (Section 2.4.5).

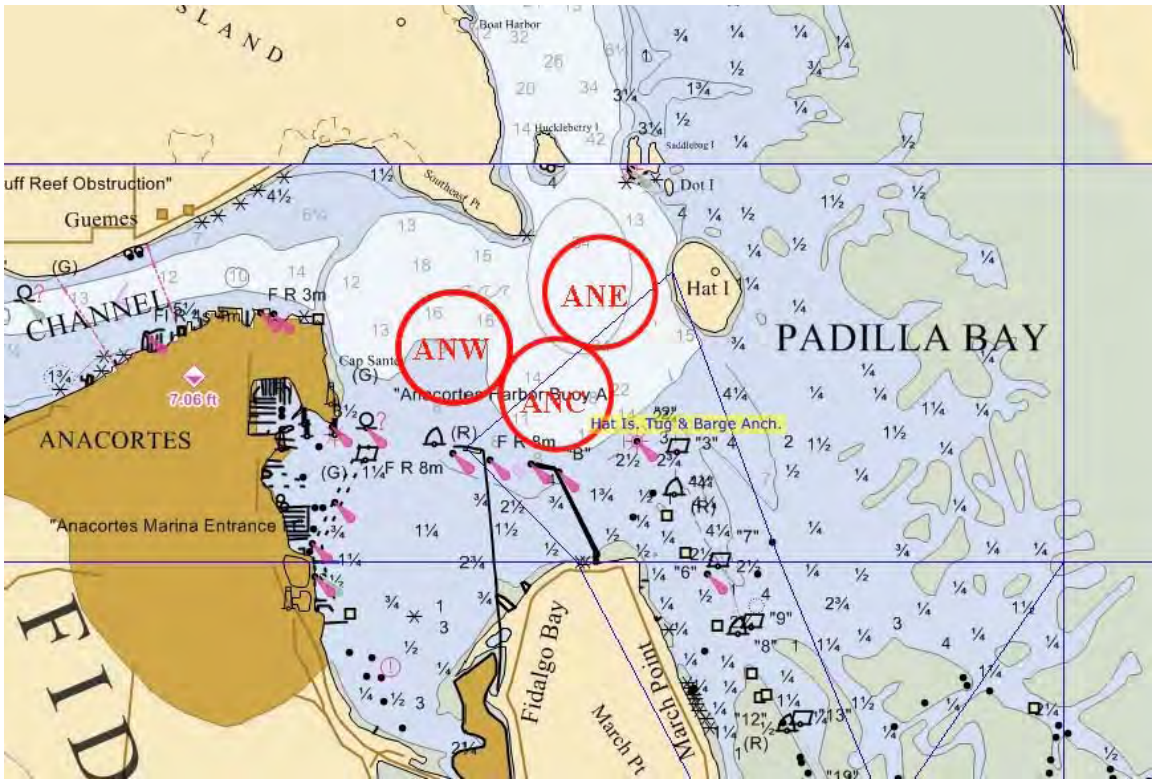

Figure 29 Guemes Channel anchorage areas

2.4.3.4 Juan de Fuca East Subarea

<u>Port Angeles Harbor Non-Designated Anchorage</u>

General statistics:

- Anchorage capacity and radius: Five (5) at 506 yards.
- Water depth: 15-20 fathoms (90-120 feet).
- Maximum ship swing radius: 473 – 522 yards.

Port Angeles is the busiest anchorage area included in the study area as measured by both reservations and total days at anchor. Ships anchor here to await berth availability in Puget Sound, avoid bad weather, or to bunker; the Port also offers ship repair, crew transportation, and general cargo facilities. Located in the eastern Strait of Juan de Fuca, Port Angeles is the first full-service operating port available to eastbound ships in the Strait (Reference 76), and the last port for bunkering before they depart westbound to sea.

Port Angeles Harbor anchorage area can accommodate five ships for a period of up to 10 days with a sixth ship in the eastern most anchorage space when approved by the COTP for inspection or other emergent need during good weather. It is managed by VTS Puget Sound on behalf of Sector Puget Sound and the COTP Puget Sound.

Port Angeles anchorage area 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 the 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 winds except easterlies, which

occasionally blow during the winter. During southeast 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 (180 to 90 feet) in the middle of the harbor. From the middle, the depths decrease regularly to the south shore, where depths reach 3 fathoms (18 feet) nearly 0.2 mile from the beach (Reference 97). The bottom of the anchorage is primarily sand but turns into mud and shells in the west end near the lagoon.

Approach to the anchorage area can be made from the Strait of Juan de Fuca, entering the anchorage area from the east and avoiding the shallower depths and restricted area in the south side of the port. Depending on the depth of each individual anchorage space, the swing radius for the Capesize vessel could be from 473 – 522 yards in the most extreme wind conditions, making the easterly anchorage spaces more favorable to GPT ships. There are, however, tugs of sufficient horsepower available in the port to assist ships in anchoring or getting underway if needed in smaller areas or wind directions that present difficulty in arrival or departure.

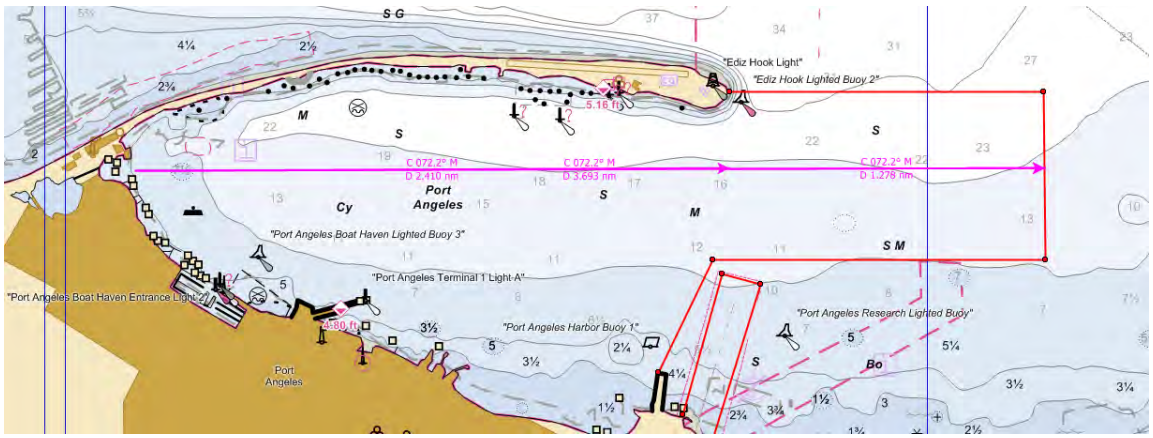

Figure 30 Port Angeles anchorage area (Juan de Fuca East subarea)

Most vessels anchoring in Port Angeles are tankers; however, both bulk and general cargo vessels also frequent the anchorage (Figure 31).

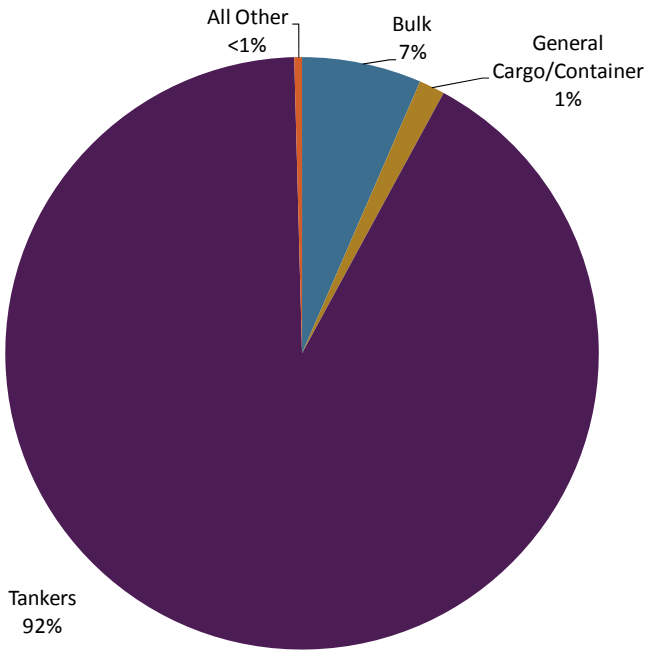

Figure 31 Use of Port Angeles anchorage area by vessel type, 2006–2010, Reference 14

Traffic data from the Marine Exchange of Puget Sound 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% 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% are from Alaska or other US ports, transiting the Strait in the opposite direction and destined for another Washington port of call (Table 6).

Table 6 Recorded last ports of call before Port Angeles, 2006–2010, Reference 75

Region of Last Port of Call	2006	2007	2008	2009	2010
			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

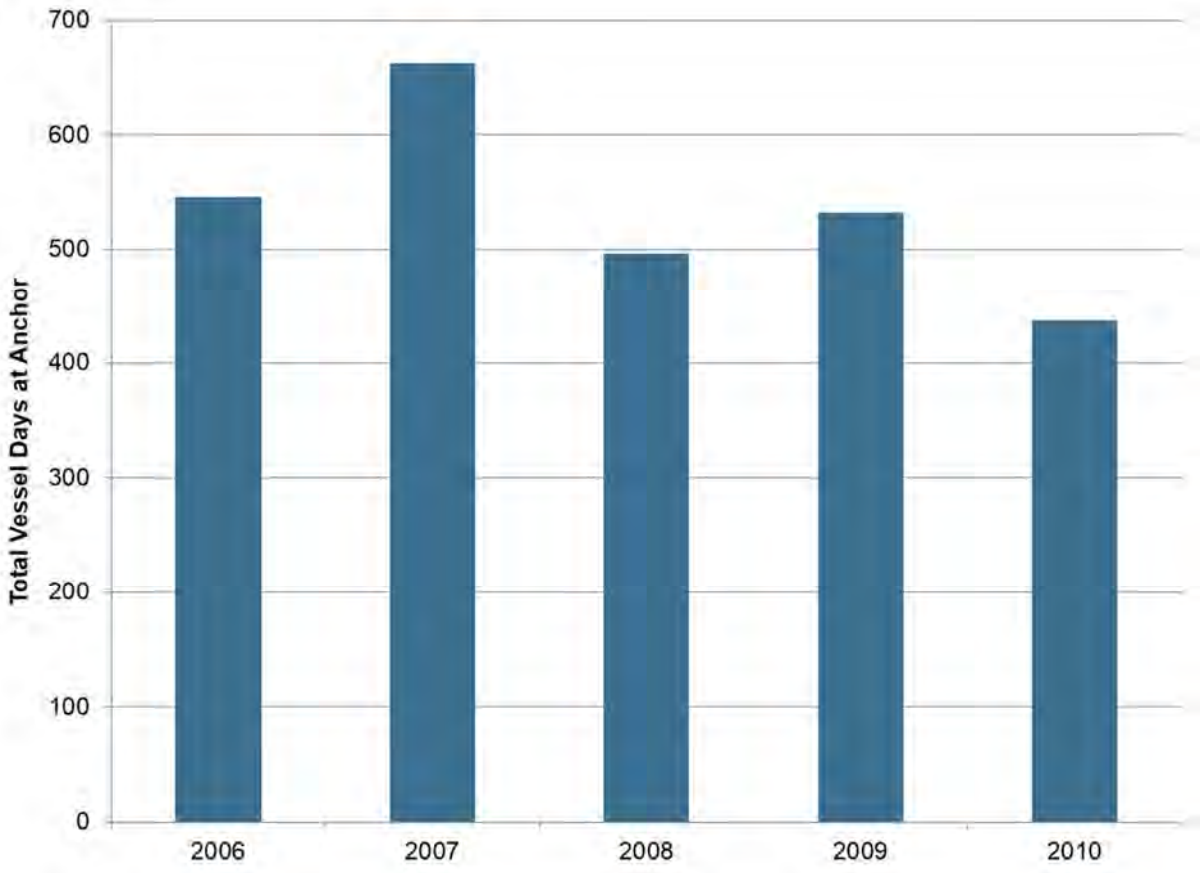

Figure 32 Vessel days at anchor for all vessel types, Juan de Fuca East anchorage area, 2006–2010, Reference 14

The Port Angeles anchorage area is occupied for more than 400 vessel days each year (Figure 32). 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 33). Vessels calling Port Angeles between 2006 and 2010 stayed for an average of 1.5 days per visit.

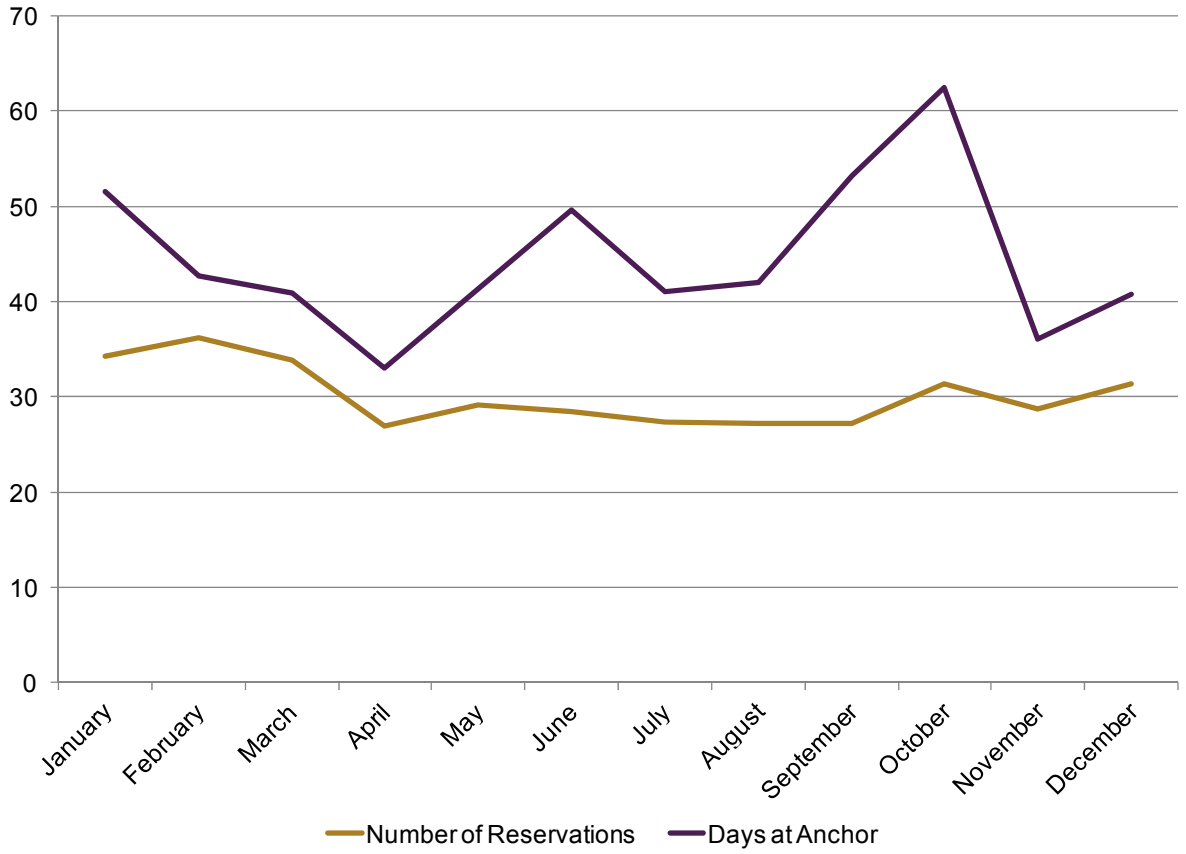

Figure 33 Average number of reservations and vessel days at Juan de Fuca East anchorage area for all vessel types, Reference 14

Port Angeles can accommodate up to five vessels at anchor at one time. On average, Port Angeles was occupied for 535 days each year between 2006 and 2010. Assuming all five anchorage spaces are available each day each year, the anchorage area operates at approximately 30% of its capacity.

2.4.4 Anchorage Activity Comparison

2.4.4.1 Anchorage Comparison Approach

Upon request, USCG Sector Puget Sound provided a history of vessels at anchor for 2006–2010 (Reference 14). The fields of the data used for this analysis are shown below in Table 7. For each record, the anchorage (area), name of the vessel, actual time of arrival, and actual time of departure are noted.

Table 7 Sample of USCG anchorage data, Reference 14

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

The USCG database does not contain information regarding vessel type, and omits any unique identifier such as IMO number or Maritime Mobile Service Identity number, which would

allow a user to accurately identify the vessel through independent sources. Data purchased through the Marine Exchange of Puget Sound (MX) were used to assess anchorage use by vessel type (Reference 75). 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 data normalization was necessary, and that some vessel names in the two databases did not match up.

In addition to assigning vessel type, study sub-area locations were assigned using the mapping noted in above sections. There are no designated anchorages in two of the study sub-areas, Rosario Strait and Haro Strait-Boundary Pass.

Table 8 shows how the information sourced from the USCG (Table 7) was transformed for the purpose of the GPT study.

Table 8 Example of anchorage data used for analysis, Reference 14 and 75

Study Area Location	Year	Vessel Type	Days at Anchor
Juan de Fuca East	2006	Crude Carrier	3.47

2.4.4.2 Anchorage Comparison Results

As previously noted, the USCG database contains data for 2006 - 2010. Using the approach outlined above, anchorage activity was summarized in each of the study subareas for the five years available. Results of this analysis are summarized in Figure 34.

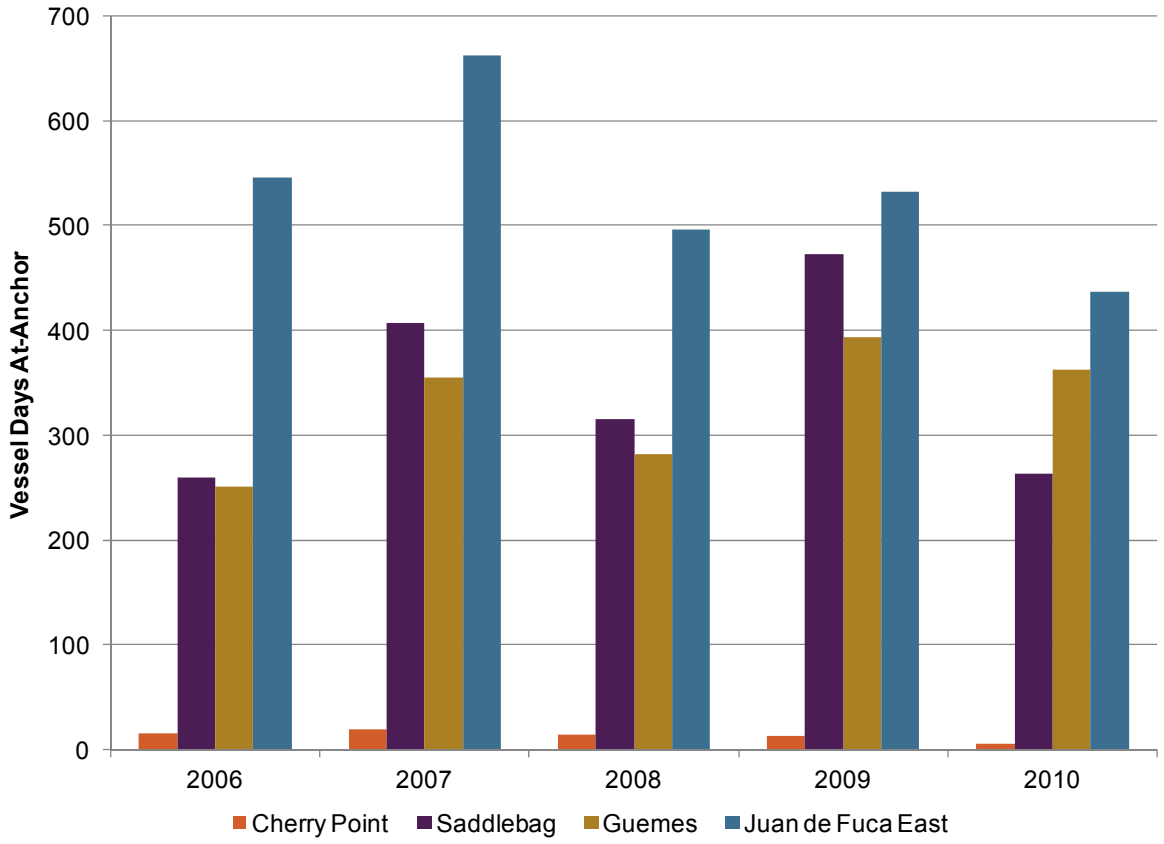

Figure 34 Vessel days at anchor by subarea and year for all vessel types, 2006–2010, Reference 14

Juan de Fuca East, which includes the Port Angeles anchorage area, is the busiest of the study subareas. Cherry Point, which can accommodate only one vessel at a time, is the least active of all of the anchorages. From 2006-2010, anchorage use for all four anchorage-containing subareas in the study area averaged 1,220.8 days each year.

The two variables that determine total time at anchor are the number of anchor visits and the visit duration. As shown in Figure 35 and Figure 36, anchorages that record the highest number of vessel visits each year do not necessarily report the longest duration of time at anchor.

The number of vessel days at anchor in each subarea for each year (2006-2010) is further broken down by vessel type in Table 9. The totals differ from those in Table 5 because this breakdown excludes a few vessel days spent at anchor by other vessel types, for example Coast Guard or fishing vessels.

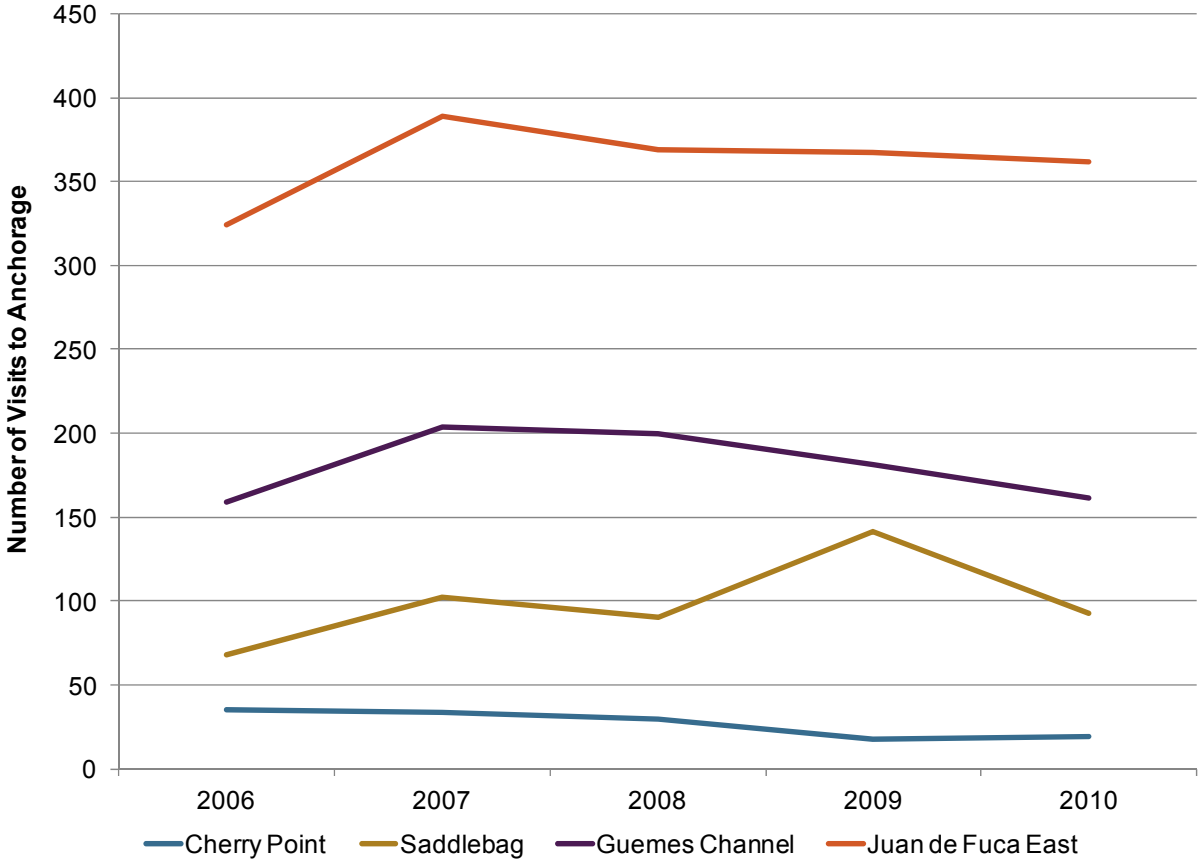

Figure 35 Annual number of visits to anchor by subarea and year for all vessel types, 2006–2010, Reference 14

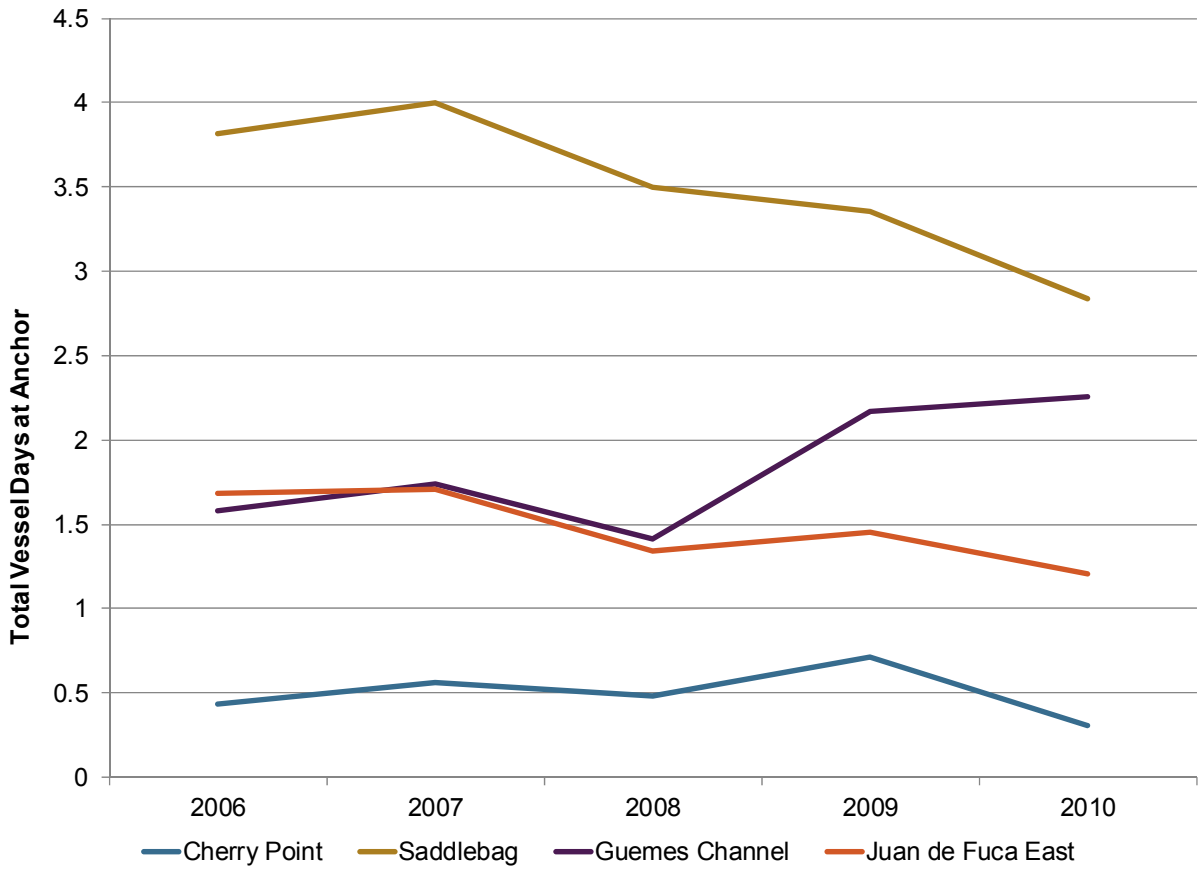

Figure 36 **Average vessel days at anchor per visit by subarea and year for all vessel types, 2006–2010, Reference 14**

Table 9 **Vessel days at anchor by vessel type, year, and subarea, 2006-2010, Reference 14 and 75**

Vessel Type / Year	Subarea							
	Juan de Fuca West	Juan de Fuca East	Haro Strait - Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
Tanker								
2006	0.00	489.85	0.00	243.81	253.42	0.00	14.71	1001.78
2007	0.00	620.58	0.00	340.45	405.80	0.00	16.25	1383.09
2008	0.00	446.13	0.00	278.29	314.03	0.00	12.98	1051.43
2009	0.00	442.42	0.00	384.52	465.92	0.00	12.40	1305.26
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

Vessel Type / Year	Subarea							
	Juan de Fuca West	Juan de Fuca East	Haro Strait - Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
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
General 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
Total								
2006	0.00	532.29	0.00	251.33	253.87	0.00	15.33	1052.81
2007	0.00	654.02	0.00	343.31	407.65	0.00	18.99	1423.97
2008	0.00	492.66	0.00	279.58	314.03	0.00	14.43	1100.70
2009	0.00	525.91	0.00	393.14	466.51	0.00	12.77	1398.32
2010	0.00	433.22	0.00	356.82	261.14	0.00	5.87	1057.06

2.4.5 Forecasted Anchorage Demand by GPT-calling Bulkers

This subsection used a simple queuing model to predict the time that GPT bulkers would spend at anchor while waiting (or queuing) for an available berth. Below is a background on queuing theory, followed by the assumptions and model inputs. The resulting statistics are then defined and reported.

2.4.5.1 Queuing Theory Background

Queuing theory is a branch of operations research that is concerned with the study of waiting lines or queues. Queuing models apply queuing theory to develop estimates of steady state conditions in a queue, with common measures of queue performance including waiting time and queue length. Queuing theory and models are commonly applied to transportation systems, among many other application areas, to determine system performance, assess costs associated with waiting and service provision, and evaluate the impact of changes to the system.

Queuing models have been used for decades to analyze port operations. An early example in the literature looked at the operations of a container terminal in the UK (Reference 42). These researchers identified several factors that make port operations variable and therefore suitable for the application of queuing models:

- "Ships operate on scheduled services. Their actual arrival times vary significantly from the schedule depending on the state of the service, the terminal, the tide, and the time of day and the day of the week."
- "Working rates depend on equipment and cargo availability, schedule requirements and tides."
- "Waiting (queuing) time is concealed either by schedule variations, equivalent to balking, slow steaming, or slow working in ports."

Edmond & Maggs (Reference 42) also noted that the kind of queuing model this study applied to the proposed GPT represented "the dependence of the arrival rates and the working rates on the state of the terminal." In their conclusions, Edmond & Maggs noted, "Simulation models may eventually be the only aesthetically satisfactory way of representing all of the relevant operations. The complexity and interactions involved would probably make such a model prohibitively expensive and time consuming. The cheapness, speed and reproducibility of queue models are definite advantages compared with simulation, and seem to make them still of considerable use in this field if account is taken of the points noted in their application and in the interpretation of their results."

The queuing analysis for the proposed terminal is discussed in detail below.

2.4.5.2 Queuing Model Inputs

The use of GPT facilities by Panamax and Capesize ships was modeled using a basic queuing model. The basic queuing model was applied for two independent queueing analyses, reflective of the independent operation between Berths 1 and 2 and Berth 3. Berths 1 and 2 service uncovered (open storage) commodities, such as coal, while Berth 3 is equipped for other, covered bulk commodities. There is no interference between the vessels arriving and departing Berths 1 and 2 and the vessels arriving and departing Berth 3. The analyses developed the following statistics:

- **Waiting time in queue (W_q):** The waiting time in queue represents the average waiting time a vessel will face in the queue, at any given point in time.
- **Number of vessels in queue (L_q):** The number of vessels in queue represents the number of vessels that have arrived and are waiting for an open berth.

- **Number of vessels in system *(L)*:** The number of vessels in the system represents the number of vessels in the queue, as well as the number of vessels that are at berth.
- **Time in system (*W*):** The time in system represents the average time a vessel will spend both in the queue as well as at berth. It represents the steady state average amount of time from when a vessel arrives to when it leaves.
- **Berth utilization rate (*ρ*):** The berth utilization rate represents the average percent of the year that berths are occupied.
- **Arrival Rate (λ)**: The rate of arrival, in ships/day.
- **Service Rate (μ)**: The rate of service, in ships/day.

The steady state solution for such a system is governed by the following equations:

Probability of zero queue length *(P_0)*:

$$P_0 = \frac{1}{\sum_n^s 0 \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{s!}\left(\frac{\lambda}{\mu}\right)^s \left(\frac{1}{1-\lambda/s\mu}\right)} \qquad \text{2-3}$$

Number of vessels in queue *(L_q)*:

$$L_q = \frac{(\lambda/\mu)^S (\lambda/s\mu)}{s!(1-\lambda/s\mu)^2} P_0 \qquad \text{2-4}$$

Number of vessels in system *(L)*:

$$L = L_q + \lambda/\mu \qquad \text{2-5}$$

Time spent in queue *(Wq)*:

$$W_q = L_q/\lambda \qquad \text{2-6}$$

Time spent in system *(W)*:

$$W_q + 1/\mu \qquad \text{2-7}$$

Berth utilization rate *(ρ)*:

$$\rho = \lambda/s\mu \qquad \text{2-8}$$

Probability of queue length:

$$P_n = \begin{cases} \dfrac{(\lambda/\mu)^2}{s!\,s^{n-s}} P_o & \text{for } n > s \\ \dfrac{(\lambda/\mu)^n}{n!} P_o & \text{for } n \le s \end{cases} \qquad \text{2-9}$$

S: Number of berths

n: Variable

These equations apply during a steady state, which is a period during which operations have been underway for some time and will remain underway for some time. Special events, such as the startup or shutdown of berths, will affect the actual queue performance, though it is assumed that any maintenance closures or other such events will be scheduled to minimize impacts on operations.

The analysis covers the year 2019, at which time 318 Panamax and 169 Capesize ships are expected to call at the facility each year (Reference 114 and 44). To inform inputs to the queuing model, PIT shared their limiting case for terminal throughput, and thereby the limiting case for queuing (Reference 109). In this case, the maximum number of bulkers calling on Berths 1 and 2 is 422 per year. The remaining 65 vessel calls are at Berth 3. While vessels are assumed to queue independently for Berths 1 and 2 and for Berth 3 without interference, three

Capesize vessels cannot fit on Berths 1, 2, and 3 concurrently. To prevent the potential interference that would arise with three Capesize vessels on Berths 1, 2, and 3, all 169 Capesize vessel calls are modeled on Berths 1 and 2. The remaining 253 vessel calls (= 422 – 169) at Berths 1 and 2 are Panamax vessels. All 65 calls at Berth 3 are Panamax vessels. The number of calls broken down by vessel size and by berths are summarized in Table 10.

Capesize vessels take a longer time to load per call than Panamax vessels. Panamax vessels require about 28 hours at berth, while Capesize vessels require about 37 hours (Reference 121). The weighted average by the number of calls of each vessel size class at Berths 1 and 2 was calculated. However, this weighted average was less than the time at berth for all vessels provided by PIT. To be conservative (predict more time), the PIT-provided time at berth was used. These provided inputs represent annual averages and include loading and non-loading time. Averaging over all vessels over one year, a vessel call occupies a berth for approximately 32 hours. Terminal operation inputs are summarized in Table 10.

The queuing analysis assumed exponential distributions for the average time between ship arrivals (i.e., interarrival time) and service times, one or two berths, a first-come first-served discipline, and a possibly unlimited queue, in terms of number of vessels in the queue and duration per vessel. While there are limited anchorage spaces in the study area, the queuing analysis results indicate that sufficient anchorage capacity exists to handle the number of vessels anticipated to be waiting to use the facility. As a result, it is reasonable to assume an infinite queue. This type of queuing model is often notated as an M/M/c queue.[12] Several texts exist that can give more information on queuing models and analysis.[13]

Table 10 Queuing analysis inputs

	Berths 1 and 2	Berth 3
Annual Vessel Calls, Total Panamax and Capesize	422	65
Annual Vessel Calls, Panamax	253	65
Annual Vessel Calls, Capesize	169	0
Time at Berth (hours)	32.2	27.9
Time at Berth (days)	1.34	1.16
Arrival Rate (ships/day) (λ)	1.16	0.18
Service Rate (ships/day) (μ)	0.74	0.86
Number of Berths	2	1

The arrival rate shows the average number of ships that are expected to arrive per day. The queuing analysis assumes that actual arrival times will vary based on delays in transit. The

[12] The parameters in this notation represent the distribution used for interarrival times (first parameter), distribution used for service times (second parameter), and the number (third parameter). The M shown for the first and second parameters indicates that the model uses a Markov arrival process, and the c shown for the third parameter stands for a variable number of servers. In this analysis, the servers are the berths that serve Panamax and Capesize ships. The Markov arrival process refer to the way in which vessels enter the system and either join the queue or, if a berth is available, go directly to that open berth. This assumes that vessels arrive at GPT a random amount of time after the previous arrival, each vessel's arrival time is independent of other vessels ("lack of memory" property), and the interarrival time follows an exponential distribution with an average time.

[13] For example, see *Introduction to Management Science* by Hillier and Hillier (2013). For a more technical discussion, see *Introduction to Operations Research* by Hillier and Lieberman (2010). Other academic and open source references are accessible online.

inverse of the arrival rate is the interarrival time. Ships calling at Berths 1 and 2 are assumed to arrive at a rate of 1.16 ships per day (= 422 ships per year / 365.25 days per year), which corresponds to an average of 0.87 days (= 1/1.16) between each arrival. The interarrival time at Berth 3 is 5.62 days, based on the arrival rate of 0.18 ships per day.

The service rate represents the speed at which ships are loaded once arriving at berth. The service rate of 0.74 ships per day at Berths 1 and 2 means that these ships arrive at a faster rate than they can be served (1.16 > 0.74) per berth. At Berth 3, the service rate is 0.86 ships per day. This means that these ships arrive at a slower rate than they can be served (0.18 < 0.86). This service rate is about 80% faster than the arrival rate, which leaves available capacity at Berth 3. This supports the position that the maximum queuing case is the maximum calls on Berths 1 and 2 and the remaining calls to Berth 3, as modeled.

2.4.5.3 Queuing Analysis Results

Total Queuing Time

Analysis results for the steady state queuing analysis are shown in Table 11. The queuing analysis results are used to estimate the at-anchor times. The total at-anchor time is calculated as the product of the number of vessel calls and average waiting time in queue per call. The analysis found that the average wait time per call is 1.75 days for vessels calling at Berths 1 and 2 and 0.26 days for vessels calling at Berth 3. Multiplying average wait time per call and number of calls gives total waiting time per year. Between all three berths and 487 vessel calls, there are 756 vessel days forecast at-anchor for GPT-bulkers. These vessel days at anchor are incorporated into the Vessel Traffic Analysis, Section 3.

The probability of a given number of vessels in the queue at once, also called queue length, is predicted in Equation 2-4. For vessels calling at Berths 1 and 2, the probability that there would be zero vessels in the queue (Equation 2-3) is 11%. This translates to approximately 324 days of the year, there will be vessels queuing for Berths 1 and 2. For vessels calling at Berth 3, this probability is 68%. This translates to approximately 249 days of the year, there will be no vessels queuing for Berth 3.

Table 11 Steady state queuing analysis results, 2019

	Eqn	Berths 1 and 2	Berth 3
Waiting time (days) in queue per call (W_q)	2-6	1.75	0.26
Number of vessels in queue (L_q)	2-4	2.02	0.05
Number of vessels in system (L)	2-5	3.57	0.25
Time (days) in system (W)	2-7	3.09	1.42
Berth utilization rate (%) (ρ)	2-8	0.78	0.21
Total waiting time (days) in queue	n/a	739.3	16.9

Queuing Time Distributed to Anchorages and Subareas

The methodology to distribute queuing time to anchorages reflects pilot preference and USCG management in the use of anchorage capacity. Anchorages are filled in a cascading sequence in the study area, in order of preference: Port Angeles, Vendovi, Anacortes, and Bellingham

Bay. As a result, at-anchor time is allocated to subareas, in order of preference: Juan de Fuca East, Saddlebag, Guemes Channel, and Saddlebag. At-anchor time is allocated up to 75% utilization. A rule of thumb is that the practical limit of utilization is 85% due to increasing delays due to congestion. By using a limit of 75% to each anchorage location, this analysis takes a conservative approach.

The queuing analysis results were used to estimate whether there is adequate anchorage capacity within the study area to meet the demand from GPT, based on historical anchorage use. The results were then compared to forecasted traffic volumes in 2019, to understand the impacts of the proposed GPT on future anchorage demand. The results of these comparisons are discussed in the following sections.

Historical Comparison

Within the study area, there are 17 anchorage spaces available to GPT bulkers;[14] each is available between 274 and 365 days a year, equating to an annual capacity of 6,114 vessel days (Table 12). As mentioned above, at-anchor times for GPT traffic is estimated at 756 vessel days per year. From 2006-2010, anchorage use averaged 1,221 days each year; this would have left approximately 4,893 annual days of capacity for GPT vessels, or 13 vessel days per actual day.[15] This means that, on average, there was capacity for 13 bulkers to anchor at once. According to the queuing analysis, there is a small (approximately 1%) chance that the queue length would exceed 13 vessels (Equation 2-4). In general, it appears that the average number of available anchorages is much greater than the average number of vessels in the queue and that available anchorages at 2010 usage would have been sufficient to handle GPT vessel traffic.

[14] Though there are 20 anchorage spaces available in the eight anchorages in the study area (Table 4), not all of them would be suited to use by GPT-calling vessels. Capacity for GPT-calling vessels is limited to 17 anchorage spaces in the model. Three anchorage spaces at the Bellingham Bay anchorage are subtracted from potential use by GPT-calling vessels due to relatively shallow depth, poor holding ground, and exposure. Other anchorage, though potentially less-well suited, are included in the model. For instance, Anacortes Center and Anacortes West anchorages may be too shallow for Capesize vessels. Despite the potential for these limitations to affect GPT-calling vessels, anchorages in the study area as a whole are not anticipated to be a limiting factor for GPT-calling vessels.

[15] Average daily anchorage availability reported reflects an even distribution of anchorage usage through the year. In practice, anchorage usage varies day to day. Anchoring activity throughout the study area would increase temporarily in inclement weather. Market and other conditions may also cause daily or seasonal fluctuations above and below the average.

Table 12 Available anchorage capacity for GPT by anchorage area

Anchorage	Spaces	Annual Capacity (Annual Vessel Days)	Average Annual Use 2006-2010 (Annual Vessel Days)	Remaining Annual Capacity (Annual Vessel Days)	Remaining Capacity per Day (Vessel Days)
Cherry Point	1	274	13.5	260.5	0.7
Vendovi	5	1,825	337.1	1,481.2	4.1
Anacortes	3	1,095	328.9	766.1	2.1
Bellingham	3	1,095	6.8	1,088.2	3.0
Port Angeles	5	1,825	534.6	1,290.4	3.5
Total	17	6,114	1,220.8	4,893.2	13.4

The queuing analysis estimates each GPT bulkers will demand 756 vessel days of anchorage time within the study area and tug and tank barge movements supporting GPT bulker bunkering operations in Port Angeles will contribute an additional 60 days of anchorage time, for a total of 816 vessel days (Table 13).

Table 13 GPT vessel days at anchor by subarea, 2019

Vessel Type	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
Bulkers	0.0	669.0	0.0	0.0	87.2	0.0	0.0	756.2
Tugs	0.0	59.9	0.0	0.0	0.0	0.0	0.0	59.9
Total Anchorage Demand	**0.0**	**729.8**	**0.0**	**0.0**	**87.2**	**0.0**	**0.0**	**816.1**
Tanks Barges	0.0	59.9	0.0	0.0	0.0	0.0	0.0	59.9
Total GPT Traffic Days at Anchor	**0.0**	**788.8**	**0.0**	**0.0.**	**87.2**	**0.0**	**0.0**	**876.0**

Note: Tank barge at-anchor time does not contribute to anchorage demand, because a tank barge will not occupy its own anchorage space. A tank barge will only be at anchor with its tug. To not double count anchorage demand for both the tug and tank barge, tank barge at-anchor time is excluded from the forecasted anchorage demand calculations. Tank barge at-anchor time is included in the total forecasted vessel traffic days at anchor from GPT-calling and supporting vessels.

The tug and tank barge time at-anchor is expected to take place concurrently with GPT bulker time at-anchor; the tug and tank barge will pull alongside the bulker to transfer fuel oil and will occupy the same anchorage. Since the tug and tank barge will not occupy independent anchorage space, the 756 vessel days of bulker time is used as the anchorage demand estimate

and the 876 vessel days are used to calculate system-wide potential spill risk by vessel and activity type. Total GPT anchorage demand (756 vessel days) is 13% of the roughly 6,114 vessel days of annual anchorage capacity available in the study area and 17% of the remaining capacity after subtracting current usage.

Case Comparison

In order to forecast the impact of GPT anchorage demand in 2019, the study team forecasted anchorage use by non-GPT vessels within the study area.

In Case A, there is no GPT project; anchorage demand by vessels within the study area increases in-line with expected changes in vessel volumes due to underlying economic trends and foreseeable projects (Table 14). In Case A, total anchorage demand is expected to be 1,562 vessel days, or 26% of the roughly 6,114 anchorage days available.

Table 14 Case A - forecasted days of anchorage demand by vessel type and subarea, 2019

Vessel	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tanker	0.0	358.2	0.0	241.6	243.4	0.0	8.5	851.7
Bulker	0.0	95.7	0.0	11.0	2.2	0.0	6.3	115.1
General Cargo and Container	0.0	16.0	0.0	1.8	0.0	0.0	0.0	17.7
Tug	1.4	230.0	3.2	204.2	133.5	5.5	0.0	577.7
Total Anchorage Demand	1.4	699.8	3.2	458.6	379.1	5.5	14.8	1,562.3

Note: Tank barge at-anchor time does not contribute to anchorage demand, because a tank barge will not occupy its own anchorage space. A tank barge will only be at anchor with its tug. To not double count anchorage demand for both the tug and tank barge, tank barge at-anchor time is excluded from the forecasted anchorage demand calculations.

As previously mentioned, the queuing analysis estimates 756 GPT-related anchorage days due to increases in bulker movements. Case B is formed by combining the baseline anchorage estimates from Case A with the GPT bulker anchorage estimates. Table 15 summarizes Case B anchorage demand, showing an overall increase to 2,378 days, or 39% of the roughly 6,114 anchorage days available.

Table 15 Case B - forecasted anchorage demand by vessel type and subarea, 2019

Vessel	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
Tanker	0.0	358.2	0.0	241.6	243.4	0.0	8.5	851.7
Bulker	0.0	764.7	0.0	11.0	89.5	0.0	6.2	871.3
General Cargo and Container	0.0	16.0	0.0	1.7	0.0	0.0	0.0	17.7
Tug	1.4	289.9	3.2	204.2	133.5	5.5	0.0	637.6
Total Anchorage Demand	1.4	1,428.7	3.2	458.6	466.3	5.5	14.8	2,378.4

Note: Tank barge at-anchor time does not contribute to anchorage demand, because a tank barge will not occupy its own anchorage space. A tank barge will only be at anchor with its tug. To not double count anchorage demand for both the tug and tank barge, tank barge at-anchor time is excluded from the forecasted anchorage demand calculations.

Looking forward, there is a tentatively scheduled expansion to the Shell rail terminal in Anacortes which, if carried out, will lower the volume of crude tankers coming into the study area – in turn lowering demand for anchorage. Case C takes this project into account and estimates a reduction of 28 days. In Case C, 2,351 days of anchorage are demanded, or 38% of the roughly 6,114 anchorage days available (Table 16).

Table 16 Case C - forecasted anchorage demand by vessel type and subarea, 2019

Vessel	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tanker	0.0	352.2	0.0	226.9	236.3	0.0	8.5	824.0
Bulker	0.0	764.7	0.0	11.0	89.5	0.0	6.2	871.3
General Cargo and Container	0.0	16.0	0.0	1.7	0.0	0.0	0.0	17.7
Tug	1.4	289.9	3.2	204.2	133.5	5.5	0.0	637.6
Total Anchorage Demand	1.4	1,422.7	3.2	443.9	459.2	5.5	14.8	2,350.7

Note: Tank barge at-anchor time does not contribute to anchorage demand, because a tank barge will not occupy its own anchorage space. A tank barge will only be at anchor with its tug. To not double count anchorage demand for both the tug and tank barge, tank barge at-anchor time is excluded from the forecasted anchorage demand calculations.

Figure 37 compares historical data, as well as forecasted cases A, B, and C to total anchorage capacity within the study area. Case B is expected to generate the largest demand for anchorage within the study area. The figure shows a higher level of anchorage activity in 2006-2010 than Table 12 due to the inclusion of tugs in the Marine Exchange data. Tugs accounted for 552 vessel days, on average, in 2006-2010; not including tugs, the Marine Exchange data show 1,207 vessel days (Reference 75) which aligns (except for minor discrepancies between the two data sources) with the 1,220 vessel days reported in Table 12 (Reference 14).

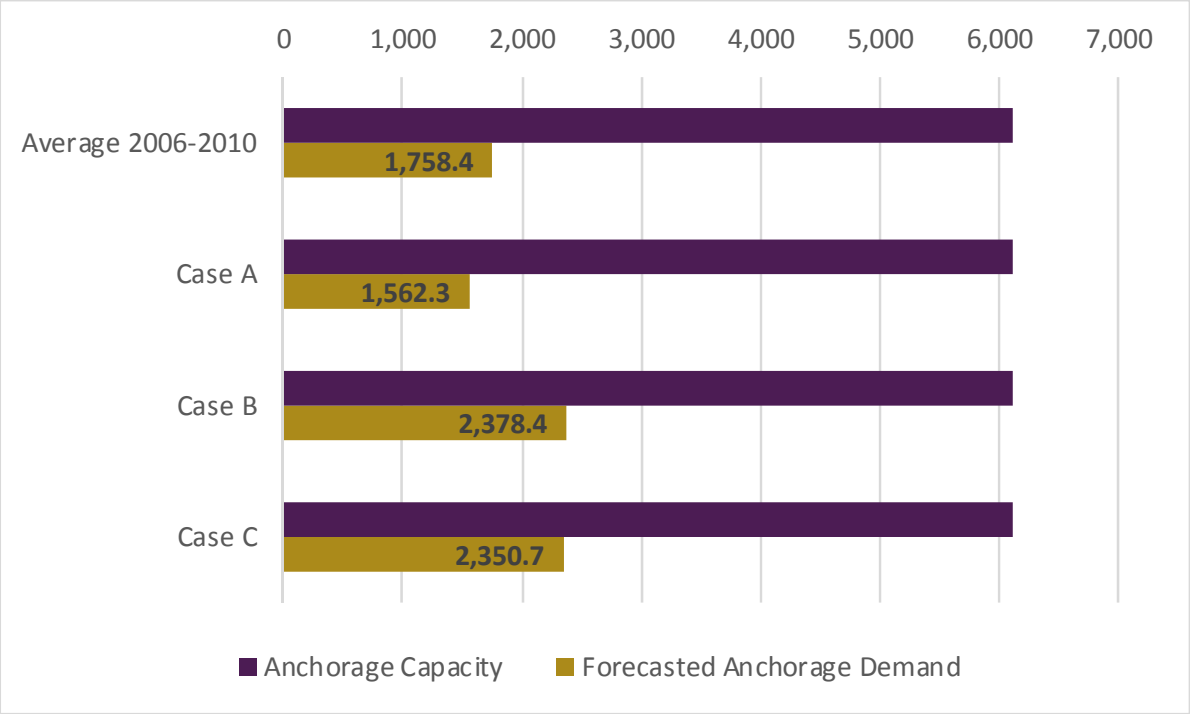

Figure 37 Historical and forecasted annual anchorage demand by Case, 2019, References 14 and 75

2.4.5.4 Just-in-Time Arrival Management

This queueing model is based on annual averages and does not take into account real-time, operational management which would reduce queuing time. Pilots, vessel agents, and the terminal are regularly in communication. This communication helps facilitate just-in-time arrivals at the berth. This means that both the cargo and the vessel arrive on schedule, so that neither is waiting for the other. For exports, the cargo is ready to be loaded onto the vessel and the berth is available when the vessel arrives. If a vessel has enough advance notice from the destination terminal that there is a delay, then the vessel may potentially reduce its speed earlier in the journey, before entering the study area, to manage arrival time and reduce cost and risk. There are costs associated with storing cargo at the terminal and with a vessel going to anchor. While at anchor, dragging anchor and other incidents are a risk. The cargo owner, terminal, and vessel are all incentivized to keep on schedule. In practice, delays occur. Even so, these operational practices could result in less queuing time than is predicted by the queuing model.

2.4.6 Anchorage Recommendation

The analysis found there is adequate anchorage capacity to accommodate forecasted demand in 2019. The analysis was conservative, because it was based on conventional queuing theory and did not take into account the management practices that will be in place. In addition, the study reduced the total available anchorage by four, as we recommend that GPT-calling bulkers avoid using the three shallower anchorages within Bellingham Bay and avoid the Cherry Point Anchorage from October to March. The study was limited to assessing the annual average anchorage usage and not the peak periods or cyclic patterns. Peak usage was studied by interviewing the VTS Director, Mark Ashley. After Port Angeles, Vendovi, Anacortes, and Bellingham Bay, there are still more available anchorages for when there is high demand. System wide, the 28 anchorage spaces have never been filled at full capacity (Reference 66). The USCG is already managing demand and evaluating safety. From the analysis finding and USCG feedback, establishment of additional anchorage capacity is not recommended.

The Vessel Traffic and Risk Assessment Study (VTARAS) included two discussion sessions, during which potential risk reduction measures (or Risk Reduction Options –RROs) were identified. The discussion group included members of Glosten's technical staff, as well as representatives of the Lummi Nation, the Department of Ecology, and PIT. These discussions considered measures with potential risk reduction for any vessel type or any area within the project area, including anchorages. The RROs represent a non-exhaustive list; the list of RROs from these discussions are presented in Section 5. There were 49 RROs identified, and only two RROs are applicable to vessels at anchor. They are:

- Anchorage management for tugs and tank barges supporting GPT-vessels.
- A near-miss reporting system for vessels underway, maneuvering, at anchor, and at dock.

Several RROs were also identified for bunkering, which is the second most likely reason to go to anchor. Anchorage management would be under the jurisdiction of the USCG Sector Puget Sound. The few number of RROs identified during the discussion session that apply to anchorages suggests that it is not necessary to develop or recommend risk reduction measures for anchorages.

2.5 Bunkering Demand

2.5.1 Introduction

This section estimates the potential increased demand for fuel oil in Puget Sound due to bulk carrier traffic at the proposed terminal. Information is provided that can be used to evaluate the potential cumulative effects of GPT calling vessels on bunkering activities in Puget Sound.

This section estimates the fuel consumption for GPT-calling bulkers and assist tugs. Fuel consumption for GPT-calling bulkers was estimated by assuming that a bulker's round trip to and from GPT includes two transits of the Pacific Ocean. The typical GPT-calling bulker is assumed to be bound for Asia, but it remains difficult to predict the bunkering behavior of bulk carriers serving the spot markets. Fuel market trends indicate that GPT bulkers will bunker at least part of their fuel demand in the Pacific Northwest. A percentage of GPT-calling bulkers

are expected to be bunkered within the study area. All tugs are expected to refuel[16] within the study area. The bunker volume from 2011 (without the proposed GPT) was used as the baseline to compare the estimated bunker demand with GPT operating at full capacity.

It is presumed that future increases in bunkering activities will occur at historically active locations; bunkering at GPT will be prohibited. This section summarizes the likely locations where such transfers could occur from information on historical bunkering activity provided by Washington State Department of Ecology. These data indicate that Port Angeles is historically the most active bunkering site.

This study found that compared to 2011, annual bunkering volumes for existing anchorages at Anacortes, Bellingham, Everett, Ferndale (Cherry Point), and Port Angeles are predicted to increase by approximately an additional 122% to 243% by 2019 due to GPT bulkers and tugs. The absolute volume demand predicted for GPT bulkers and assist tugs is on the order of 4,337,000 oil barrels (bbl). These results are summarized in Section 2.5.3.3, Table 29.

Based on historic pricing differences and recent and anticipated increases in crude oil production in North America it is assumed that prices for bunker fuel will be lower in the Puget Sound area than in Asian ports so vessel owners and charterers will be more likely to seek to bunker in ports with the lowest prices. This assumption is reflected in recent price differentials for bunker fuel in Seattle compared to other Pacific Rim ports presented later in this section. Bunkering demand was predicted assuming that there will be adequate bunker supply to meet predicted demand.

2.5.2 Methods

2.5.2.1 Baseline Bunkering Volume and Locations

It is presumed that future increases in bunkering activities will occur at historically active locations. Five existing North Puget Sound bunkering locations are located along the GPT bulker routes: Anacortes, Bellingham, Everett, Ferndale, and Port Angeles. The 2011 bunkering volume for these locations is given in Table 17. The 2011 bunker volume is within 0.1% of the average North Puget Sound bunker volume from 2009, 2010, and 2011, Reference 30. While the percentage increase is sensitive to the baseline comparison volume, the baseline year is neither uncharacteristically low nor high.

Port Angeles supplied most of the bunkering capacity. No bunkering will occur at the proposed GPT. Under current patterns, most bulkers that bunker are expected to do so in the Port Angeles harbor with bunker barges rafted alongside while at anchor. Alternate bunkering locations are an area suggested for further study as part of the Risk Reduction Options table (Section 5). These four existing bunkering locations are shown in Figure 38.

[16] For the purposes of this study, the term "bunker" is used inclusive of all vessels, irrespective of fuel type.

Table 17 2011 North Puget Sound annual bunkering volumes, Reference 30

Location	Bunkers (bbl)	Annual Percent
Anacortes	84,567	4.7%
Bellingham	4,762	0.3%
Ferndale	376,500	21.1%
Port Angeles	1,320,260	73.9%
Totals	1,786,260	100%

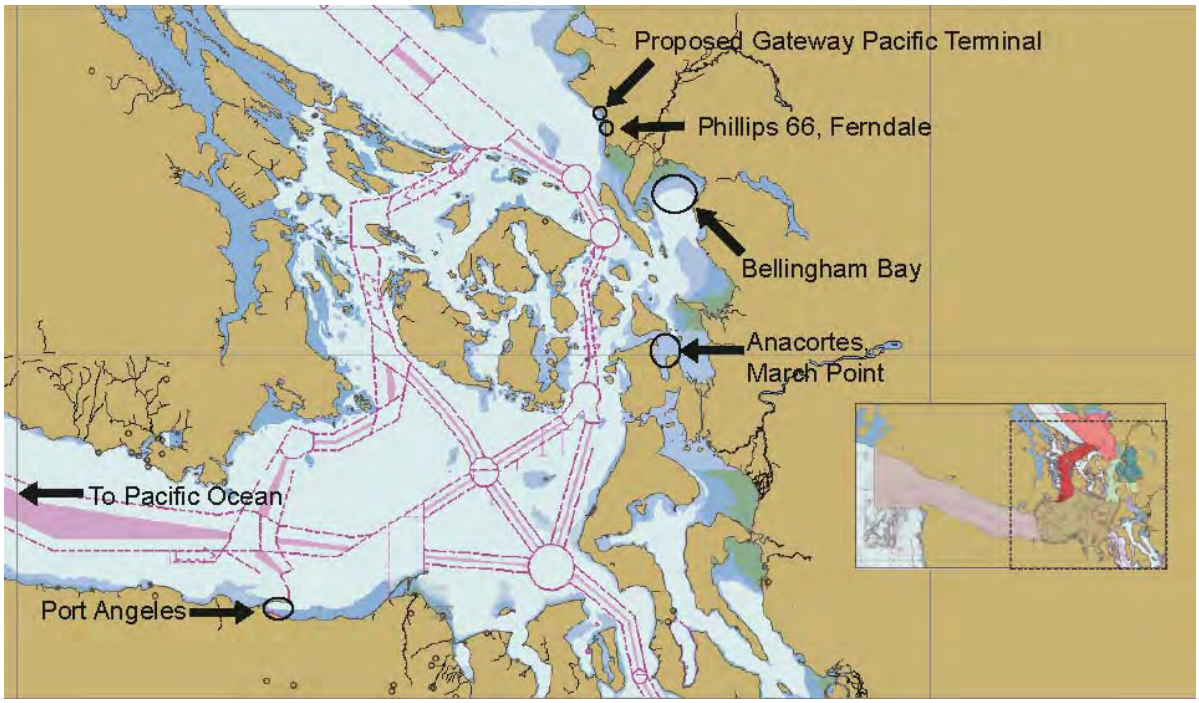

Figure 38 Bunkering locations in relation to proposed GPT location (bunkering would not be allowed at the proposed GPT)

2.5.2.2 Approach to Estimating Fuel Demand

Similar to automobiles, fuel consumption rates among vessels are highly variable. Different vessel models and different operators will achieve different consumption rates. Similarly, marine vessels will have a wide range of fuel consumption rates. While fuel consumption rates are closely monitored, they are also closely protected as competitive market data; therefore, operational fuel consumption rates are not typically available. A single data point is estimated, about which actual fuel consumption will vary. This fuel consumption and demand estimate should only be interpreted as a rough, order-of-magnitude result.

Total fuel consumption is estimated by multiplying a consumption rate with the activity duration and frequency. The longest activity duration is the bulkers' trans-pacific voyage. This single activity is the largest fuel use in the overall estimate and the only activity factored into the estimate for bulker fuel consumption. The tug operational profile, however, is more variable. Tug consumption is refined by time in transit, loitering, and ship handling. Per call fuel consumption was calculated for both bulkers and tugs, and then total fuel demand was

found by multiplying per-call demand by the number of calls planned per Reference 114. Due to variability and future uncertainty, a fuel demand range is provided.

Fuel availability with respect to increased fuel consumption is not considered. Future market forces toward expansion in the bunkering industry to meet postulated demands, along with future bunker cost trends, could be the topic of other studies. Demand is estimated assuming it is not limited by either availability or operational capacity.

2.5.2.3 Fuel Types and Units

At least two types of marine fuel would be burned by GPT-calling vessels. Bulkers primarily burn IFO380 fuel oil (Intermediate Fuel Oil of 380 centistokes (cSt) grade). Tugs burn marine gas oil (MGO) grade fuel. While IFO380 is typically sold on the international market in metric tons (mt), MGO is metered locally in US gallons (Table 18). Standard units of sale have been used to retain meaning within the industry as a priority over SI/Imperial unit system consistency. Where total volumes with different industry metering standards are combined, they are converted to oilfield barrels (bbl), a standard unit in bunkering risk descriptions. Metric tons are rounded to the nearest 150 mt, gallons are rounded to the nearest 42,000 gals; and barrels are rounded to the nearest 1,000 bbl. These three are approximately the same volume in each unit. In this report, volumes of both IFO380 and MGO fuel types have also been summarized in oilfield barrels for comparison to current bunkering volumes.

Table 18 Nominal fuel type and unit for GPT-calling vessels

Vessel Type	Fuel	Units Sold by
Bulker	IFO380	mt
Tug	MGO	US Gallons

Bulkers also burn low-sulfur fuel within the North American Emission Control Area (ECA). The entire study area is within the ECA; the ECA boundary is roughly 200 nm offshore. It is assumed that the fuel consumption rate burning LS IFO 380 (low sulfur IFO 380) is not significantly higher or lower than the reported rate for IFO380. Further, operation within the ECA is a relatively small percentage (less than 4%) of the total baseline roundtrip mileage between Asia and the proposed terminal. Therefore, for the purposes of estimating the quantity of fuel burned, this additional fuel type is not separated out, but can be estimated to be about 4% of total fuel consumed.

Estimates for increased fuel demand are made for the two sizes of bulkers planned to be calling at the GPT and for the assist tugs servicing them at terminal and at anchor.

2.5.3 Results

2.5.3.1 GPT Bulker Fuel Demand

<u>Bulker Fuel Demand Assumptions</u>

Fuel consumption was calculated for a baseline roundtrip voyage for the Capesize and the Panamax vessels. Existing throughput plans estimate that 35% of the 487 expected calls would be Capesize, and 65% of calls would be Panamax class bulkers. The roundtrip (laden and unladen) Capesize and Panamax fuel consumption was summed for total bulker fuel consumption.

The fuel consumption estimate assumes that all calls will be from long-term roundtrip charters, but in practice, some calls may be from spot charters. For a long-term chartered fleet, bunkering would be scheduled to coordinate terminal berth openings with GPT fleet traffic. Spot charter vessels are contracted on a per-cruise basis and will typically bunker with affordable fuel at each availability due to variable voyage planning beyond the immediate contracts. Spot charters are noted only as a source of undocumented variation.

Representative Bulkers

Speed and fuel consumption rates were found for a Capesize: *DHL Pacific* (IMO 9587350) and for a Panamax vessel: *Good Luck* (IMO 9395226). The Capesize bulker speed and fuel consumption rate was reported at 14.5 kts at sea on 61.5 mt/day IFO380, Reference 64. The Panamax Bulker speed and fuel consumption rate was reported at 14.0 kts laden on 33.9 mt/day IFO380, main plus auxiliary, Reference 32. Representative bulker vessel specifications are summarized in Table 19. The representative Capesize and Panamax bulkers were chosen because their fuel consumption data were reported.

Table 19 Representative bulker fuel consumption

Representative Vessel Size	Daily Consumption (mt/day)
Capesize: *DHL Pacific*	61.5
Panamax: *Good Luck*	33.9

Bulker Demand Quantity per Call

A baseline roundtrip voyage estimate of 11,400 nm (GPT to Caofeidian, China to GPT) was used to develop bunker requirements. At 14.5 kts, the one-way trip takes: (11,400 nm/2)/14.5 kts = 393 hours = 16 days and burns approximately 1,000 mt. There are 169 outbound, laden, Capesize voyages per year, totaling approximately 170,250 mt fuel burned, Table 20.[17]

Table 20 Laden Capesize annual fuel demand calculation

Laden Trip Duration (GPT to Asia)	16	Days/Call
Fuel Consumption Per Day	62	mt/Day
Number of Calls per Year	× 169	Calls/Year
Fuel Consumption per Year	170,250	mt/Year

The calculation for the Panamax vessel and for the unladen voyages is parallel, Table 21 - Table 23.[17] Unladen inbound voyages are assumed to have a 1 kt faster transit speed and to have a 10% reduction in fuel consumption over the laden outbound legs. The variability of

[17] Days per call are shown rounded to the nearest whole day; fuel consumption per day is shown rounded to the nearest metric ton (mt). Fuel consumption per year is calculated from non-rounded values and is shown rounded to the nearest 150 mt. Through this subsection, metric tons are rounded to the nearest 150 mt, gallons are rounded to the nearest 42,000 gals; and barrels are rounded to the nearest 1,000 bbl. These three are approximately the same volume in each unit. Results are rounded to reflect the estimate's rough level of accuracy.

unladen consumption rates across vessels, routing and seasonal weather is beyond this study. Presented is an approximation based on operational experience.

Table 21 Laden Panamax annual fuel demand calculation

Laden Trip Duration (GPT to Asia)	17	Days/Call
Fuel Consumption Per Day	34	mt/Day
Number of Calls per Year	× 318	Calls/Year
Fuel Consumption per Year	182,850	mt/Year

Table 22 Unladen Capesize annual fuel demand calculation

Unladen Trip Duration (GPT to Asia)	15	Days/Call
Fuel Consumption Per Day	55	mt/Day
Number of Calls per Year	× 169	Calls/Year
Fuel Consumption per Year	143,400	mt/Year

Table 23 Unladen Panamax annual fuel demand calculation

Unladen Trip Duration (GPT to Asia)	16	Days/Call
Fuel Consumption Per Day	31	mt/Day
Number of Calls per Year	× 318	Calls/Year
Fuel Consumption per Year	153,600	mt/Year

Percent of Bulker Fuel Bunkered in the Study Area

Research on the existing marine fuel markets in the Trans-Pacific show savings for vessels that bunker in the Pacific Northwest. Prices for IFO380 in October 2012 (Reference 40) are 2.5% higher for fuel purchases in Dalian and Guangzhou, China, with prices typically higher in other Asian ports. IFO380 fuel prices are generally more expensive at two representative Chinese ports than at two representative Pacific Northwest ports over the last five years, as compared in Figure 39. The price of fuel is highly variable, and the vessel managers are most likely to bunker where fuel is less expensive.

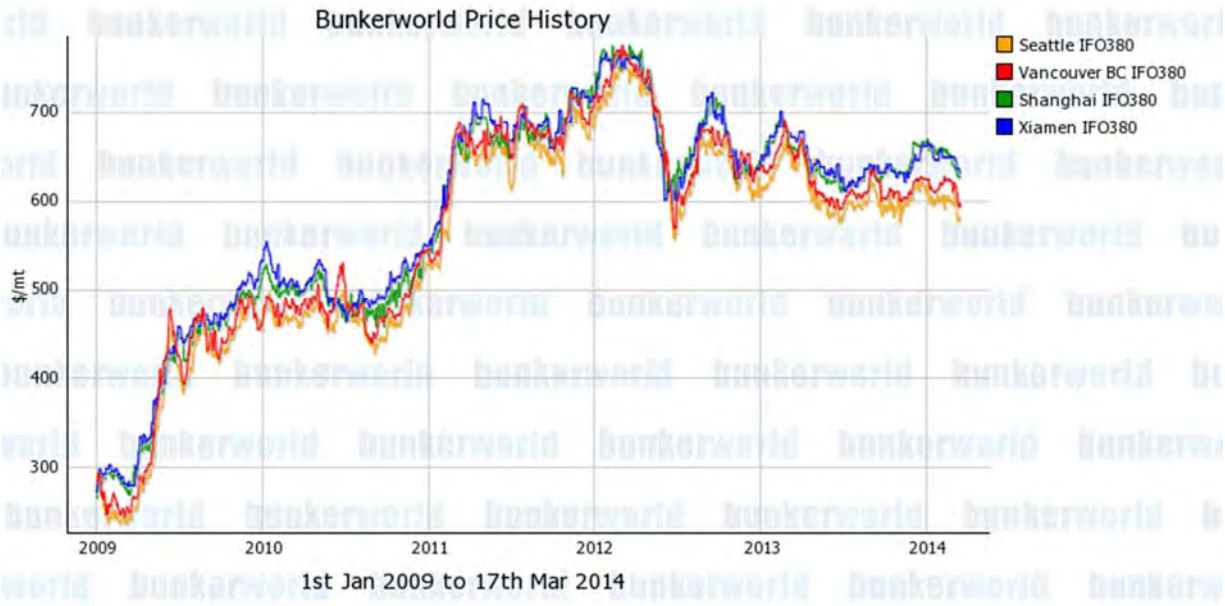

Figure 39 ***Bunkerworld*** **Price History for IFO380 at Seattle, Vancouver, Shanghai, and Xiamen from 2009**

Forecasted fuel availability also suggests that GPT calling bulkers trading between the Pacific Northwest and Asia will more likely bunker within the study area. US Energy Information Administration (EIA) International Energy Statistics database provided consumption and production statistics for conventional liquids, including "…crude oil and lease condensates, natural gas plant liquids, and refinery gains." Annual growth rate for 2008-2035 of liquids consumptions is 0.4% in the United States and 2.9% in China. Over the same time period, annual growth rate for production is 0.9% in the United States and 0.3% in China (Reference 60). Overall, increase in production is exceeding increase in consumption in the United States, while the opposite trend is seen and forecast in China. Fuel is more likely available in the study area than in Asia.

Beyond price and availability, there are additional factors that will influence where, how much, how often, and even what fuel type vessels will bunker in 2019 and beyond. Future demand for LNG as a marine fuel will increase, due to its cheaper price and regulatory requirements for low-sulfur fuel within the North American ECA. This would have the effect of reducing demand for IFO380 and LS IFO380. Alternatively, vessels may comply with the ECA requirements by installing exhaust gas scrubbers, and the demand for IFO380 or MGO would not be affected to as great an extent. Creation of an Asian ECA would change bunkering behavior.

Given this variability and future uncertainty, a range is provided. At most, 100% of the fuel consumed by GPT-calling bulkers will be bunkered in the study area. The lower bound assumed is 50%; half of the fuel consumed will be bunkered outside the study area. This lower bound also considers that the "Steering Committee determined that 47% of GPT vessels

would bunker on the inbound transit," (Reference 133).[18] International Chartering Services, Ltd (ICS) supplies bunker fuel to ships calling Port Metro Vancouver. Their Manager of Operations estimated that 75% of vessels calling PMV take on fuel to some extent (Reference 41). 75% is in the middle of the range provided for this study. The range of annual bunker demand in the study area for GPT bulker fuel is given in Table 24.

Bulker Fuel Demand Estimate

Table 24 Estimated GPT bulker fuel demand

Percent of fuel consumed that is bunkered within the study area	50%		100%	
	mt/year	Bbl/year	mt/year	Bbl/year
IFO380	325,050	2,152,000	650,100	4,304,000

2.5.3.2 Tug Fuel Demand

Tug Fuel Demand Assumptions

Assist tugs are expected for each berthing maneuver at the terminal and for anchoring. In line with the current regulatory scheme, GPT bulkers are assumed to be unescorted underway. No escort tug services are included for estimating tug fuel demand. Tugs with tank barges supplying bunker for and/or to GPT bulkers are also excluded from the estimate. The tug fuel demand estimate does not include any non-routine vessel movements. Only the fuel demand associated with assist tugs is included.

Assist tugs fuel demand is estimated for assisting GPT-calling bulkers to and from berth and for maneuvering to or from anchor. All GPT assist tugs are assumed to refuel within the study area.

Representative Tug

Currently two tug companies that operate in the study area would be called for bulker assist: Foss[19] and Crowley.[20] Their fleets were reviewed to characterize the available horsepower of a 'typical' tug. The fuel demand estimate used a rated horsepower of 5,000 hp and a fuel consumption rate of 0.048 gal/hp-hr at 100% maximum continuous rating (MCR), based on a Cat C280-6, similar to what is installed on the Crowley Sea Robin Class (Reference 117). The representative fuel consumption rate is used for estimating fuel consumption for both assisting at the terminal and at anchor.

Assist at Terminal

Two tugs will routinely be employed in assisting bulkers at GPT, given the anticipated size of the GPT-bound vessels, the common bollard pull of the typical tug to be employed, and the

[18] The average Capesize and Panamax bulkers have fuel capacity for two round trips between the study area and Asia. Thus, they could fuel every other trip on long-term charter. However, the bulker will improve its fuel efficiency and reduce its fuel cost by carrying the fuel needed and not twice that amount. This would not reduce the bunker demand in the study area. A bulker may bunker at 50% of its calls, and still only bunker in the study area.
[19] http://www.foss.com/wp-content/uploads/FOSS_Fleet_Sheet-Harbor_Tugs.pdf
[20] http://www.crowley.com/What-We-Do/Harbor-Ship-Assist-and-Tanker-Escort/Fleet-Description/Locations/Pacific-Northwest

routine environmental conditions in the study area. Three tugs might be appropriate for heavy weather docking, but accounting for the third tug's additional fuel demand is already within the uncertainty of the overall estimate.

The tugs are assumed to transit to the terminal from Anacortes or Bellingham for this study. This is approximately a 44 nautical mile round trip for each callout. Foss homeports tugs in Bellingham. Crowley homeports tugs in Anacortes. Depending on market demands, tugs are often re-located between different company homeports. Existing assist tug homeports and routings may change specifically for the new traffic.

In this study, a callout is defined as the complete round trip made by a tug leaving its homeport, performing an assist job or jobs, and returning to its homeport.[21] A representative callout to the terminal includes: transit from the homeport to a loitering area nearby the terminal, assisting a departing bulker, assisting an arriving bulker, and transit from the terminal back to the homeport. An approximate transit speed is 8 kts, found for the tug vessel type in the subareas through which the route passes, see Section 3.2.3.1. An 8 kt transit speed is approximately 50% engine MCR. At 8 kts, a 44 nautical mile round trip takes approximately 5.5 hours. Table 25 lists the representative parameters for a callout in the study's vessel traffic model.

Table 25 Typical callout parameters for assist tugs in the study area

Callout Parameter	Typical Value
Roundtrip Length	44 nm
Transit Speed	8 kts
Roundtrip Transit Duration	5.5 hrs
Number of Assist Jobs	2

Table 25 indicates that each callout is assumed to contain two assist jobs. Given the frequency of bulker arrivals and departures at the terminal at full capacity, one assist job occurs when a bulker leaves the terminal, and the second assist job occurs when a bulker arrives at the terminal. At the 2019 GPT throughput rate (Reference 114), the tugs will service bulkers arriving 487 times per year, which equals approximately 40 arrivals per month or 18 hours per arrival. Departure ship handling is expected to immediately precede arrival berthing, per standard practice, so that bulkers are un-berthed and berthed during each tug callout.

Queueing analysis, Section 2.4.5, findings suggested there will be no delay between bulker departures and arrivals, allowing for two assist jobs per callout. The queuing analysis found that, on average, there will be approximately two ships at anchor, waiting to come to the berth, and that there is only an 11% probability of zero (0) ships waiting at anchor. Between Berths 1, 2, and 3, a tug may support more than two assist jobs per callout. The tug may also service other terminals and anchorages nearby GPT.[22]

Two assist jobs per callout may not occur every time a bulker calls at GPT. In practice, there may be a delay between bulkers departing and arriving. Given this delay, a tug may decide to

[21] A callout is distinct from a call, which is defined as the arrival of a vessel at the terminal.
[22] The time spent on jobs for other terminals would not contribute to traffic time associated with the proposed GPT.

either loiter at the terminal or return to its homeport before its next job. There are two main reasons that tugs loiter at the terminal:

- *Early arrival*. Tugs regularly arrive early to an assist job and loiter, in order to be available at the required time to meet their ship.
- *Next job proximity*. Tugs may also loiter in between assist jobs when it is more cost effective to stay nearby than to transit back to the homeport. If the next assist job is in less than approximately 5.5 hours, then there is not enough time to transit to the homeport and back. Tugs may also loiter longer than 5.5 hours to conserve fuel.

Loitering is like transit, or underway, without making way. Engines are idling around 25% MCR. This estimate accounts for two hours of loitering time for each callout. In practice and in the vessel traffic analysis, Section 3, a range of one to two hours is expected and is modeled.

Shiphandling, or ship assisting, is estimated, conservatively, to take up to two hours supporting both the berth and unberth assists. This is the time spent with lines up between the tugs and the bulker. Ship handling MCR is 85%. Approximations for time spent and percent MCR for transiting, loitering, and ship assisting are based on past operational experience (Reference 46) and summarized in Table 26.

Table 26 Tug activity time and engine load for callout to terminal

Activity	Hours Per Callout	%MCR
Roundtrip Transit Duration	5.5	50%
Loiter	2.0	25%
Assisting/Ship Handling	2.0	85%
Total Tug Activity Time per Callout	9.5	

There are 974 callouts to the terminal. This total is arrived at from 487 × 2 × 2/2:

- 487 bulkers calls per year.
- Two (2) assists (undock and dock) per bulker call.
- Two (2) tugs per assist.
- Two (2) bulkers assisted per tug callout.

Fuel costs, labor rates, labor shifts, number of tugs available, traffic or cargo delays, and other variables beyond the scope of this study will contribute to how tugs are dispatched in real-time.

Tug Assists at Port Angeles

Assist tugs may also be called for maneuvering a GPT bulker to or from anchor. Historical anchorage usage and GPT bulker time at anchor is reported in Section 2.4. GPT bulker time at anchor is distributed between the historically active anchorages, but for the purposes of estimating fuel demand of assist tugs, only the Port Angeles anchorage is considered. This simplification is consistent with the position that most bulkers are expected to bunker in Port Angeles in Section 2.5.2.1, Baseline Bunkering Volume and Locations.

Puget Sound Pilots, Reference 50, recommend tug assist based on ship size and on whether a laden tanker is also at the anchorage. A pilot may also request an assist tug based on wind conditions and/or anchorage position, for example approaching the three most westerly anchorages at Port Angeles with a northerly wind. All calls may request assistance but none are required to do so. Ultimately, the pilot decides whether a tug assists.

The activity and engine load profile for one anchorage assist call is estimated to take three-quarters of an hour transit and one and a half hours of ship handling (Table 27). Just one tug is used in this maneuver. The tug's homeport is assumed to be Port Angeles. The vessel traffic analysis models a distribution around these expected durations and does not include time at dock (Section 3.2). The conservative assumption is made that all GPT-bulker calls result in a tug assist; this assumption results in a higher bunker demand.

Table 27 Tug activity time and engine load for callout to Port Angeles anchorage

Activity	Hours Per Callout	% MCR
Transit	0.75	50%
Loiter	0.0	NA
Assisting/Ship Handling	1.5	85%

Tug Fuel Demand Estimate

Fuel consumption for each activity is the product of hours operating, tug rated horsepower, percent maximum continuous rating, and specific fuel oil consumption rate per horsepower. Consumption per callout is the sum of consumption for the three activities: transiting, loitering, and assisting. Total consumption is the product of consumption per callout and number of callouts for both assists at the terminal and at Port Angeles. Assist at the terminal constitutes approximately 86% of the total consumption forecast. Annual assist tug demand is given in Table 28, rounded to the nearest 42,000 gals and 1,000 bbl. The annual tug demand is less than 2% of the bulker demand at the lower bound (50%) of bulkers bunkering and less than 1% of the bulker demand at the upper bound (100%).

Table 28 Estimated GPT tug fuel (MGO) demand at GPT and Port Angeles

	Gal/year	Bbl/year
GPT Assist Tug Demand	1,386,000	33,000

A separate fuel demand estimate for tugs supporting bunkering of GPT-calling bulkers was not made. The fuel demand estimate for tugs is not further refined in part because the overall fuel demand is dominated by the rough, order of magnitude estimate for bulkers.

2.5.3.3 GPT Increase in Local Fuel Demand

The 2019 GPT calling bulkers and assist tugs are forecast to bunker between 2,185,000 and 4,337,000 bbl within the study area. This volume represents an increase on the order of 122% to 243% over the 2011 level.

Future bunkering at the increased volumes noted is likely to change the utilization rates of existing recognized bunkering locations. Utilization rates at specific bunkering locations are not predicted.

Table 29 Summary of estimated GPT fuel demand

	2011 Bunker Demand in North Sound*	2019 Bunker Demand from GPT Calling Bulkers and Assist Tugs	
Percent of bulker fuel consumed that is bunkered within the study area	-	50%	100%
Bunker Demand (bbl/yr)	1,786,260	2,185,000	4,337,000
Additional required over 2011	-	122%	243%

* Anacortes, Bellingham, Everett, Ferndale, and Port Angeles. See Reference 30.

2.5.3.4 Fuel Demand Incorporated Into Vessel Traffic Forecast

The fuel demand is carried through to the vessel traffic forecast, Section 3.2. The time at anchor required to transfer the estimated fuel oil volume is estimated with a nominal fuel transfer rate of 2,500 barrels per hour, per an industry source. The time at anchor required to transfer the estimated fuel oil volume was found to be less than the amount of time at anchor required for queueing (Section 2.4.5). Therefore, it is assumed that time spent bunkering is included within the time spent queuing in the forecast time at anchor for GPT-calling bulkers. Tug and tank barge transits to supply bunker are added.[23] This vessel traffic is described in Section 3.2. Specific bunkering facilities at the bunkering locations were not considered in the volume demand estimate or transfer time estimate.

2.6 Ballast Water Management

2.6.1 Introduction

This section estimates the volume of ballast water discharged into Puget Sound from vessels calling at the proposed GPT. International, federal, and state guidelines and regulations currently require all marine vessels to exchange near coastal ballast water from outside of Puget Sound with oceanic water prior to discharging in Puget Sound. Vessels may perform this exchange in a variety of ways. In recent years, ballast water exchange is being eliminated and replaced by more efficacious ballast water treatment systems.

Bulk carriers will typically carry ballast water in order to maintain their stability and limit hull stresses as they transit from other coastal ports and foreign ports into Puget Sound. Ballast water has the potential to introduce harmful non-indigenous species and pathogens when discharged from marine vessels. The risks of ballast water discharges are discussed in terms of the propagule pressure. Propagule pressure is akin to the likelihood for a new species to propagate, or take hold and flourish in a new habitat. The likelihood of introducing ballast water induced invasions is proportional to volume discharged and the potential residual toxicity in ballast water.

This study estimates that GPT activities will nearly triple existing ballast water discharge volumes into Puget Sound. The Washington State Department of Fish and Wildlife (WDFW)

[23] GPT-related oil tug and tank barge trips were modeled using total demand; total annual bunker demand was divided by tank barge capacity to derive annual tank barge trips.

estimated that in 2013[24] there was 6,996,112 cubic meters of ballast water released into Puget Sound by all marine vessels. GPT-calling carriers would discharge their ballast water primarily at GPT and, to a lesser extent, at bunkering locations. These discharges are estimated at approximately 13,900,000 cubic meters in 2019 almost exclusively within the Cherry Point subarea. Ballast water discharges from GPT-associated service vessels, such as tugboats and bunker barges, if any, are not included in this study's estimate. Ballast water discharge operations, associated risks from introducing harmful non-indigenous species and pathogens, and management practices to reduce these risks are discussed.

This section first discusses the risks of ballast water discharges in terms of the propagule pressure, or likelihood of introducing ballast water induced invasions, and the potential residual toxicity in ballast water (Section 2.6.2). Next, a projection of the quantity of ballast water that might be discharged at the proposed GPT is developed by reviewing two example vessels and then extrapolating to the GPT port-call estimates (Section 2.6.3). The quality of those discharges is discussed in terms of current regulatory requirements, with snap-shots provided for 2016, 2019, and 2021 (Section 2.6.4). Uncertainty is discussed in terms of regulatory requirements and the implementation of technology to meet those requirements (Section 2.6.5).

2.6.2 Ballast Water Discharge Risk

This section presents some fundamental principles of ballast water, and then reviews the two primary risks of ballast water discharges to the natural environment: introduction of non-indigenous species and discharge of acute or persistent toxic substances.

2.6.2.1 Principles of Ballast Water

Bulk carriers arriving at the proposed GPT will typically arrive "in ballast." This means that they will not have cargo on board, but rather ballast water previously taken up for various purposes, including: maintaining stability, minimizing longitudinal bending stresses, submerging the propeller, and adjusting trim. As cargo is taken on at the terminal, the majority of this ballast water will be discharged into the local waters. Vessel draft "in ballast" is shallower than when the vessel is fully loaded with cargo. The weight of the cargo loaded is greater than the weight of the ballast discharged. The quantity of ballast water discharged will vary by vessel and its arrival condition, but will generally be one-quarter the weight of the cargo loaded. A bulk carrier, similar to many other ocean going vessels, may also discharge ballast water if the vessel takes on fuel oil bunkers at a port.

The source of this ballast water, if unmanaged, is generally the local waters where the bulk carrier discharged its last cargo load. The zooplankton, phytoplankton, and bacteria organisms in that local water, if unmanaged, will be taken up with the ballast water into the bulk carrier. Unmanaged, organisms from locations such as San Francisco Bay and Far East ports are known to survive transit and discharge into Puget Sound waters (Reference 69). Because of

[24] The incremental risk associated with an increase in ballast water discharge is the only estimate in this report that uses a 2013 baseline. The approach to estimate this incremental risk was revised in 2013, and the current data at the time was used.

this risk, an evolving set of international, federal, and state guidelines and requirements govern the management of marine vessel ballast water discharges.

2.6.2.2 Non-Indigenous Species

The US Congress, as first published in the *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990*, determined that ballast water discharges from marine vessels posed a significant threat to US waters (Reference 1). The first two findings of the act are:

> *"(1) The discharge of untreated water in the ballast tanks of vessels and through other means results in unintentional introductions of nonindigenous species to fresh, brackish, and saltwater environments;*
>
> *(2) When environmental conditions are favorable, nonindigenous species become established, may compete with or prey upon native species of plants, fish, and wildlife, may carry diseases or parasites that affect native species, and may disrupt the aquatic environment and economy of affected nearshore areas;"*

The National Academy of Science formed an expert team to study the factors that might lead to an invasion, and in 2011 published *Assessing the Relationship between Propagule Pressure and Invasion Risk in Ballast Water* (Reference 38). The study conclusions, with the emphasis shown from the original document, include:

> ***"It is abundantly clear that significantly reducing propagule pressure will reduce the probability of invasions, when controlling for all other variables.*** *There is both strong theoretical and empirical support for this, across a diverse range of habitats, geographic regions, and types of organisms. However, the precise nature of the response can vary enormously over species, time, and environments. In short, while inoculum density is a key component, it is but one of scores of variables that can and do influence invasion outcome.* ***Thus, any method that attempts to predict invasion outcomes based upon only one factor in the multi-dimensional world of the invasion process is likely to suffer from a high level of uncertainty."***

Propagule pressure can be reduced by decreasing the discharge frequency, the total quantity of viable organisms discharged, and the concentration density of viable organisms. However, there is a lack of data that can quantify the reduction in invasion risk due to controlling these factors. In light of this lack of data, this study only projects the quantity of discharged ballast water and the standard to which that ballast water is required to be managed. Further assessment could consider the impact of repeated of discharges in one location on propagule pressure.

2.6.2.3 Residual Toxicity

Certain ballast water management techniques administer chemicals, also known as active substances or preparations, to kill potential NIS (non-indigenous species). In general, these chemicals are applied to the ballast water while it is being taken up into the ship so that the chemicals have adequate contact time to kill the organisms in the ballast water tanks. This treated ballast water should not be toxic at the time of discharge, however, or the organisms in the local receiving water may be subject to unacceptable harm. Chemical-based treatment systems typically monitor for indications of residual toxicity, and utilize a controlled neutralization system as required.

International and federal guidelines and regulations require the evaluation of residual toxicity from ballast water treatment systems that employ chemicals. Separate federal regulations require periodic discharge testing of such systems for compliance with mandated maximum residual chemical levels. It is assumed that only treatment systems that have been approved to comply with these minimums will discharge at GPT, and that these minimums do not pose a significant risk to the local waters. As there are very few chemical-based systems currently in operation, there are little or no data on failure rates or actual residual toxicity. As such, this report does not estimate the risk of monitoring equipment or neutralization system failures.

2.6.3 Ballast Water Operations

This section predicts the quantity of ballast water that might be discharged at GPT. It is expected that GPT will be serviced by Capesize and Panamax size bulk carriers. In terms of ballast water management, these sizes can be characterized by the quantity and rate of ballast water discharge, as well as the timing of the discharge. The ballast water operations of these vessel sizes are typically similar, with the differences focused on the ballast holding capacities and discharge rates. This section outlines typical operational practices of bulk carriers in general, provides the particulars of two example vessels, and then extrapolates these data to expected future ballast water discharges at GPT.

2.6.3.1 Ballast Water Operations

Ballast water handling, for purposes of hull stress and stability, is considered a vital system on board marine vessels by regulatory agencies. Mishandling of ballast water can result in vessel capsizing or breaking apart. In either case, mishandling of ballast water can result in loss of life, environmental impact, and loss of equipment.

The movement of ballast water is a controlled process. All movements of ballast water – uptake, discharge, or internal transfer – must first be evaluated for compliance with the requirements of a vessel-specific trim and stability booklet or computer program. Further, the actual movements can only be performed under the supervision of a ship's officer who is trained and licensed for those operations.

<u>Ballast Water Discharge after Entering Protected Waters</u>

The bulk carriers calling at GPT, unless already arriving from within the greater Salish Sea, will arrive with adequate ballast water for ocean conditions. Such open ocean conditions typically require more ballast water than is required in protected waters. As a result, such bulk carriers may discharge limited quantities of ballast water once they have entered the protected waters of Puget Sound on their way to GPT.

In rough weather conditions, bulk carriers commonly take-on "storm ballast," by filling one or more cargo holds with ballast water. It would be typical to begin discharging such storm ballast soon after entering protected waters and before reaching a cargo loading terminal.

<u>Ballast Water Discharge for Fuel Oil Bunkering</u>

Bulk carriers arriving at GPT may take on fuel oil bunkers while in Puget Sound. Annual bunker consumption and demand for bunkering in the study area is estimated in Section 2.5.3.3. As the bunkers are taken on, some ballast water might be offloaded for

purposes of maintaining trim, or to reduce ballast water discharge operations if subsequently loading cargo at the terminal.

Ballast Water Discharge during Cargo Loading

Bulk carriers arriving at GPT will typically arrive "in ballast," meaning that the cargo holds will be empty and the ballast water tanks mostly full. While some ballast water may be discharged prior to arrival at the terminal, the majority of the ballast water will be discharged at the terminal.

Before cargo loading, the bulk carrier and the terminal will jointly develop a cargo loading plan. This planning will develop a sequence for loading the cargo holds that considers several factors including terminal facility logistics, ship stability requirements, and ship longitudinal bending stresses. Discharging ballast water is a significant part of this sequence. The discharge of ballast water is closely matched to the cargo loading rate and hold loading sequence. As the ship is loaded, ballast water is discharged.

Upon completion of cargo loading, the ballast water remaining on board is minimal, as it is required only to make trim and list corrections. Bulk carriers are often loaded "to the marks," meaning that loading only stops when the ship has submerged to the deepest limits assigned in accordance with the International Load Line Convention of 1966 (Reference 70). Any ballast water remaining on the ship reduces the quantity of cargo that can be carried.

2.6.3.2 Typical GPT-Calling Bulkers

A summary of typical characteristics for Panamax and Capesize vessels that would call at GPT are summarized below in Table 30. This includes a listing of several references for deadweight capacities. Deadweight refers to the cargo carrying capacity of a ship. The deadweight grouping is less defined than other ship characteristics, and therefore different sources provide different guidance on what deadweight belongs to what ship size. Ballast water system characteristics also vary between vessels within a given ship size. In order to develop estimates of ballast water discharge volumes, one example vessel was selected for each of these groups. The example vessels were selected to align with the typical characteristics, including the representative ballast capacity prescribed by the ABS BWM Advisory (Reference 38). The characteristics of these two example vessels are provided in Table 31. Reference photos of the example ships are shown in Figure 40 and Figure 41.

Table 30 General bulk carrier characteristics for GPT

Particulars	Panamax	Capesize	Reference	Reference No.
Deadweight (mt)	55,000 to 84,999	80,000 to 149,999 (small) More than 150,000 (large)	UNCTAD, 2011	128
	55,000 to 80,000	More than 80,000	IACS FSA, 2001	49
	65,000 to 80,000	100,000 to 180,000	Lloyds Register, 2012	20
Molded breadth (m)	Less than 32.31	More than 32.31	UNCTAD, 2011	128
Representative Ballast Capacity (m^3)	35,000	65,000	ABS BWM Advisory, 2011	19
Representative Ballast Pumping Rate (m^3/hr)	1,800	3,000	ABS BWM Advisory, 2011	19

Table 31 Example bulk carrier characteristics

Particulars	*Grand Amanda*	*Golden Future*	Reference	Reference No.
Ship Size	Panamax	Capesize		
Delivery Date	August 2011	February 2010	ABS Ship Record	52
Deadweight (mt)	79,600	175,800	ABS Ship Record	52
Molded breadth (m)	32.26	45	ABS Ship Record	52
Ballast Capacity (m^3)	20,481	52,642	ABS Ship Record	52
Storm Ballast (m^3)	13,830	22,670	ABS Ship Record	52
Typical Discharge Volume (m^3)	18,400	47,400	Estimates based on 90% of ballast capacity	
Ballast Pumping Rate (m^3/hr)	1,700	4,200	Estimates assume 12 hour discharge	
Ballast Tanks	25	21	ABS Ship Record	52

Figure 40 ***Grand Amanda*** **in Gladstone, Australia, Reference 53**

Figure 41 ***Golden Future*** **at Cowichan Bay anchorage, Reference 146**

2.6.3.3 Projected Ballast Water Discharge Volumes at GPT

Projected ballast water discharges are based on the number of expected ship calls at GPT and the estimated ballast water discharge volumes. These volumes are estimated at 18,400 m^3 per Panamax ship call and 47,400 m^3 per Capesize ship call. These volumes are not ballast capacities, but rather the discharge volumes expected from the two example vessels detailed in Table 31 above. The projected Panamax volumes are generally supported by discharge volumes that have been reported to the US National Ballast Information Clearinghouse (NBIC) for similar vessels. Capesize volumes are more difficult to verify given a lack of corroborating data.

Table 32 Projected ballast water discharge volumes at GPT, Reference 52 and 114

Year	Panamax Ship Calls	Capesize Ship Calls	Annual Discharge (cubic meters)
2019	318	169	13,861,800

Washington Department of Fish and Wildlife (WDFW) tracked 4,239 vessel arrivals in Washington State in 2013, estimating total ballast water discharges at 14,928,438 cubic meters (Reference 136). Specific to Puget Sound, WDFW tracked 3,314 vessel arrivals in 2013, estimating total ballast water discharges at 6,996,112 cubic meters (Reference 21). Adding the projected annual discharge from calls at GPT (13,861,800 m^3 as per the above Table 32) to this 2013 volume nearly triples the volume of ballast water discharged into Puget Sound by 2019.

NBIC, corroborating WDFW data, tracked 4,119 vessel arrivals in Washington State in 2013, estimating total ballast water discharges at 14,569,000 m^3 (Reference 21). Further, NBIC estimates that of 3,267 Puget Sound vessel arrivals, only 730 actually discharged ballast water. Considering both the WDFW Puget Sound discharge data (6,996,112 $m^{3)}$ and NBIC Puget Sound vessel data (730 vessels) indicate that the average Puget Sound ballast discharge volume was 9,580 m^3. In other words, the majority of Puget Sound calling vessels do not currently discharge ballast water, and the average discharge of those that do is significantly less than the bulk carriers that are expected to call at GPT.

2.6.4 Management Requirements

This section utilizes the example vessels, in the above Table 31, to outline the regulated management practices at GPT in 2019. Bulk carriers calling at GPT will be required to meet a combination of international, federal, and state guidelines and requirements. Many of these requirements are overlapping in both the details of the required practices and in the phase-in implementation dates of those required practices.

This review makes the following regulatory implementation assumptions:

- The USCG phase-in schedule requiring ballast water treatment remains on track for marine vessels with ballast water capacities greater than 5,000 cubic meters.
- The IMO driven phase-in schedule for requiring ballast water treatment is aligned with the USCG; specifically, that the IMO implementation schedule will change its basis to the first dry-docking after the compliance date rather than first intermediate survey.
- Washington State ballast water management requirements continue to accept USCG approved ballast water treatment systems.
- Vessels calling at GPT will be in compliance with USCG ballast water management requirements without exception.

2.6.4.1 Ballast Water Exchange

Currently, all marine vessels are required to have exchanged near coastal ballast water from outside of Puget Sound with oceanic water prior to discharging in Puget Sound. This is

governed by international, federal, and state guidelines and regulations. The required exchange can be achieved in two ways:

- Empty-Refill: Emptying a ballast water tank and then refilling it with oceanic water.
- Flow-Through: Continually pumping oceanic water into a full ballast water tank, overflowing it until at least 300% of the ballast water tank capacity is flushed through.

The requirements differ for vessels on trans-oceanic voyages and near coastal voyages. Specifically, vessels that transit outside of the US Exclusive Economic Zone are required to perform the exchange at least 200 nautical miles from the nearest land and in waters of at least 2,000 m in depth. Vessels operating within the US Exclusive Economic Zone are required to perform the exchange at least 50 nautical miles from nearest land and in waters of at least 200 m in depth.

Ballast water exchange is being eliminated and replaced by ballast water treatment systems, which are considered more efficacious at removing non-indigenous invasive species (NIS), and avoid potential ship stability and hull stress issues associated with ballast water exchange.

2.6.4.2 Ballast Water Treatment

Federal regulations start phasing-out ballast water exchange requirements for new marine vessels with keel lay dates on or after 1 December 2013. Existing vessels of high ballast water capacity, such as bulk carriers that might call at GPT, will require the fitting of treatment systems at their first dry-docking after 1 January 2016. Assuming a five-year dry-docking schedule, this fleet would complete its refitting by 31 December 2020, effectively phasing-out ballast water exchange within two years of GPT start-up in 2019.

2.6.4.3 Ballast Water Requirements Compliance and Enforcement

Allen Pleus presented a review of WDFW's Ballast Water Management Program on April 15, 2014 (Reference 96). The program's core functions include: assisting vessels on state laws and regulations, assessing compliance with state laws and regulations, and preventing the discharge of non-compliant ballast water. Compliance trends from 2008-2013 were reported, showing steadily increasing compliance, which reached 94% in 2013. Over those six years, an annual average of 4,100 vessels arrived in Washington State waters and an annual average of 304 vessels (7.4%) were inspected. This equated to one vessel per day, or 1 in every 14 vessels, being inspected. The program's 2012-2013 budget supported 3.3 FTEs (full-time equivalent personnel). The Ballast Water Management Program also coordinates with the US Coast Guard and EPA.

2.6.4.4 Treatment System Phase-In Trends

In both new builds and retrofits, there are several trends that influence the phase-in of ballast water treatment systems by new and existing vessels. Treatment system phase-in trending is projected in Figure 42. The schedule of treatment system phase-in is significantly impacted by the rate of new builds delivered with systems installed as compared to the rate of existing vessels that get refitted with treatment systems. Construction of new bulk carriers, which would have a treatment system installed, follow market trends of periods with significant construction alternating with periods when there is little construction. Instead of attempting to predict those trends, this study assumes a replacement rate of 5% annually assuming that the

average vessel age calling at GPT will be 10 years. This is shifted towards newer vessels as compared to the United Nations data indicating the average age of broken-up dry bulk carriers at 30.9 years (Reference 128). The shift is assumed due to the increased likelihood that newer vessels would be more likely to meet US environmental requirements.

Refit of ballast water systems is predicted on a straight-line trend based on the USCG ballast water rules for existing vessels during their first dry-docking starting in 2016. These dry-docks are typically at a five year interval, but might be extended to six years. The more conservative, showing fewer vessels being refitted, six-year interval is applied.

In October 2013, the USCG issued a circular that would allow vessels to request an extension from installing ballast water treatment systems until there were USCG type approved systems. As of April 2014, USCG has not yet approved any ballast water treatment systems. However, they do permit the installation of alternative management systems (AMS) that are approved by another administration. Most new construction vessels are being outfitted with AMS and existing vessels are not yet required to be refitted. As such, the extension program does not currently impact the predictions.

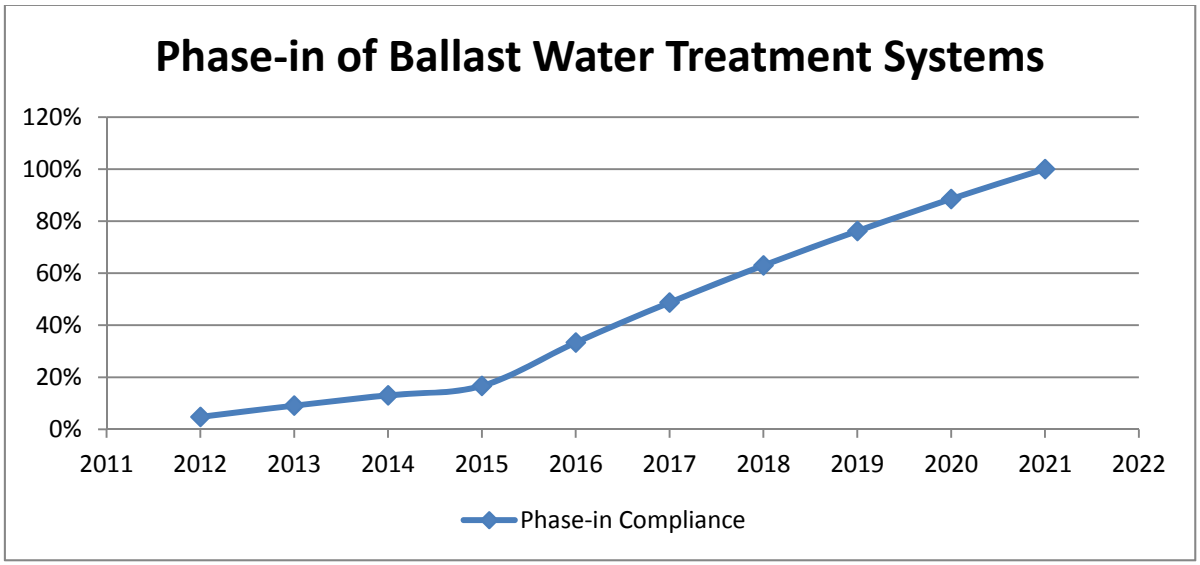

Figure 42 Bulk carrier treatment system installation projections

2.6.4.5 Consideration of GPT-Calling Bulkers

It is estimated that in 2019, when GPT operations are predicted to commence, approximately 75% of the discharged ballast will be managed by a treatment system, and the remaining 25% will be managed by ballast water exchange. These percentages are expected to steadily rise to near 100% treatment by 2021, when the USCG phase-in period concludes (Figure 42).

There is not expected to be a significant difference in compliance rates between Panamax and Capesize bulk carriers. If there is a difference, it would more likely be a delay in refitting the larger Capesize bulk carriers given their higher ballast water flow rate. For example, these larger treatment systems might require additional electrical generating capacity.

2.6.4.6 Ballast Water Management Implementation Timeline

Vessels calling at GPT will be required to comply with international, federal, and state guidelines and regulations. These combined requirements include maintaining a ballast water management plan, filing a ballast water report with USCG and WDFW at least 24 hours prior to arrival in Puget Sound, and maintaining a sediment management program. Relative to management of the ballast water, the vessel will either need to perform an exchange 200 or 50 nautical miles from nearest land or utilize a ballast water treatment system. Table 33, below, provides a summary of these practices.

Table 33 Ballast water management requirements by year

Requirement	2016	2019	2021
Ballast Management Plan	Required	Required	Required
Ballast Discharge Report	Required	Required	Required
Exchange >50 n. miles*	Near Coastal Voyages	Near Coastal Voyages	Exceptions Possible
Exchange >200 n. miles	Voyages Outside EEZ	Voyages Outside EEZ	Exceptions Possible
Utilize Treatment System	~30%	~75%	~100%
Manage Sediment	Required	Required	Required

*Due to fuel sulfur requirements, some near coastal voyages might result in ballast exchanges conducted outside of 200 nautical miles.

2.6.5 Uncertainty Associated with Ballast Water Management

Ballast water management regulations and technology development are in a period of rapid development. For example, the US Coast Guard final rule was only issued in March of 2012, and the first US Environmental Protection Agency permit with numerical standards for ballast water only entered into force in November 2013. In addition, the US Coast Guard is still developing its procedures for reviewing and approving treatment technologies.

While there are bridging strategies in place, such as the US Coast Guard alternative management system program, this rapid development cycle introduces uncertainty regarding whether technology can consistently meet efficacy standards. Additional concerns include:

- The low number (perhaps less than six) of technologies that have been tested to the US Environmental Technology Verification (ETV) protocol for land-based testing. This testing, or similar, is required to gain US Coast Guard type approval.
- The current development of methods to perform compliance monitoring audits of ships that will be discharging ballast water. These methods are being developed by administrations, including the US.

There is also uncertainty related to the reliability of ballast water treatment systems due to a lack of operational data from existing marine vessel installations. Most of these systems are in either prototype phases or first generation development cycles. Further development will generate more reliability data to evaluate the frequency of equipment mechanical failures or predictions on the frequency with which the treatment system process is overwhelmed by the natural conditions of the ballast water.

There has been some work on contingency measures in response to reliability concerns. These approaches include the use of a reception facility for treating the ballast water once it is off-loaded from the ship, and the use of mobile equipment that would enable treatment of the ballast water on-board the ship itself. Further development and testing of these approaches is required before their utility can be fully evaluated.

Multiple development phases or cycles are normal for a new system. There is a history of challenges with migrating shoreside technology to marine vessels, as evidenced by oily water separator and marine sanitation devices. At the same time, the technologies being migrated, such as ultraviolet irradiation, ozone disinfection, and electro-chlorination, are mature and effective technologies.

More clarity will be gained over the next couple of years as more treatment systems are tested to the ETV protocols, and the US Coast Guard program continues to develop. It is anticipated that these uncertainties will get resolved over the next several years leading up to 2016, when the treatment system phase-in period is scheduled to start for existing bulkers that might call at the proposed GPT.

2.7 Herring Spawning Area Mitigation

There is concern that the operation of the proposed terminal will adversely affect the spawning habitat of the Cherry Point herring stock. A herring monitoring program has been proposed in Appendix C of the 1999 Settlement Agreement that suggests several alternative operating procedures for the maneuvering area near the proposed GPT, the alignment of the wharf, and the operating periods for loading Bulkers calling at GPT.

This section will focus on evaluating the feasibility of the alternative operations suggested in the 1999 Settlement Agreement on the terminal operations, but will not review the cost implications of the alternatives.

2.7.1 Alternative Operations for the Local Maneuvering Area

If the result of surveys performed by the Washington Department of Fish and Wildlife (WDFW) demonstrate that GPT vessel movements within the local maneuvering area disrupt the herring migration, then during the period of April 26 through May 27, Appendix C suggests that a small vessel be used to evaluate whether the local maneuvering area is essentially clear of pre-spawner schools of herring before the calling bulker is berthed. If the presence of pre-spawner herring is discovered, then the calling bulker must wait until the local area is clear. Operationally, this can be accomplished with an increased focus on scheduling bulker arrival and departure times. Local anchorages may be used if it is anticipated that the presence of pre-spawner herring will be of considerable duration.

2.7.2 Alternative Operating Periods for Loading Bulkers

If monitoring by the WDFW during the period of April 10 through May 20 indicates that loading operations near the wharf adversely impact herring migration, Appendix C recommends minimizing loading activities to adhere to an “8 hours on, 8 hours off” schedule. This can also be accomplished operationally, although it may have an impact on schedule.

2.7.3 Alternative Alignments for the GPT Wharf

If the WDFW determines that the proposed wharf alignment overlaps a preferred nearshore migration corridor or schooling area, then Appendix C suggests that berthing activity be prohibited from one hour after the beginning of the flood tide to one hour after the beginning of the ebb tide during April 10 through May 20. Operationally, this can be accomplished through scheduling bulker arrival times or the use of local anchorages. Alternatively, a different wharf alignment may be considered.

2.7.4 Conclusion

Advance scheduling and availability of local anchorages addresses virtually every operational constraint posed by the potential impact of berthing operations upon pre-spawning herring. If it is discovered that berthing operations do impact pre-spawning herring during the period of April 10 through May 20, an opportunity exists for wharf and equipment maintenance until normal operations can commence.

Section 3 Vessel Traffic Analysis

3.1 Introduction

This section of the VTARAS focuses on the impact of the proposed GPT upon potential incidents and spills from marine traffic. This section includes:

- Characterization of existing vessel traffic patterns.
- Forecast of vessel traffic based on an underlying commodity throughput economic forecast.
- Counts and statistics on 429 historical incidents over a 16-year baseline.
- A statistical, probabilistic prediction for representative risk parameters: annual number of potential incidents, annual number of potential spills, and annual potential oil and bulk outflow.

Case A (Baseline)	Case B (GPT)	Case C (Cumulative)
• Existing vessel traffic forecast to 2019 • Additional traffic from port expansions or new ports completed since 2010 or currently under construction and completed by 2019	• Case A traffic • Gateway Pacific Terminal vessel traffic	• Case B traffic • Projects expected to take place in the study area in the near future

Figure 43 Forecast cases

This section analyzes three cases of vessel traffic forecast to 2019 (Figure 43). Case A is the baseline. Case B adds to Case A: GPT-calling bulkers, assist tugs, and tugs and tank barges which support GPT bunkering. Reasonably foreseeable, cumulative traffic volumes are added to Case B in Case C.

Although the existing vessel traffic levels from 2010 are presented for informational purposes, the analysis centered on the incremental impact of marine vessel traffic from the proposed GPT. The analysis was performed by examining the changes from Case A to Case B.

Quantitative analyses to inform the reader and to develop conclusions are organized into the following subsections:

- Section 3.2 reports on historical and forecast routing and volumes of vessel traffic by the six project-specific vessel types: tanker, tank barge, bulker, cargo, tugs, and passenger and fishing vessels.
- Section 3.3 reports on the historical baseline of incidents from 1995-2010 and by aligning traffic data and incident types, defines incident rates with respect to vessel traffic for six project-specific incident types: collision, allision, grounding, cargo transfer error, bunker error, and other, non-impact.

- Section 3.4 quantitatively predicts contaminant (bunker fuel oil, cargo oil, and dry bulk) outflow. Annual results by subarea are presented in probability distribution functions, reflective of the inherent uncertainty in predicting the future.

In general, the findings and conclusions are as follows:

- GPT adds traffic to the baseline traffic. Overall, the expected increase is 15%. The greatest absolute increase by subarea is in Juan de Fuca East (1,105 vessel traffic days), and the greatest percent increase by subarea is in Cherry Point (33%).
- Incident rates (IR) vary by activity type from 0.0101 incidents per vessel traffic day (24 hours) while maneuvering, followed by less frequent incidents while underway (0.0017), at-dock (0.0010), and anchored (0.0005). Historically overall, IR = 0.0013.
- The increase in potential oil and bulk outflow with GPT is proportional with the increase in traffic with GPT. Between Case A and B, the average annual number of potential spills is predicted to increase by 26%, and median total annual spill volume is predicted to increase by 28%. Total median annual bulk outflow is predicted to increase from zero to 7,376 cubic feet.

3.1.1 Section 3 Abbreviations and Definitions

The terms defined here are of special importance for the quantitative analyses presented in Section 3, and particularly in Section 3.3 and Section 3.4. These terms are also defined in the Definitions section.

Section 3 Abbreviations and Definitions	
Activity Type (a)	A scenario parameter. The four (4) project-specific activity categories are: Underway Maneuvering Docked Anchored
AIR	Adjusted Incident Rate
Case Parameter (c)	The parameter describing traffic volume case. The three (3) project-specific traffic volume cases are: A. Baseline Traffic B. Baseline + GPT Traffic C. Baseline + GPT + Cumulative Traffic
CDF	Cumulative Distribution Function
Contaminant	Bunker oil, cargo oil, and dry bulk cargo.
Deadweight Tonnage	A measure of how much weight a ship is carrying or can safely carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew. Deadweight tonnage was historically expressed in long tons (2,240 pounds) but is now usually given internationally in tonnes; the mass equal to 1,000 kilograms (2,204.6 pounds) or 1 megagram (1 Mg), also known as a metric ton in the United States.
ERC	Environmental Research Consulting
GPT	Gateway Pacific Terminal

Section 3 Abbreviations and Definitions	
GPT Tank Barges	Tank barges are defined as GPT tank barges when they are supporting bunkering for GPT calling vessels.
GPT Tugboats	Tugboats are defined as GPT tugboats during the time they are transiting to or from the GPT dock and while docking GPT-calling vessels.
Incident (I)	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 Error *For the purposes of this study, the term "bunker" is used inclusive of all vessels, irrespective of fuel type.
Location (l)	A scenario parameter. The seven (7) project-specific subareas, as shown in Figure 44, 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. Saddlebag 7. Guemes Channel Fidalgo Bay
Location Group (l_group)	The three (3) location groupings are: 1. Strait of Juan de Fuca West and Strait of Juan de Fuca East 2. Haro Strait Boundary Pass and Rosario Strait 3. Cherry Point, Saddlebag, and Guemes Channel Fidalgo Bay
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 scenario or scenarios.
NEI	Northern Economics, Inc.
NI	Number of Incidents
Parameter	An attribute with a set of prescribed, possible values for selection to input or for calculation to output.
Poisson Distribution	A probability distribution used to describe rare events for which each time of occurrence is independent of the time of the last occurrence.

Section 3 Abbreviations and Definitions	
Probability Distribution	A function describing the likelihood of each possible outcome.
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.
Scenario	A combination of parameters present during a particular incident, as defined in Table 52 of this report, which includes: vessel type (*v*), activity type (*a*), incident type (*i*), and location (*l*).
Stochastic Result	One possible contaminant outflow result; obtained by sampling all 1,008 scenarios (*v,a,i,l* combinations) once each.
Study Area	The geographic bounds of the area considered in the study. The area covered by all locations (*l*), as shown in Figure 44.
Subarea	See *Location*.
Traffic Day (TD)	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*).
Vessel Capacity	The capacity of a given vessel type for a given contaminant type (oil or bulk), including cargo and bunkers (fuel).
Vessel Type (v)	A scenario parameter. The six (6) project-specific vessel categories are: Tanker Tank Barge Bulk Carrier General Cargo Ship Tug Passenger and Fishing Vessel
VTS Vessel	A vessel belonging to one of the project-specific vessel types.
y	Year Index for 1995-2010

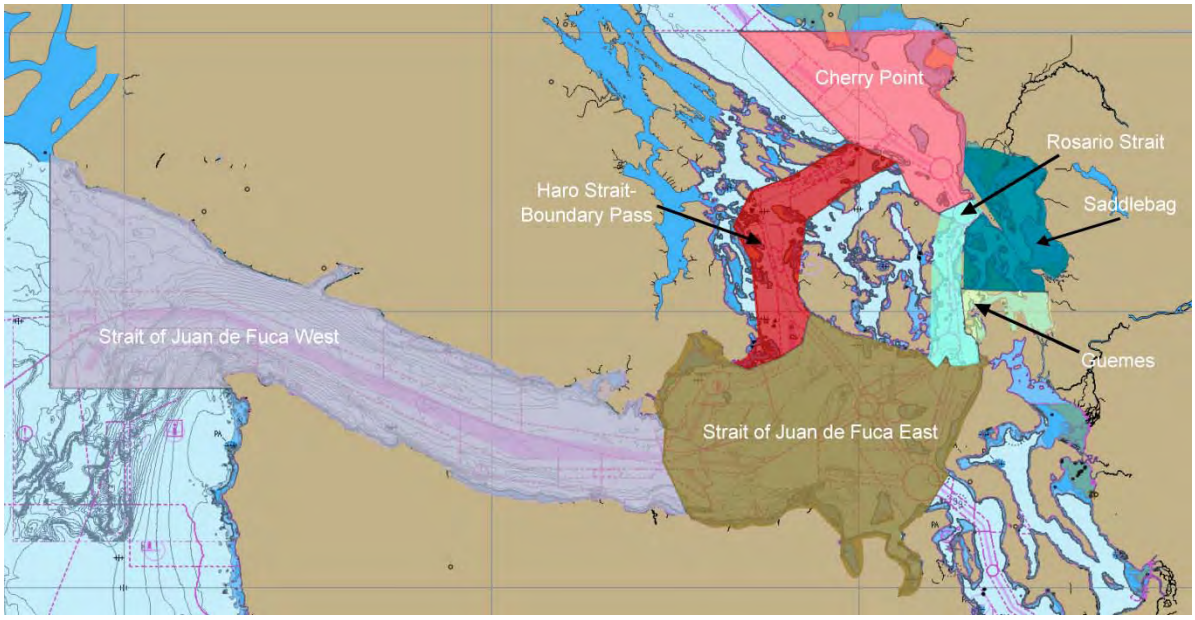

Figure 44 Project study area showing subareas (locations)

Scenarios

Scenarios are defined by the combination of four scenario parameters: six (6) vessel types (*v*), four (4) activity types (*a*), six (6) incident types (*i*), and seven (7) locations (*l*). The exhaustive enumeration of scenario parameter combinations is defined by Equation 3-1.

$$v \times a \times i \times l = \text{Number of Scenarios} \qquad 3\text{-}1$$

For example, the total number of possible combinations (i.e., when all parameters are at their maximum values: $v = 6$, $a = 4$, $i = 6$, and $l = 7$) is 1,008 scenarios. These 1,008 combinations are assumed to include all scenarios that will significantly contribute to the quantity of contaminants that may be spilled.

Incident Types

The six (6) incident types are Collision, Allision, Grounding, Cargo Transfer Error, Bunker Error, and Other Non-Impact Incidents. Collisions, Allisions, and Groundings are impact incidents. Cargo Transfer Error, Bunker Error, and Other Non-Impact are non-impact incidents. Internal transfer errors were not included. Only over-water transfers were included. 'Cargo Transfer Error' and 'Bunker Error,' Incident Types 5 and 6, respectively, are grouped into one incident type called 'Transfer Error' in Appendix C. The other incident type includes other non-impact causes: equipment failure, fire, explosion, operator error, structural failure. Historical incidents with unknown cause are also assigned to the other, non-impact incident type.

3.2 Traffic Analysis

3.2.1 Introduction

This section summarizes the traffic analysis and forecast performed by Northern Economics, Inc. (NEI) in order to understand current and future traffic associated with the proposed GPT.

To paint a comprehensive picture of future traffic volumes, the study team forecast the volumes of study area vessel traffic in 2019 for different traffic scenarios. This report section describes how vessel traffic data necessary to conduct the analysis were generated, how existing transits and calls were estimated, and how future traffic volumes were forecast.

Northern Economics, Inc. examined the historical and current patterns of traffic in North Puget Sound and used these data and other information to forecast vessel activity in the study area. The study team forecast the volumes of study area vessel traffic in 2019 under three different traffic scenarios. Components of the forecasted scenarios—Case A, Case B, and Case C—are described in Figure 43.

The results of the vessel traffic forecasts are summarized in Table 34 and Table 35, which show the predicted mean values for traffic volumes. Table 34 also shows that latest year of the historical traffic dataset, 2010. This year was not an analysis case, and 2010 vessel traffic days are not indicative of the longer historical trends, from which the forecast was made. It is a snapshot in time and provides a comparison between 2010 and 2019. Vessel traffic days from 2010 are given for historical context also in Table 41 through Table 47.

Table 34 Study area vessel traffic volumes, in vessel traffic days, for all vessel types and activity types, 2019

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle bag	Rosario Strait	Cherry Point	Total
2010	2,364	3,927	777	3,952	3,089	516	2,624	17,249
Case A	2,692	4,079	877	4,025	3,218	550	2,796	18,237
Case B	3,004	5,184	889	4,165	3,420	666	3,715	21,043
Case C	3,154	5,360	1,038	4,127	3,413	662	3,845	21,599
Percentage Changes								
Case A to Case B	12%	27%	1%	3%	6%	21%	33%	15%
Case B to Case C	5%	3%	17%	-1%	0%	-1%	3%	3%
Case A to Case C	17%	31%	18%	3%	6%	20%	38%	18%

GPT is expected to increase the total number of vessel traffic days in the study area by 15% over the Case A forecast. The expected traffic increase can be attributed to increases in bulker, tug, and tank barge traffic days, which individually may increase more than 15%.

Table 35 GPT vessel traffic volumes, in vessel traffic days, for all vessel types and activity types, 2019

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
GPT	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2

GPT will generate the greatest increase of vessel traffic days in the Strait of Juan de Fuca East and Cherry Point subareas. This is primarily due to time at anchor spent at Port Angeles and

time at GPT located in the Cherry Point subarea.

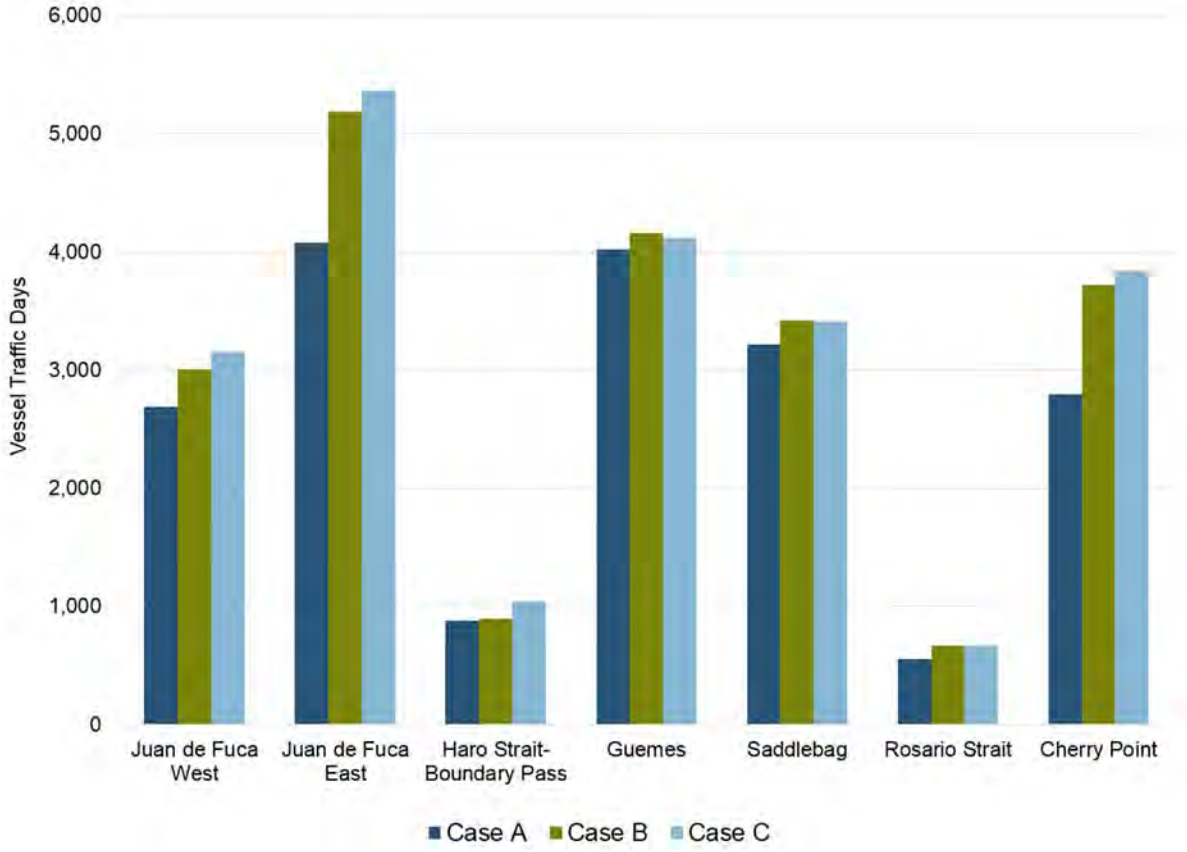

Figure 45 Study area vessel traffic days by case and subarea, for all vessel types and activity types

Section 3.2 summarizes Northern Economics' vessel traffic database and analysis. It discusses how the vessels designed to handle dry bulk commodities (bulkers) travelling to and from the GPT facility compare to other vessel traffic in the study area. Results and methodology are presented for each vessel type, activity type, and subarea. Section 3.2.2 describes the various types of vessel traffic included in the analysis, and the basic movements of each vessel type. Section 3.2.3 summarizes the modeling results. Vessel traffic days by area and activity type are presented, and a description of the information and processes used by the study team is included. Section 3.2.4 presents the 2019 estimates of vessel traffic days by area and activity type. A description of the forecasting methodology and approach is included.

3.2.2 Transits and Calls

This section describes the various vessel types operating in the traffic analysis study area, including a brief description of the activities and transit patterns of each vessel type, to provide a baseline understanding of vessel traffic in the Strait of Juan de Fuca and the adjacent waters of North Puget Sound.

The traffic analysis study area, shown in Figure 46, extends west to the west entrance of the Strait of Juan de Fuca, north to the Canadian border, and south to Admiralty Inlet. While most Canadian and Central or South Puget Sound destinations were not included in the study area, vessels which transit the study area en route to these destinations have been incorporated.

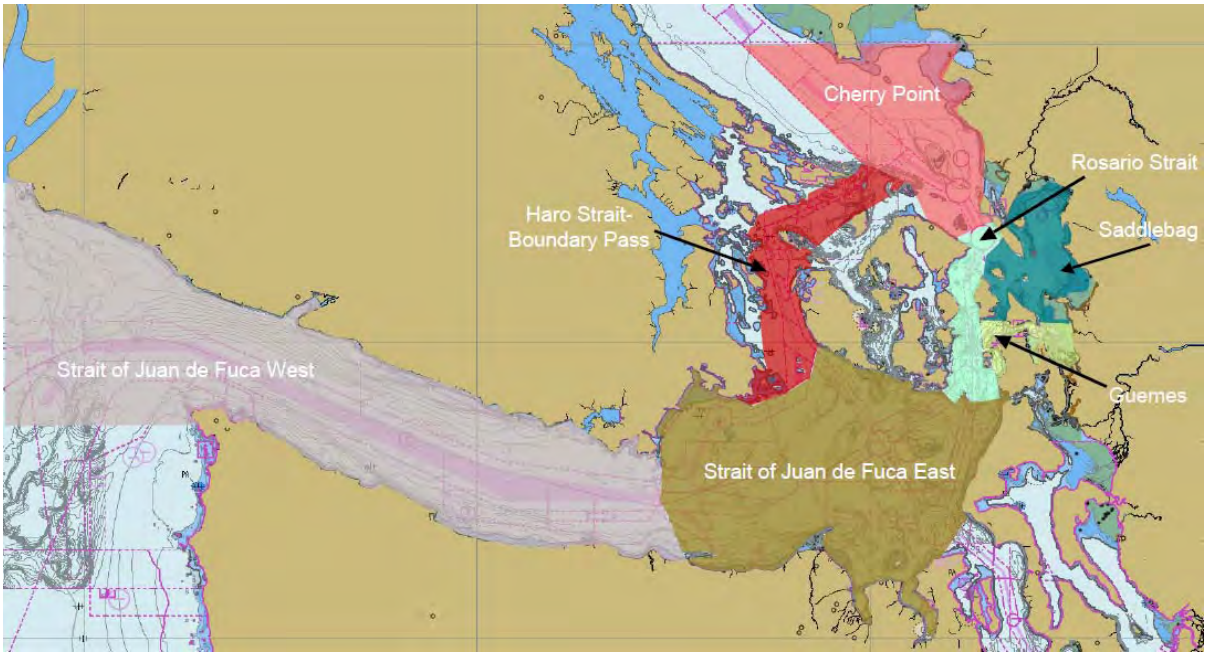

Figure 46 Map of GPT study subareas

For the purpose of this analysis, vessel traffic includes tank vessels, dry bulk carriers, container and general cargo vessels, tank barges, towing vessels (tugs), and fishing and passenger vessels. A more detailed breakdown of vessel type categories is provided in Figure 47.

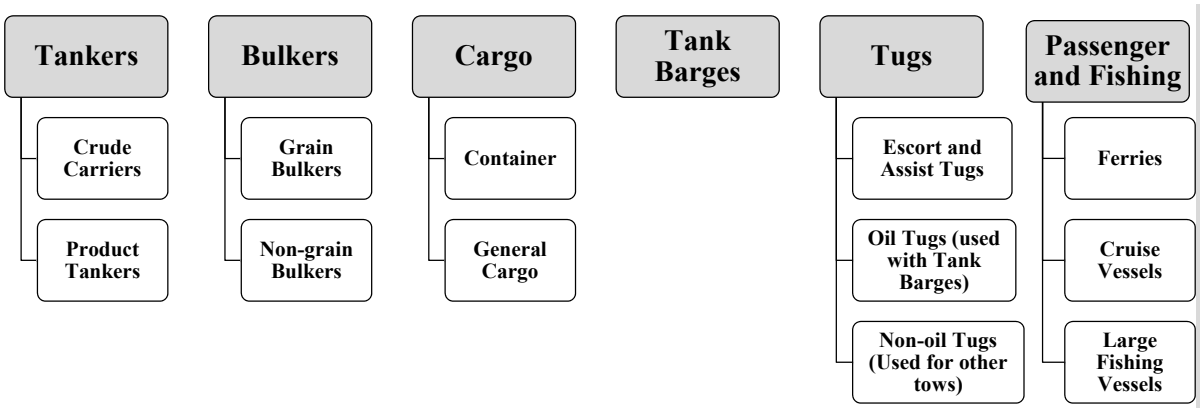

Figure 47 Vessel types

3.2.2.1 Small Vessels

Small fishing, charter, and recreational vessels were omitted from the quantitative portion of the analysis because their movements and behavior could not be accurately tracked with the data sources available. The available data sources were analyzed qualitatively and, to the extent practicable, quantitatively in Appendix B, Small Vessel Memo.

Puget Sound (PSP) and British Columbia (BCCP) pilot vessels were not included in the vessel traffic model as they do not fall under any of the vessel types analyzed (Figure 47). Pilot vessels are in the NRT data, recorded as “Unknown”, “Other Specific Service”, or “Government Vessel”. The names of the two PSP pilot boats out of Port Angeles are *Pilot*

Boat Juan de Fuca and *Pilot Boat Puget Sound*. The BCCP pilot boat that operates at Brotchie Ledge (Victoria) is *Pilot Vessel Pacific Scout*. Pilot vessel marine traffic is limited to the Strait of Juan de Fuca East subarea. Pilot vessels spend approximately 1-2 hours in transit per assignment. Representatives from the PSP reported in 2013 that they make approximately 7,600 assignments per year. At this rate, their pilot vessels would contribute approximately 300 – 650 vessel traffic days per year, or 10% of the vessel traffic days forecast in the Case A baseline for the Strait of Juan de Fuca East subarea (Table 40). Pilot vessels account for only a small percentage of overall traffic. Pilotage is discussed in Section 2.2.3, Pilot Response Summaries.

Freight barges, separate from tugs, are not included in the analysis. They do not carry bunker fuel or cargo oil. Their dry bulk cargo capacity would be small in comparison to a bulker.

3.2.2.2 Tankers

Tankers, as defined within the study, include tank vessels moving crude oil and other liquid bulk cargoes (including articulated tank barges (ATBs) and integrated tank barges (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, BC 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.

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

> *"Per 33 CFR § 165.1303, all tank vessels, U.S. or foreign flag, larger than 125,000 deadweight tons 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 [ed.: American Bureau of Shipping] to add a special Puget Sound load line mark ("PS") to the domestic U.S. load line "ladder" for certain TAPS [ed.: Trans Alaska Pipeline System] 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."* (Reference 104)

As indicated above, many of the vessels calling at 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 (Reference 13).

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 refinery outside of Washington State to perform a partial offload. For example, the *Alaskan Explorer*, a double-hulled tanker that operates between Alaska and Lower-48 refineries, has made the voyage shown below in Figure 48. Similarly, tankers that load to the 125,000 DWT

limit may proceed directly to Puget Sound, but may still carry a volume of crude to be discharged at more than one refinery. Crude tankers calling directly at Washington refineries frequently conduct multiple offloads, with itineraries similar to that shown for the *Polar Adventure*.

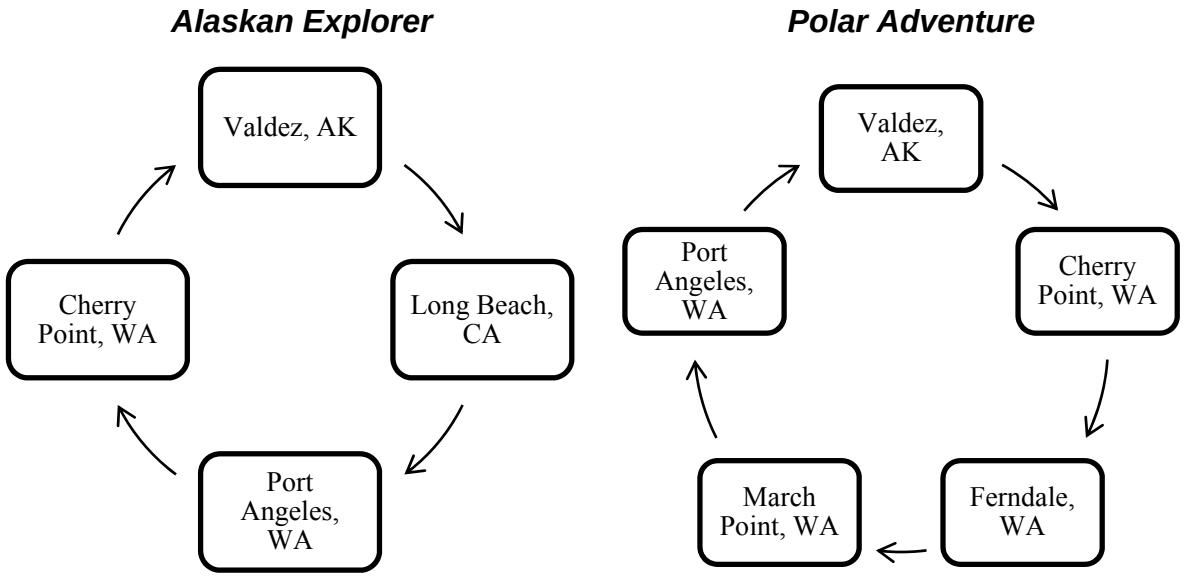

Figure 48 Sample tanker itineraries, 2010, Reference 75

Note: The Port Angeles calls are predominantly either for maintenance or bunkering, not offloading crude.

BP Cherry Point and Phillips 66 are the refineries with the deepest dockside water 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.

While the majority of tanker activity at Washington ports is attributable to domestic vessels on regularly scheduled routings, such as those shown in Figure 48, foreign flag tankers also call at refineries in Washington.[25] Foreign tanker moves can be more unpredictable than those made by domestic tankers. For example, in 2010 a crude tanker named 'Eurochampion 2004' called on a terminal in the study area just once. This vessel traveled from Long Beach, CA to Port Angeles, WA, then on to the BP facility in Cherry Point, WA where it discharged crude. The tanker then went to anchor in Vendovi, where it sat for a week before returning to the BP dock to discharge additional crude. Ten days after entering the study area, 'Eurochampion 2004' sailed for West Africa, and did not return for the remainder of the year.

In contrast to crude carriers, MX data show that the majority of product tankers visit refineries to load cargo. The MX data identify whether cargo was loaded or discharged, as well as the cargo type. Volume of cargo loaded or discharged was not included in the data. Offloads are less common and these data imply that product tankers discharge their cargo outside of the study area. Product tankers tend to be smaller than crude carriers, and include vessels such as

[25] Between 2006 and 2010, each year USA flag crude carriers account for 70-80 percent of total crude carrier moves recorded in the Marine Exchange data.

ATBs and ITBs. Examples are the *Coastal Reliance* and *Ocean Reliance*. Refinery products transported through the study area include petrol, gas oil, diesel oil, gasoline, and jet fuels.

3.2.2.3 Bulkers

The majority of bulker vessels transiting the study area are headed to or from Seattle or Tacoma in South Puget Sound, or Port Metro Vancouver in British Columbia. Seattle-bound bulkers are typically either loading grain or discharging cement or gypsum. Similarly, Tacoma-calling bulkers typically load grain, logs and scrap metal, or discharge gypsum. While some bulk vessels load petroleum coke at the Port of Anacortes, 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 coal export terminal in North America (Reference 143).

3.2.2.4 Cargo Ships

For the purpose of this analysis, cargo ships are comprised of both container vessels and general cargo vessels. Container vessels transport cargo in ISO marine containers, which are individually transferred from the ship to marine cargo terminals. In contrast, general cargo vessels often carry a combination of cargo types. Those in the data set most often carry autos and other rolling stock, containers, and military project cargo.

Container Vessels

Container vessels within the study area operate on fixed schedules predominantly. They typically make direct transits between marine cargo terminals, though occasionally they must anchor to wait for an available berth. Container vessels operating in Puget Sound call almost exclusively at Everett, Seattle, Tacoma, and Vancouver, BC.

General Cargo Vessels

General cargo vessels are similar to container vessels in terms of their operational profiles; however, they also call at smaller ports such as Bellingham and Sidney, BC. In addition, there are many cargo vessels that transit between Canadian destinations via the Inside Passage.

While it is possible for vessels to access Vancouver, BC from the north (via Johnstone Strait and the Strait of Georgia), for the purpose of this analysis it was assumed that all foreign flagged container and general cargo vessels calling at Port Metro Vancouver transit the GPT study area.

3.2.2.5 Tank Barges

Tank barges are defined as petroleum product or crude barges.[26] They are most often used to deliver petroleum products to customers or to fuel oceangoing vessels (bunkering). Documented 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. Please note that though a tug is necessary to move a tank barge, the risk for tug

[26] ATBs and ITBs are classified as tankers, not tank barges

collisions has been incorporated separately in the tug vessel type category and is discussed further in Section 3.2.2.6.

The data show that tank barges are moved more frequently than product tankers and are moved to a wider range of locations, including small harbors. While more frequent, tank barge transit and load patterns are similar to those of product tankers (excluding inter-harbor shifts).

3.2.2.6 Tugs

Tugs within the study area were organized into three distinct categories:

- Ship Assist/Escort Tugs. Ship assist tugs aid in the maneuvering and berthing of large ships near their respective berths (on arrival and departure). Particularly for large vessels such as container and dry bulk carriers, ship assist tugs are generally fit-for-purpose vessels and do not normally tow barges. Ship escort tugs accompany larger vessels within the study area (namely crude and petroleum product tankers, by regulation) and provide emergency assistance in the event of a steering or propulsion failure, or other event. Ship escort tugs are, by design, assist tugs as well, and do not normally tow barges.
- 'Oil-tugs.' Though not an industry-recognized term, the term 'oil-tugs,' for the purposes of this study, refers to a line haul tug that is generally paired with a tank barge in its day-to-day operations (such pairings are common for barge lines focused on petroleum distribution as their core business). As explained in Section 3.1, these vessels provide a means to track the movements of tank barges within the study area, which are not fitted with AIS transponders of their own.
- 'Non-oil tugs.' Though not an industry-recognized term, 'non-oil tugs,' for the purposes of this study, refers to any line haul tug not normally paired with a tank barge in its day-to-day operations. In Puget Sound, these tugs typically tow barges and scows loaded with aggregate (rock, limestone, sand, and gravel), wood chips, breakbulk and project cargoes (e.g. equipment), containers, and other products.

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

3.2.2.7 Passenger and Fishing Vessels

The passenger vessel component of this combined category includes:

- Cruise vessels of 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 vary significantly in terms of their size and movements, and are not included in the passenger vessel category.

Cruise Vessels

Cruise vessels operating within the study area frequently travel between Washington State, British Columbia (Victoria), and Alaska.

Like most other large vessels, cruise vessels most often 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, most cruise ships (bound for Southeast Alaska or the Inside Passage) stop in Seattle to pick up passengers, then travel north through Haro Strait and exit the study area via the Cherry Point subarea.[27] Only those cruise ships exiting the study area destined for other U.S. or foreign ports travel back out through the Strait of Juan de Fuca. In addition:

- Cruise ships were assumed to use Haro Strait-Boundary Pass exclusively when traveling north and south within the study area (not Rosario Strait).
- Both ferries and cruise ships make terminal-to-terminal transits. Neither vessel type anchors regularly in the study area. All destinations in the Saddlebag subarea were assumed to be Bellingham, as neither ferries nor cruise ships anchor at Vendovi Island.

Ferries

Three major public ferry systems operate within the study area, as well as several smaller, local, and privately owned ferries. The traffic analysis took into account the transit times of these ferries, as well as at-berth time for ferries that homeport within the study area. As previously mentioned, ferries do not have at-anchor time as they travel from terminal to terminal.

- The Alaska Marine Highway System (AMHS) is the northernmost ferry route within the study area. AMHS operates year-round between points in Alaska and Bellingham, WA. This ferry traffic will only affect the Cherry Point, Rosario, and Saddlebag subareas.
- British Columbia Ferry Services (BC Ferries) operates an extensive network of ferries within the internal waters of British Columbia. The BC Ferry route between Tsawwassen and Swartz Bay passes through the Cherry Point subarea.
- 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 Washington State Ferries transit between Anacortes, the San Juan Islands, and Sidney, BC.

Private and local ferries operating within the study area include:

- Whatcom County ferry between Gooseberry Point and Lummi Island.
- Black Ball Transit, which runs between Port Angeles and Victoria, BC.
- The Victoria Clipper, which runs between Seattle, Victoria, BC, and the San Juan Islands.

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[27] Cruise vessel itineraries frequently include a stop at a Canadian port such as Victoria or Vancouver to fulfill the Jones Act requirement for a foreign call by non-U.S. flagged vessels.

- 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.

Large Fishing Vessels

For purposes of this report, "large fishing vessels" were defined as vessels with an overall length (LOA) greater than 60 feet[28] that are involved in commercial fishing or processing activities. It was assumed that large fishing and processing vessels are not actively harvesting or processing fish during their transits. Instead, they are moving through the study area to fishing grounds in Alaska or the West Coast. In general, large fishing vessels do not deliver harvests within the study area unless it is at the end of an extended trip.[29]

As shown in Figure 49, 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% of the estimated transits in 1995. The number of transits involving the Port of Bellingham has seen a similar decline – 2011 transits are 45% of 1995 transits.

The decline in the number of transits is a result of changes in fisheries management regimes and changes in the profitability of certain commercial fisheries (References 67 and 141). Large fishing vessels that transit through the Strait of Juan de Fuca are bound for fishing grounds either off the West Coast of Washington and Oregon, or in Alaska. Management regimes for these regions are unrelated, but both have been transitioning to catch share management systems that in general result in fewer fishing vessels.[30]

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[28] 60 feet was used as it approximates the regulation size for vessels that must carry AIS and is also the cutoff size for Alaska salmon boats; it is a common size delineation already used within the industry.

[29] Contacts in the local fishing industry indicated that much of the product delivered to Bellingham Cold Storage has already been processed and does not come directly from fishing vessels. Our assumption with respect to large vessels fishing within Puget Sound and the Strait of Juan de Fuca was based primarily on the types of fisheries that take place in these areas (i.e. seining and gillnetting for salmon and pot fishing for Dungeness crab). These fisheries are generally small boat fisheries, particularly the salmon fisheries. In general, the operation of large vessels in these low-volume near-shore fisheries is assumed to be neither cost effective nor profitable.

[30] This is a modeling assumption made by the study team based on knowledge of the fishing industry. Should management regimes or market dynamics change, there is a possibility that fishing vessel transits could stay level or increase.

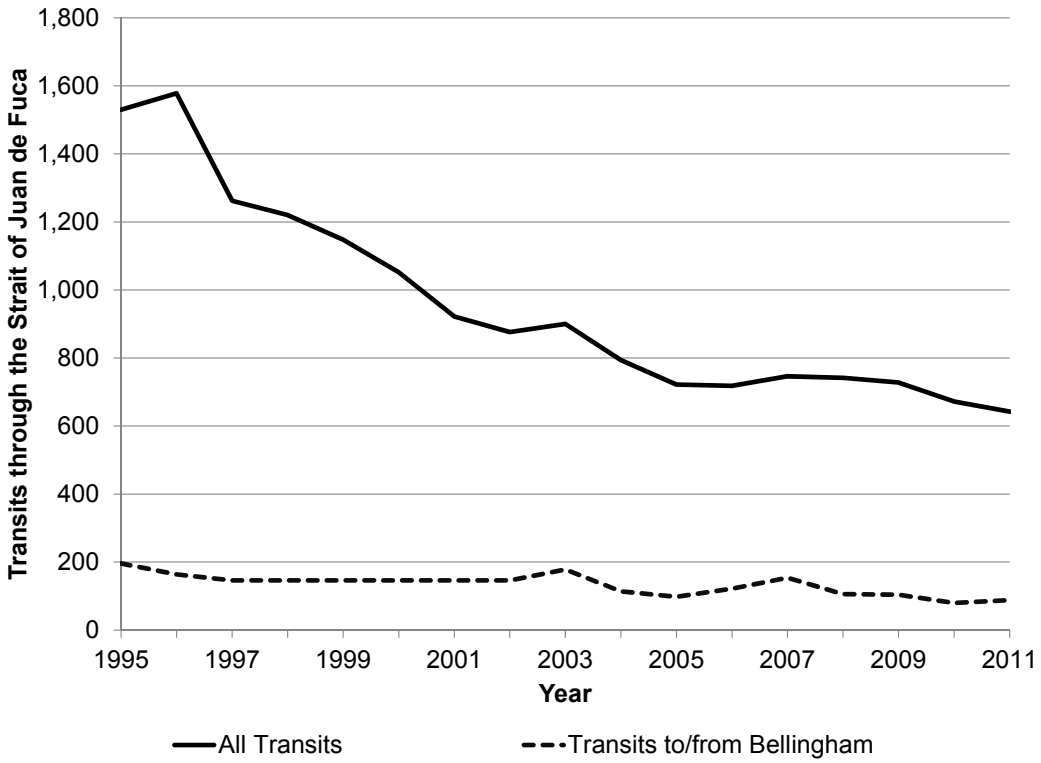

Figure 49 Declines in large fishing vessel transits in the Strait of Juan de Fuca, 1995-2011
Source: Developed by Northern Economics from multiple sources, References 56, 37, and 90

3.2.2.8 Canadian-Bound Vessels

Vessels transiting the study area en route to Canadian destinations were included in the analysis, and mapped separately from vessel traffic calling at Washington ports. Port Metro Vancouver (which includes Fraser River and Burnaby) provided the study team with historical vessel calls by type (Table 36). These data were combined with VEAT data (1995–2010) to estimate total vessel calls at Canadian Ports by type.[31] 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 historical VEAT data.

[31] VEAT data identify Canadian-bound vessels; the proportion of vessels by type provided by Port Metro Vancouver for 2008-2011 were applied to the VEAT data to estimate historical transits by vessel type.

Table 36 Vessel calls to Port Metro Vancouver by vessel type, 2008–2011

Vancouver Vessel Title	GPT 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

3.2.3 Vessel Traffic Data

3.2.3.1 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 provided by 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** (MX) 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 individual vessel movements from the initial point of detection through all inter-harbor and coastwise shifts, and ultimately departure. MX can generate reports from its database, along with certain reports from 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. MX data were also obtained 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, AIS data are captured by separate USCG and Canadian Coast Guard (CCG) Vessel Traffic 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 WADOE, is derived from Canadian and U.S. Coast Guard Vessel Traffic data. VEAT data capture one-way transits of tanker, cargo and

passenger vessels of 300 gross tons and greater through the Strait of Juan de Fuca. They also capture the movements of tank barges transporting oil or chemicals (any tonnage) between two locations via Washington state waters (Reference 138). VEAT data were available for the length of the study period (1995-2010) and were used to determine historical vessel 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 area.

None of the data sets mentioned above afforded a complete picture of the vessel traffic patterns in the study area; consequently, the study team had to combine sources to meet study objectives.

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 first step was to organize 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 masters. This process yielded estimates of vessel transit and at-berth days by subarea and type, for 2006-2010.

Time at anchor was estimated using the USCG anchorage database. 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 WADOE VEAT data. VEAT data are available for all non-forecast years covered by the study period (1995–2010). VEAT historical 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 50.

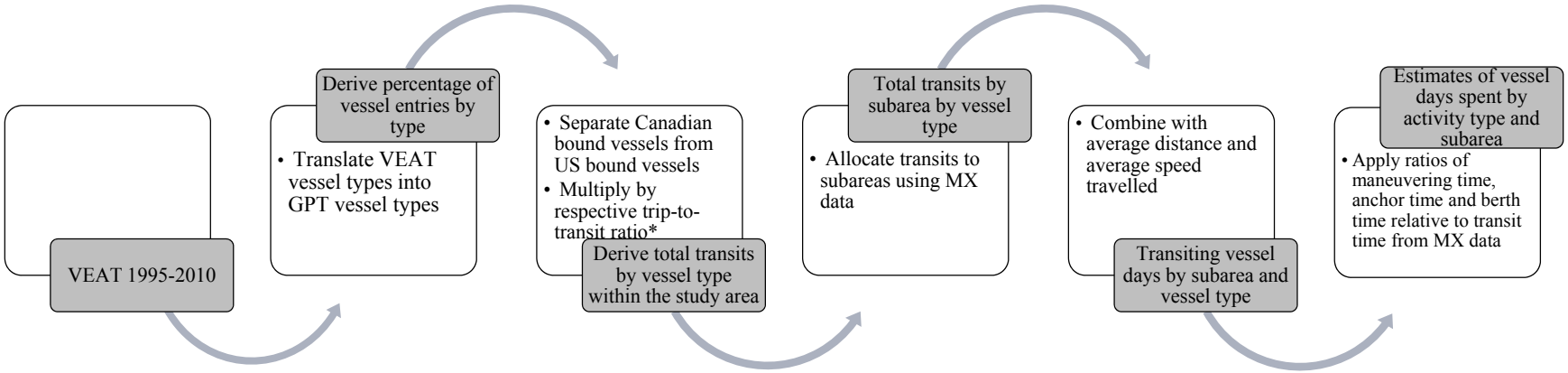

Figure 50 Methodology for deriving historical vessel activity

*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. It is derived using the ratio of moves to unique trips within the study area and varies by vessel type.

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, available NRT data were sampled. 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 NRT data were sampled for the following:[18]

(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%) 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.[19]

Tugs

Tug transits (both oil and non-oil) were estimated using the NRT data. Tugs with tows are identifiable within the data set and were categorized as moving either freight or oil barges. Tugs without tows may be ship assist/escort tugs, or they may be tugs transiting between tows (running light). To gauge the volume of tugs moving, 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. Tugs were also categorized as either oil tugs[20] (those which typically move tank barges) or non-oil tugs (those which move freight or other non-tank barges, or are used for assist/escort work). For example, in 2010, the sampled NRT data show 348 tug transits in Rosario Strait for tugs reporting a trip between Puget Sound and Alaska. The transit associated with this OD pair (Puget Sound and Alaska) is a distance of approximately 19.5 miles in Rosario Strait. At an average speed of 8.2 nautical miles per hour,[21] these transits account for 828 hours or 34.5 vessel days. Since both the origin and

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[18] Canadian Coast Guard VTS data sets (which cover some U.S. as well as Canadian waters) show when a tug moves an oil tow. Given the limited data available and the industry knowledge that tugs which move oil tows tend to primarily move oil tows, the study team labeled tugs moving oil tows in the Canadian data as 'oil tugs' and estimated the proportion of time they move with and without oil tows. The proportion was then applied to the oil tugs in the U.S. Coast Guard VTS data, which do not identify tows.

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

[20] While oil barges (tank barges) are included in the analysis, freight barges are not.

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

destination points of these transits are outside of the study area, no at-berth or maneuvering time is associated with these moves.

Passenger and Fishing Vessels

Passenger Vessels

For the purpose of this analysis, only piloted, deep draft cruise vessels and ferries operating on regular schedules were included. Local sightseeing boats and charter cruises were 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, BC transit through the study area. Cruise vessels calling in Canada directly were estimated using counts from Port Metro Vancouver. Vessels that call at a Washington port before calling at Port Metro Vancouver were backed out of the analysis to avoid double counting.[22]

The major ferry services operating within the study area are Washington State Ferries, the Alaska Marine Highway System, BC Ferries, 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 historical estimates of annual trips, trip distance within the study area, and 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 Strait of Juan de Fuca East, Haro Strait-Boundary Pass, Guemes Channel, Cherry Point, and Saddlebag. Rosario Strait and Strait of Juan de Fuca West are the only subareas in which a ferry is not docked.

Fishing Vessels

Transits of large fishing vessels (> 60 feet LOA) 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.

(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 was assumed that large fishing vessels did not undertake harvesting activities within Puget Sound or the Strait of Juan de Fuca.[23]

Large Alaska Fishing Vessels Registered to 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 (Reference 56), data from the Alaska Commercial Fishing Entry Commission (CFEC; Reference 37), and a set of fishing vessel profiles

[22] Transits which would have been double counted (represented in both the MX data and the Port Metro data) were omitted to maintain transit accuracy.
[23] Local fisheries typically use vessels smaller than those within this category

developed by Northern Economics for the North Pacific Fishery Management Council (Reference 90), along with discussions with industry representatives and the personal experience and expertise of the analysts.

The primary supposition with respect to these vessels was that, with few exceptions, the vessels return to the study area or South Puget Sound[24] 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 was also assumed that all shipyards are located in Central or South Puget Sound, and that when making the transit, vessels travel west of Vancouver Island via the Strait of Juan de Fuca.

The Alaska fishing vessels were divided into seven groups as listed below. For each group the number of active vessels by year was estimated and assumptions about the frequency of shipyard work and the likely time of transits were made. Of note was the fact that a small number of vessels 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. Additional transits have been added to account for these fishing activities.

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 feet LOA. Because they participate both in Alaska and in the Pacific whiting fisheries they make two inbound and two outbound transits through the study area each year.

2) **Floating Processors:** These vessels process primarily salmon and crab in nearshore waters and range from 200–300 feet LOA. It is assumed that these vessels make one inbound transit and one outbound for shipyard work every two-years.

3) **Trawl Catcher Processors (CPs):** These vessels range from 125–300 feet LOA and harvest pollock, flatfish, and Atka Mackerel using trawl gear and process their harvests onboard. 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 one inbound transit and one outbound transit during the year.

4) **Trawl Catcher Vessels (CVs):** These vessels use trawl gear to harvest groundfish (primarily Pollock), but the smaller vessels also harvest Pacific cod and flatfish. Vessels range generally from 70–200 feet LOA. A few of the vessels also participate in the West Coast Pacific whiting fishery. It is assumed that, on average, these vessels make one round trip between Alaska and the Puget Sound every two years (one inbound transit and one outbound transit through the study area).

5) **Crab CVs and CPs:** These vessels use pot gear to harvest crab in the Bering Sea and the Aleutian Islands. These vessels range generally from 80–185 feet LOA, including some that both harvest and process their own catch onboard. In an average year, it is assumed that 50% of these vessels make one round-trip transit between Alaska and Puget Sound (one inbound transit and one outbound transit through the study area).

[24] The study team acknowledges that fishing vessels have also used shipyards in Bellingham, Anacortes and Victoria. These vessels are interpreted as exceptions to the assumptions used for modeling.

Most of these transits are 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 own catch on-board. In general they range from 100–185 feet LOA with a few smaller exceptions. It is assumed that, on average, these vessels make one round trip between Alaska and the Puget Sound every two years (one inbound transit and one outbound transit through the study area).

7) **Longline CVs:** These vessels use longline gear to harvest primarily sablefish and halibut and range from 60–90 feet LOA. In an average year it is assumed that 50% 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 (one inbound transit and one outbound transit through the study area).

Large West-Coast Fishing Vessels Registered to Puget Sound Entities

The second group of large fishing vessels operates in the Limited Entry (LE) 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 the National Marine Fisheries Service.

The limited entry permit data for the years 1995–2011 were filtered for vessels >60 feet LOA, 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 feet LOA were assumed to make eight round-trips to the coast per year (eight inbound transits and eight outbound transits through the study area). From 1995–2011, on average, there were 9.9 permitted vessels, but only five (5) vessels in 2011.
- Vessels with both trawl and fixed gear from 60–89 feet LOA were assumed to make 12 round-trips to the coast per year (12 inbound transits and 12 outbound transits through the study area). From 1995–2011, on average, there were 0.5 permitted vessels, but there were three (3) vessels in 2011.
- Fixed gear vessels from 60–89 feet LOA were assumed to make eight round-trips to the coast per year (eight inbound transits and eight outbound transits through the study area). From 1995–2011, on average, there were 12.5 permitted vessels, but only six (6) vessels in 2011.
- Fixed gear only 90–150 feet LOA were assumed to make 12 round-trips to the coast per year (12 inbound transits and 12 outbound transits through the study area). From 1995–2011, on average, there were 1.5 permitted vessels, but in 2011 there were no permitted vessels in this group.

3.2.3.2 Summary of Findings

Table 37 and Figure 51 summarize the results, showing average annual vessel traffic days by subarea. Passenger and large fishing vessels account for the vast majority of vessel days spent in most subareas.

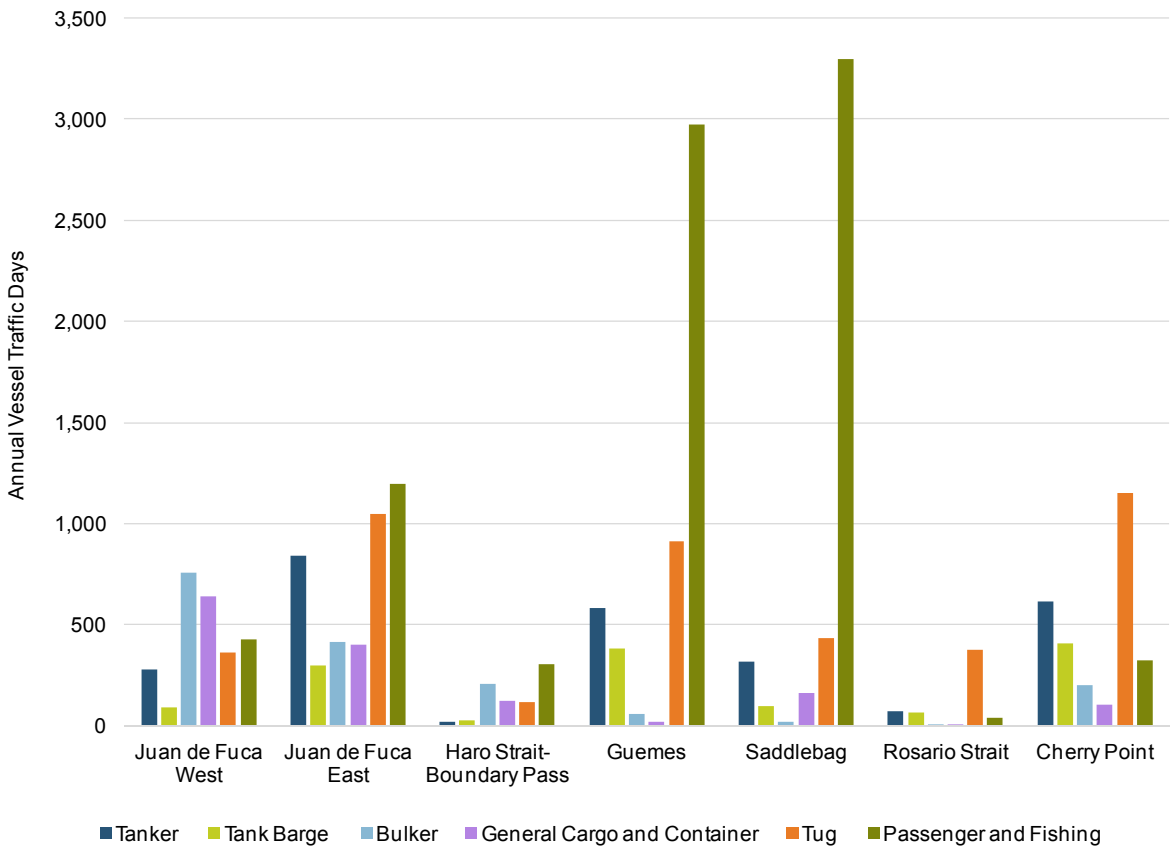

Figure 51 Annual average vessel traffic days by subarea and vessel type, for all activity types, 1995–2010

Note: Data from 1995–2005 are historical estimates.

Table 37 Annual average vessel traffic days by subarea and vessel type, for all activity types, 1995–2010

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tankers	277.4	838.3	20.0	583.3	316.1	74.1	613.4	2,722.5
Bulkers	760.0	416.2	210.7	58.3	22.3	2.9	204.0	1,674.4
Cargo Ships	641.5	404.4	125.6	16.8	160.1	3.4	106.9	1,458.7
Tank Barges	88.0	294.8	29.3	382.9	98.6	62.2	408.5	1,364.3
Tugs	361.7	1,045.0	119.1	912.0	431.9	375.6	1,152.4	4,397.8
Passenger & Fishing	427.5	1,194.0	302.8	2,977.0	3,296.9	36.3	323.1	8,557.6
Total	2,556.1	4,192.7	807.5	4,930.3	4,325.9	554.5	2,808.3	20,175.3

Note: Data from 1995-2005 are historical estimates

Between 1995 and 2010, time spent by passenger and fishing vessels decreased significantly from 11,100 vessel days a year to less than 6,200 (Figure 49 shows a similar trend, in units of "transits"). 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% of the estimated transits in 1995. As discussed in the previous section, the decline in the number of large fishing vessel transits is a result of changes in fishery management regimes and changes in the profitability of the fisheries.

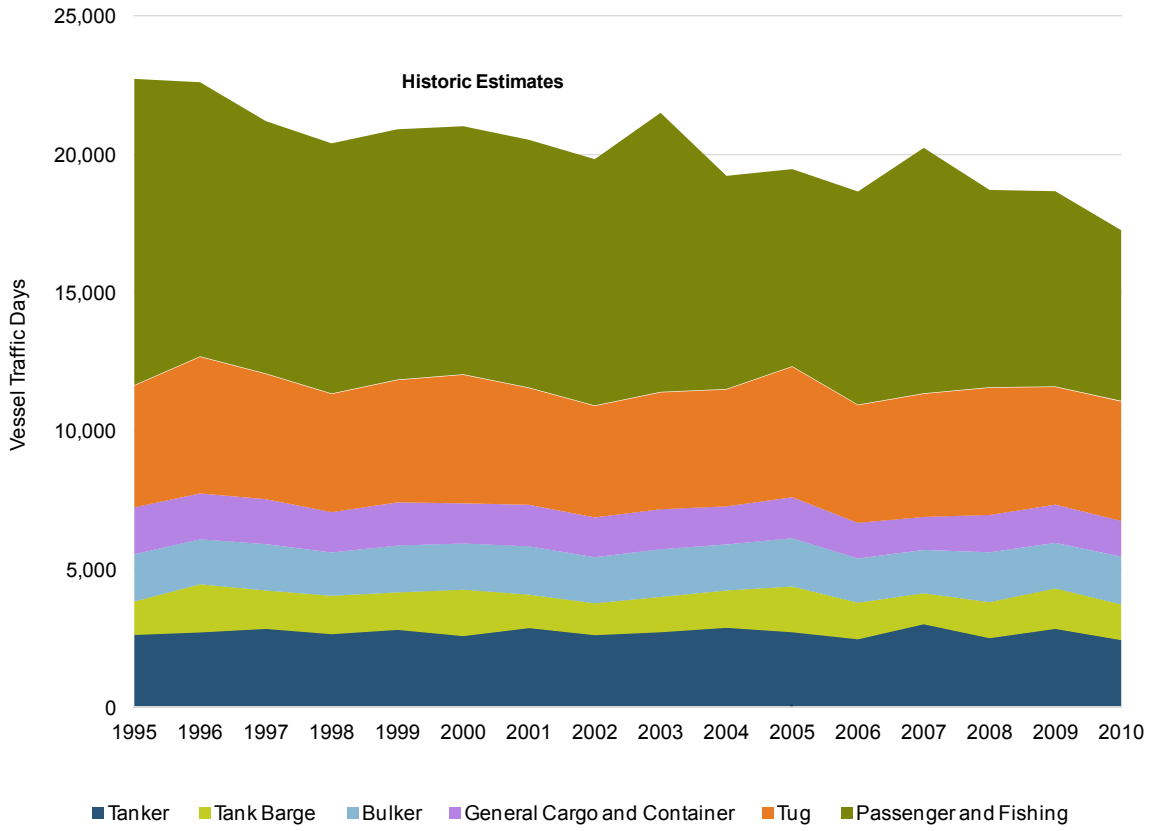

Figure 52 Total vessel days by vessel type, for all subareas and activity types, average, 1995–2010

Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historical estimates.

The following subsections detail the results of an analysis by vessel and activity type. All tables and figures were produced using Northern Economics' estimates of vessel days by subarea and activity type.

3.2.3.3 Tankers

Tankers spend most of their transiting time in Strait of Juan de Fuca West. This is not surprising given the long distance they must travel in this subarea (71 miles). However, transit time is overshadowed by time at anchor and time at berth. As shown in Table 37, total time by subarea is greatest in Strait of Juan de Fuca East, Guemes Channel, and Cherry Point. The majority of the vessel traffic days in Strait of Juan de Fuca East and Guemes Channel are reflective of time at anchor at Port Angeles and Vendovi Island. The vessel days in Cherry Point are almost exclusively days spent at berth.

Of total time spent by tankers in the study area, 29% of vessel days are spent in transit,[25] 30% of vessel days are spent at berth, and 40% of vessel days are spent at anchor.[26]

3.2.3.4 Bulkers

The vast majority of bulkers in the study area are transiting en route to Canadian or South Puget Sound destinations. Those traveling north to Canada's Inside Passage use Haro Strait almost exclusively. Very few transit days are spent in Rosario Strait (Table 37). Bulkers transiting to and from South Puget Sound, most of which are transporting grain from Seattle and Tacoma to foreign markets, spend a significant portion of time transiting Strait of Juan de Fuca East and Strait of Juan de Fuca West.

Almost all vessel traffic days for bulkers within the study are therefore spent transiting. Comparatively few vessel traffic days are spent at anchor or at berth within the study area. Bulkers that do call within the study area are most often calling at Anacortes (Guemes Channel), Bellingham (Saddlebag), and Intalco (Cherry Point).

3.2.3.5 Cargo Ships

Container vessels do not typically call at marine terminals within the study area. Instead, they transit through en route to Seattle, Tacoma, or Vancouver, BC. Nearly all container vessel days spent within the study area are considered transit days and are restricted to Strait of Juan de Fuca West, Strait of Juan de Fuca East, Haro Strait-Boundary Pass, and Cherry Point. The exceptions to this pattern are non-transiting vessel days spent in Guemes Channel, Saddlebag, and Strait of Juan de Fuca East:

- In 2010, a single container vessel recorded a four-day period at a dock in Anacortes.
- In 2006, 2007 and 2009, small numbers of vessels recorded long periods of at-berth time in Bellingham. These vessels were most likely laid up or undergoing repair.
- Each year between 2006 and 2010 a small number of container vessels stopped at Port Angeles (either at berth or at anchor). These stops are not part of a regular fixed schedule and could have been made for bunkering, repairs, or mandated by USCG Captain of the Port Order.

In contrast to container vessels, some 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 (Strait of Juan de Fuca East) each year. However, 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).

Since most port calls made by cargo vessels are outside of the study area, the bulk of time spent within the study area is attributable to transiting.

3.2.3.6 Tank Barges

Tank barge activity within the study area is tracked by the Washington State Department of Ecology (WADOE). The numbers presented in this section have been adjusted downward

[25] Transit time = underway plus maneuvering time.
[26] Percentages do not sum to 100% due to rounding.

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 move daily within the study area, but coastwise voyages are less frequent. This accounts for the much smaller proportion of total vessel days spent in Strait of Juan de Fuca West (Table 37).

Tank barges operating within the study area spend a relatively large portion of time at anchor and at berth.[27] Based on feedback from the local barge transportation industry, it was estimated that tank barges spend, on average, approximately 16 hours at berth per call. This is an approximation of the time required to fully load or fully discharge a standard tank barge. In addition, it was estimated that tank barges take approximately 1.5 hours to maneuver to and from their respective berths.

3.2.3.7 Tugs

The time that tugs spend towing, escorting and assisting vessels within the study area contributes a significant amount of vessel days. Particularly high volumes of tug traffic are present in Strait of Juan de Fuca East, Guemes Channel, and Cherry Point.

A large portion of tug vessel days are spent transiting. This activity pattern is to be expected as primary tug activities – towing, escorting, and assisting – all contribute to in-transit time.

3.2.3.8 Passenger and Fishing Vessels

As shown in Table 37, passenger and fishing vessels spend the most vessel days in Saddlebag and Guemes Channel subareas. The least amount of time is spent in Haro and Rosario Strait. Reasons for this traffic pattern include:

- High volumes of ferry traffic transiting and docking in Saddlebag and Guemes Channel.
- High volumes of fishing vessels transiting Strait of Juan de Fuca East and docking for extended periods in Saddlebag and Guemes Channel.
- Cruise vessels tend to make a one-way transit through the study area, and frequently travel between Washington State, British Columbia (Victoria), and Alaska.

A large portion of passenger and fishing vessel days are spent at dock, while none are spent at anchor. Passenger vessels typically transit from terminal to terminal without anchoring, though many of the ferries that operate as part of the Washington State Ferry System dock within the study area at night. The Alaska Marine Highway System traffic will only impact the Cherry Point, Rosario, and Saddlebag subareas. The BC ferry route between Tsawwassen and Swartz Bay passes through the Cherry Point subarea. Large fishing vessels typically transit straight through the study area en route to their homeports, where they spend long periods of time at dock in Bellingham or Anacortes.

[27] A portion of the time tank barges spend at anchor is used for bunkering; however, the portion of time spent bunkering cannot be determined given currently available data.

3.2.4 Forecasting

In order to meet project objectives, the study team forecast the volumes of study area vessel traffic in 2019, under three different traffic scenarios. Components of the forecast scenarios – Case A, Case B, and Case C – are described in Figure 53.

Case A (Baseline)	Case B (GPT)	Case C (Cumulative)
• Existing vessel traffic forecasted to 2019 • Additional traffic from port expansions or new ports completed since 2010 or currently under construction and completed by 2019	• Case A traffic • Gateway Pacific Terminal vessel traffic	• Case B traffic • Projects expected to take place in the study area in the near future

Figure 53 Forecast cases

The results of the vessel traffic forecasts are summarized in Table 38 and Figure 54, which show the predicted mean values for traffic volumes. The proposed GPT is expected to increase the number of bulker traffic days, tug traffic days, and tank barge traffic days in the study area.

Table 38 Study area vessel traffic volumes and percent change by subarea, in vessel traffic days by subarea, for all vessel types and activity types, 2019

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Case A	2,692	4,079	877	4,025	3,218	550	2,796	18,237
Case B	3,004	5,184	889	4,165	3,420	666	3,715	21,043
Case C	3,154	5,360	1,038	4,127	3,413	662	3,845	21,599
Percentage Change: Case A to Case B	12%	27%	1%	3%	6%	21%	33%	*15%*
Percentage Change: Case B to Case C	5%	3%	17%	-1%	0%	-1%	4%	*3%*
Percentage Change: Case A to Case C	17%	31%	18%	3%	6%	20%	38%	*18%*

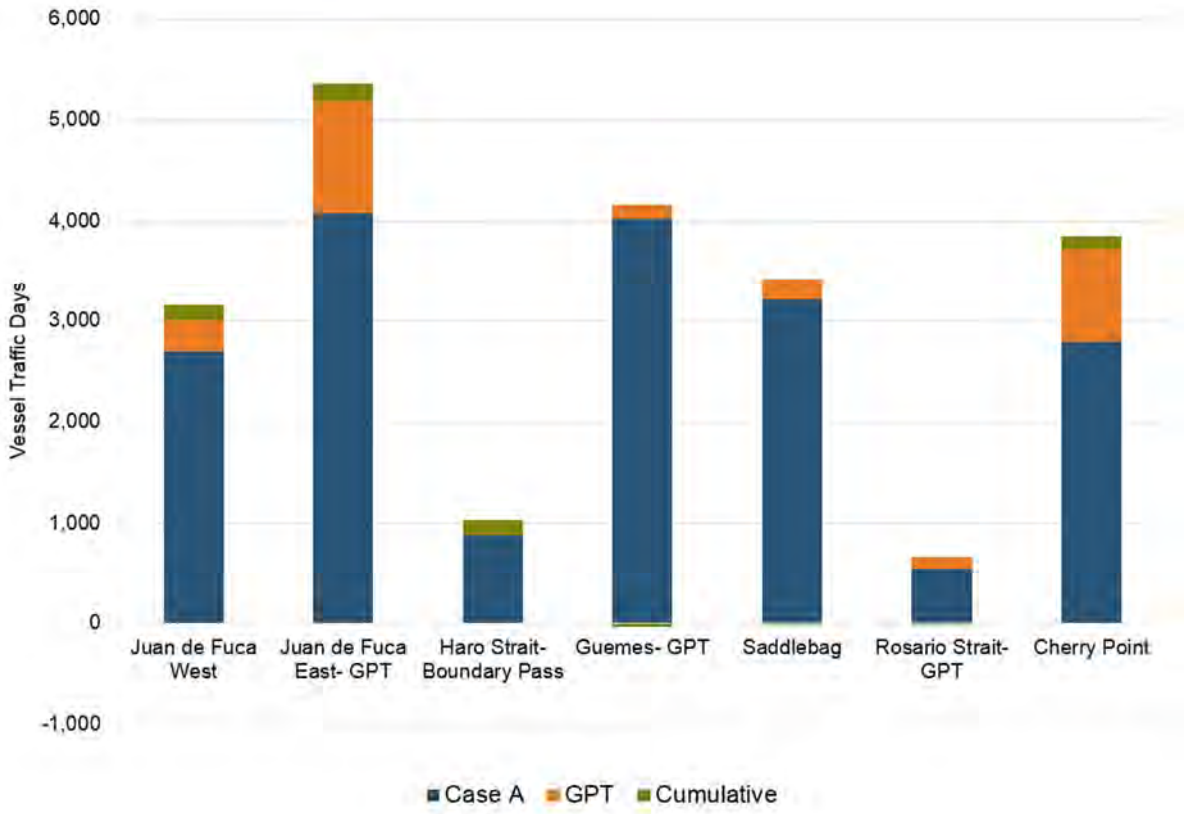

Figure 54 Study area vessel traffic volumes, by subarea and by case, for all vessel types and activity types, 2019

In the following sections we explain the methodology used to generate estimates of vessel activity by type and subarea. Forecast results are presented by case.

3.2.4.1 Case A

Case A consists of two components: the baseline forecast and baseline projects. The baseline forecast is the existing (2010) vessel traffic projected out to 2019 using regional economic forecasts. Baseline projects are those that are not included in the 2010 vessel traffic data, but will contribute additional vessel days to the study area by 2019. These include facility expansions completed since 2010 and those that are currently under construction or for which permits are not needed. The components of Case A are described in detail in Table 39.

Table 39 Case A components

Case A Forecast Assumptions
Baseline Forecast: Existing (2010) vessel traffic increased to account for historical trends
Baseline Projects: Expansions completed since 2010 or currently permitted; traffic not captured in historical trends:
Tankers
Completed and ongoing expansion of crude by rail offloading facilities reduces demand for crude by tanker. Tesoro reduces calls by 11, BP reduces calls by 13, and Phillips 66 reduces calls by 7. This generates a corresponding decrease in escort and assist tug time.
Bulkers
Westshore expansions completed in 2012 increases capacity to 33 million tons or 62 Capesize and 28 Panamax additional vessel calls; equipment replacement to be completed by 2017 increases capacity to 36 million tons and an additional 16 Capesize vessels and 7 Panamax vessels
Neptune expansion completed in 2015 results in an additional 36 Capesize and 16 Panamax vessel calls
Tug and Tank barges
Expansions at Westshore and Neptune are expected to increase tug and tank barge bunker supply roundtrips between Ferndale and PMV by 7.
Container Ships
Deltaport expansion completed in 2010 and vessel calls increase with historical trends

Note: the last year of data used to forecast baseline vessel traffic was 2010; data from later years is not reflected.

Using the forecast assumptions outlined above, the study team estimated that Case A will generate approximately 18,237 vessel traffic days in the study area in 2019 (Table 38 and Figure 54). The majority of this time will be spent in Strait of Juan de Fuca East. Vessels travelling to South Puget Sound, Canadian ports, and most study area destinations must transit through this subarea.

Table 40 Case A vessel traffic days by subarea for all vessel types and activity types, 2019

Compo-nent	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4

Tankers

Using historical transit and activity patterns, combined with local economic forecasts, the study team estimated tanker vessel traffic volumes by type and subarea in 2019. Between 2010 and 2019, liquid bulk commodity volumes traveling through Washington ports were expected to remain steady (Figure 55, Appendix A).

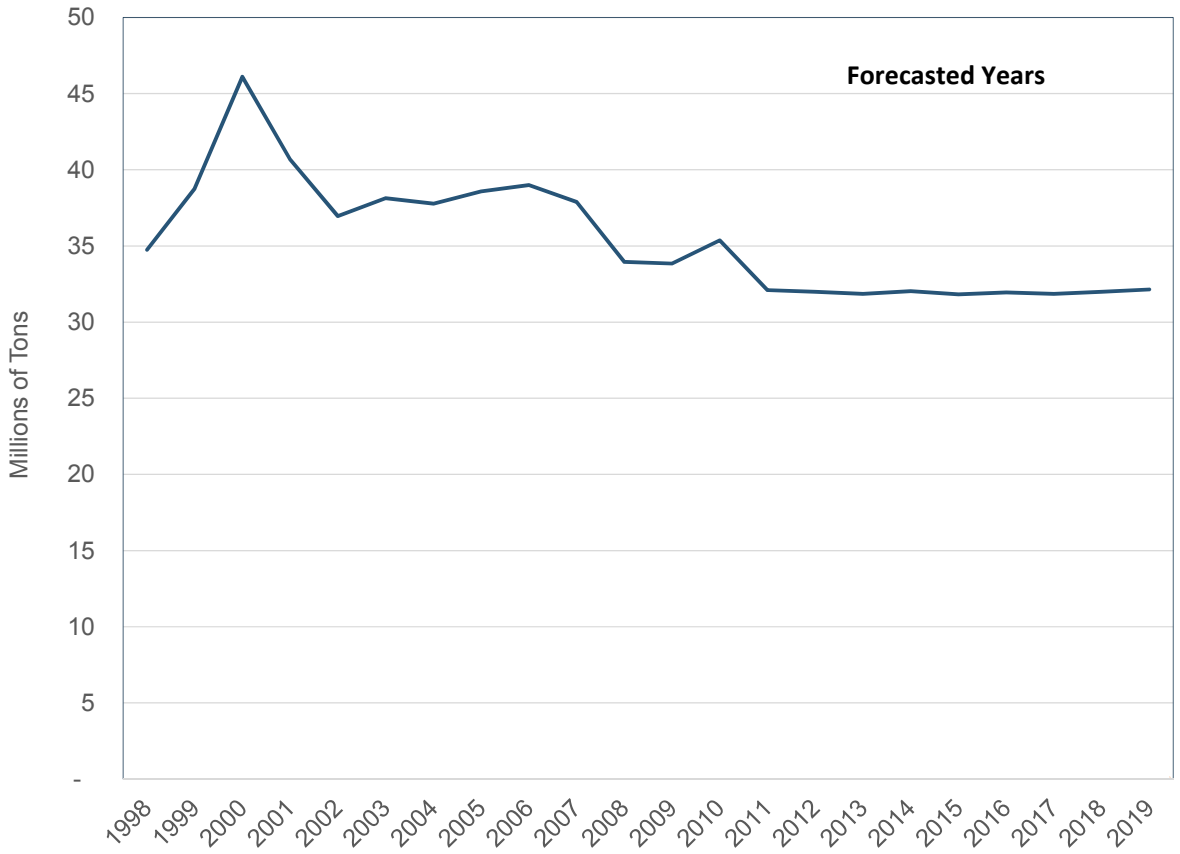

Figure 55 Liquid bulk commodity volumes, 1998-2019, Reference 27

Note: Forecast begins in 2010 as 2011 and 2012 actual volumes were unavailable.

While underlying bulk commodity volume forecasts show little change, rail terminal expansion projects at refineries within the study area will reduce demand for marine shipments of crude. Proposed oil terminals on the Columbia River and Grays Harbor could result in increased deliveries of crude oil by tank barge to study area refineries. However, the price differential between North Dakota crude oil and ANS West Coast price or Brent (foreign imports) prices would have to be very large to offset the estimated $10 cost per barrel to rail crude to the West Coast plus the cost of barging to study area refineries (Reference 108). Given that the proposed oil terminals are not yet permitted or under construction, they are considered speculative at this time and were not included in the analysis.

Over the past few years three of the major refiners in the study area (Tesoro, BP, and Phillips 66) have either built[28] or begun constructing[29] rail transport facilities to source crude oil from North Dakota, which will eventually replace declining Alaska North Slope (ANS) crude. New rail infrastructure will also allow Washington refineries to access crude oil from North Dakota's Bakken field, which is lower cost than ANS or foreign crude oil.

The Tesoro rail terminal has a daily capacity of about 50,000 barrels of oil per day (bopd), BP's rail terminal is about 60,000 bopd, and the Phillips 66 rail terminal will have a capacity of about 30,000 bopd. Summing this rail terminal capacity and anticipating a practical

[28] Tesoro in 2012 and BP in 2013
[29] Phillips 66

throughput of 90% of maximum capacity results in approximately 126,000 barrels of oil per day. This daily throughput is expected to occur prior to completion of the proposed GPT project in 2019. The effect of these rail terminals will be to decrease the number of foreign or ANS crude oil tanker calls at study area refineries by approximately 31 per year.[30]

The results of the tanker Case A forecast are summarized in Table 41 and Figure 56. In Case A, tanker vessel days in all subareas are expected to drop from 2010, the latest year of the historical traffic dataset.

Table 41 Tanker vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	295.9	741.4	30.1	577.3	272.1	61.5	475.3	2,453.7
2019 Case A	268.3	662.4	29.5	493.0	277.9	52.6	371.2	2,154.8
Percent Change (2010 to Case A)	-9%	-11%	-2%	-15%	2%	-15%	-22%	-12%

[30] This displacement of foreign or ANS tankers by rail delivery is a known over-simplification of the process that refiners will use to source crude oil. Study area refineries were built to process ANS crude, but Bakken crude oil is lighter and needs to be blended with other feedstocks in order to optimize refinery outputs. The refiners could source these other feedstocks from pipelines, barges, rail, or tanker. It is likely that pipeline deliveries from Alberta are the lowest cost crudes available, followed by crude by rail. Barge and tanker deliveries are likely the highest cost options and the modes most likely to be displaced by crude by rail, up to the limits imposed by the refineries' production processes and equipment.

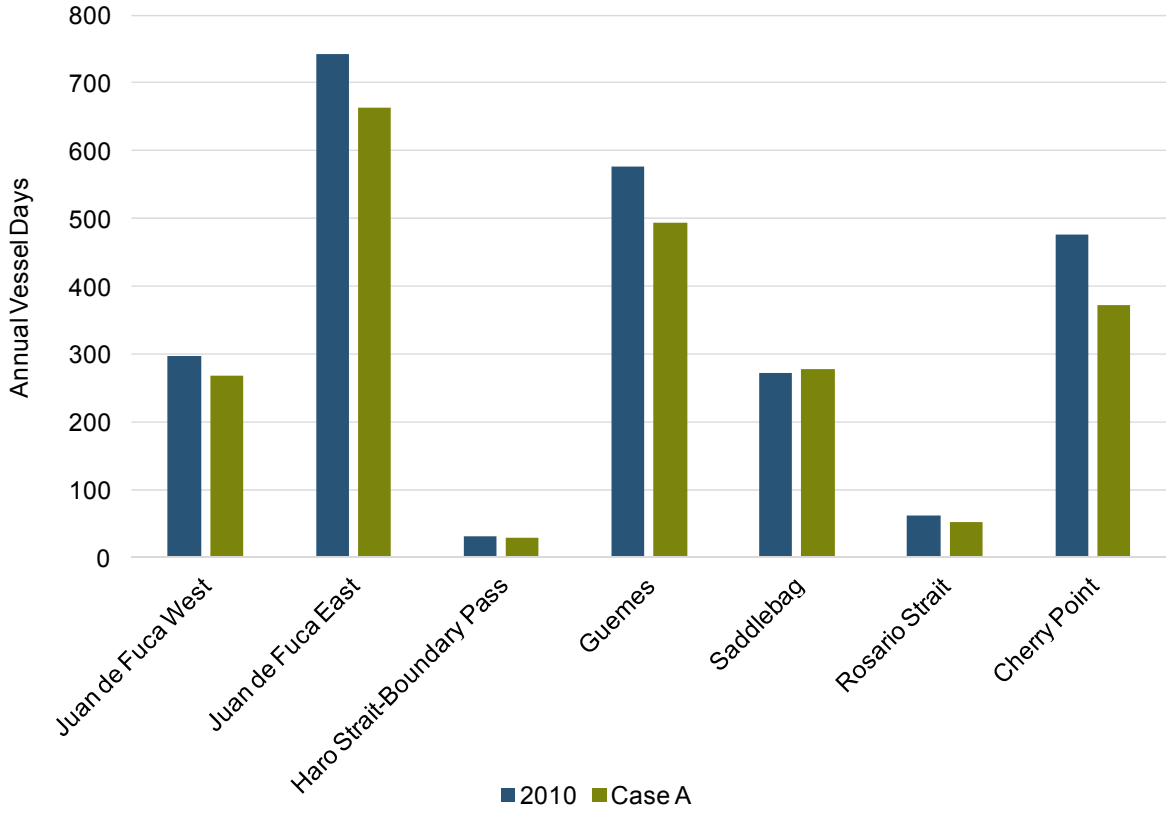

Figure 56 Tanker vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Bulkers

BST Associates' commodity volume forecasts for dry bulk and grain were used to forecast non-GPT bulker traffic volumes (Figure 57). BST's 2011 forecast anticipated 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, BC. Over the long term, the proposed GPT is expected to capture most of the BNSF Railway coal shipments, as well as some Canadian potash exports (Reference 144).

According to data received from Port Metro Vancouver (which includes Robert's Bank commodity volumes), bulker transits did not increase at the rate forecasted by BST. The study team adjusted down the forecasted dry bulk commodity volumes by effectively removing the large volume step in the original forecast, and mapped in GPT-calling bulkers separately to account for this discrepancy. The red "adjusted bulk volumes" shown in Figure 57 were used to forecast non-GPT bulker vessel volumes.

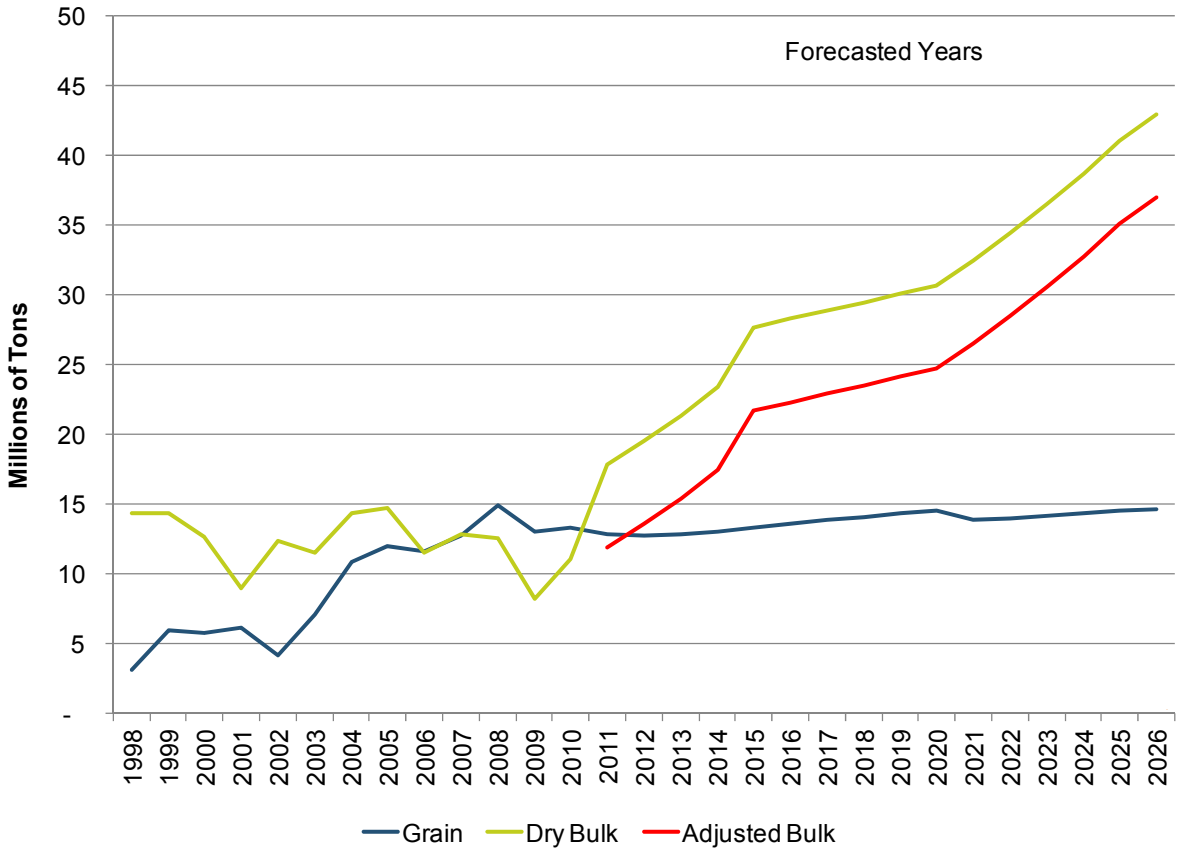

Figure 57 Grain and dry bulk commodity volumes, 1998-2026, Reference 27

In addition to the economic forecast, the study team modeled growth in bulker volumes due to expansions at Westshore Terminals and Neptune Terminal in Vancouver, BC.

Westshore

Westshore Terminals, which operates the dry bulk terminal at Roberts Bank in Port Metro Vancouver, is the largest coal export facility in Canada and on the North American West Coast. In 2012 they completed an expansion of the facility which increased their throughput to 33 million metric tons per year. They have announced an upgrade to some of their older equipment (i.e., loaders and reclaimers) and that the process will be completed by 2017. These upgrades will increase capacity to 36 million tons per year (Reference 143). Samples of vessel calls at Westshore Terminals were used to estimate the ratio of Capesize and Panamax vessels calling at Westshore Terminals (Reference 142).

Neptune

Neptune Terminals is in the process of expanding their dry bulk commodity terminal in Port Metro Vancouver to handle approximately six million additional metric tons, or about one additional ship per week (Reference 88). No data are available on the size of ships calling at Neptune; however, the berths are capable of accommodating Capesize vessels. Therefore, the analysis assumed the same ratio of Capesize to Panamax vessels as documented for Westshore.

The results of the non-GPT bulker forecast are summarized in Table 42 and Figure 58. Current trends are expected to continue, with increasing vessel days in all subareas where

current bulker activity takes place. Growth is particularly high in Strait of Juan de Fuca West and Strait of Juan de Fuca East. Bulkers transiting to Canada or South Puget Sound overlap in both portions of the Strait of Juan de Fuca, accounting for the large increase in vessel days forecasted compared to 2010, the latest year of the historical traffic dataset.

Table 42 Bulker vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
2010	756.0	464.2	208.7	35.5	22.4	1.7	237.6	1,726.1
Case A	1,042.4	662.9	265.5	177.2	89.9	7.4	424.6	2,669.9
Percent Change (2010 to Case A)	38%	43%	27%	400%	302%	338%	79%	55%

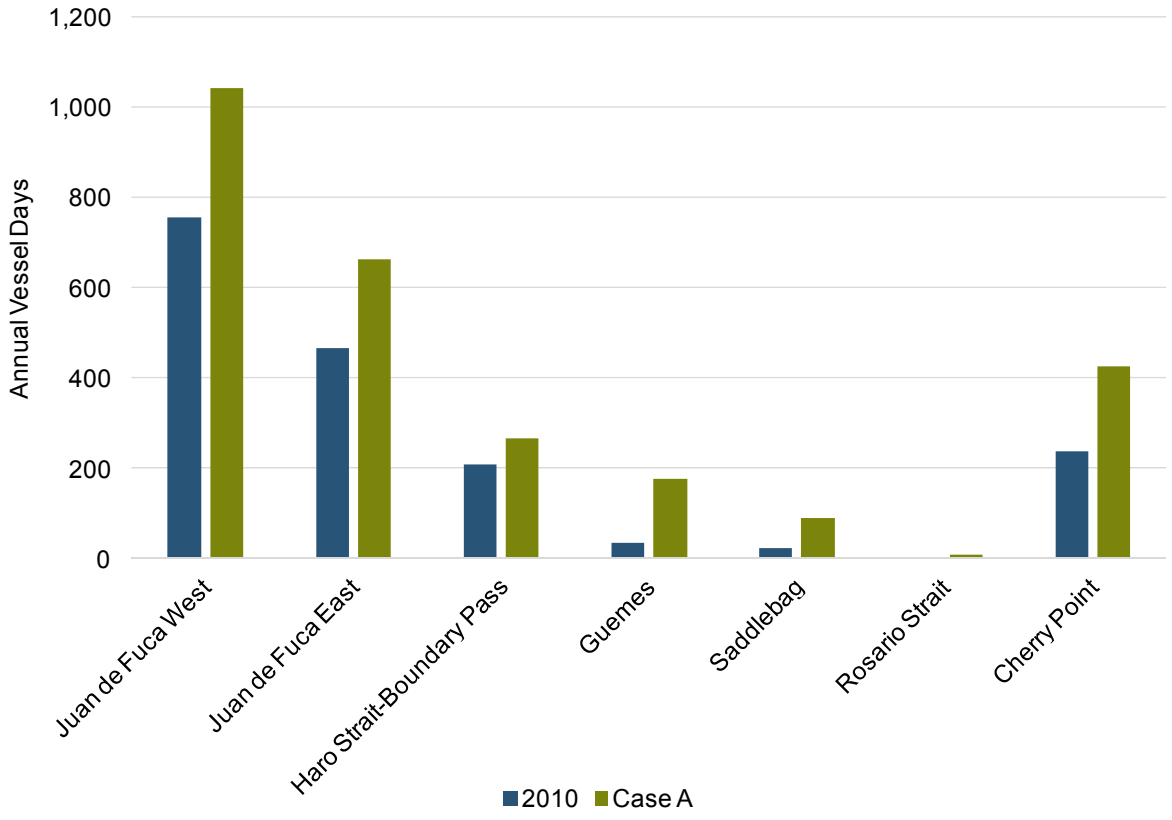

Figure 58 Bulker vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Cargo Ships

The study team forecast cargo ship traffic carrying container, 'neo bulk,' and break bulk cargo volumes. Containerized cargo includes any cargoes carried inside standard ISO containers (e.g. food products and manufactured goods). Neo bulk is general cargo that is bundled or pre-packaged, but not containerized. Examples include steel coils, lumber packs, woodpulp bales, and supersacks. Rolling stock (e.g. autos, trailers, excavators) is also

generally categorized as neo bulk cargo. Break bulk cargo is similar to neo bulk, but is shipped as individual components. Examples of break bulk cargo include: large crates, tanks and other steel structures, machinery components, electrical equipment (e.g. generators and transformers), yachts, etc.

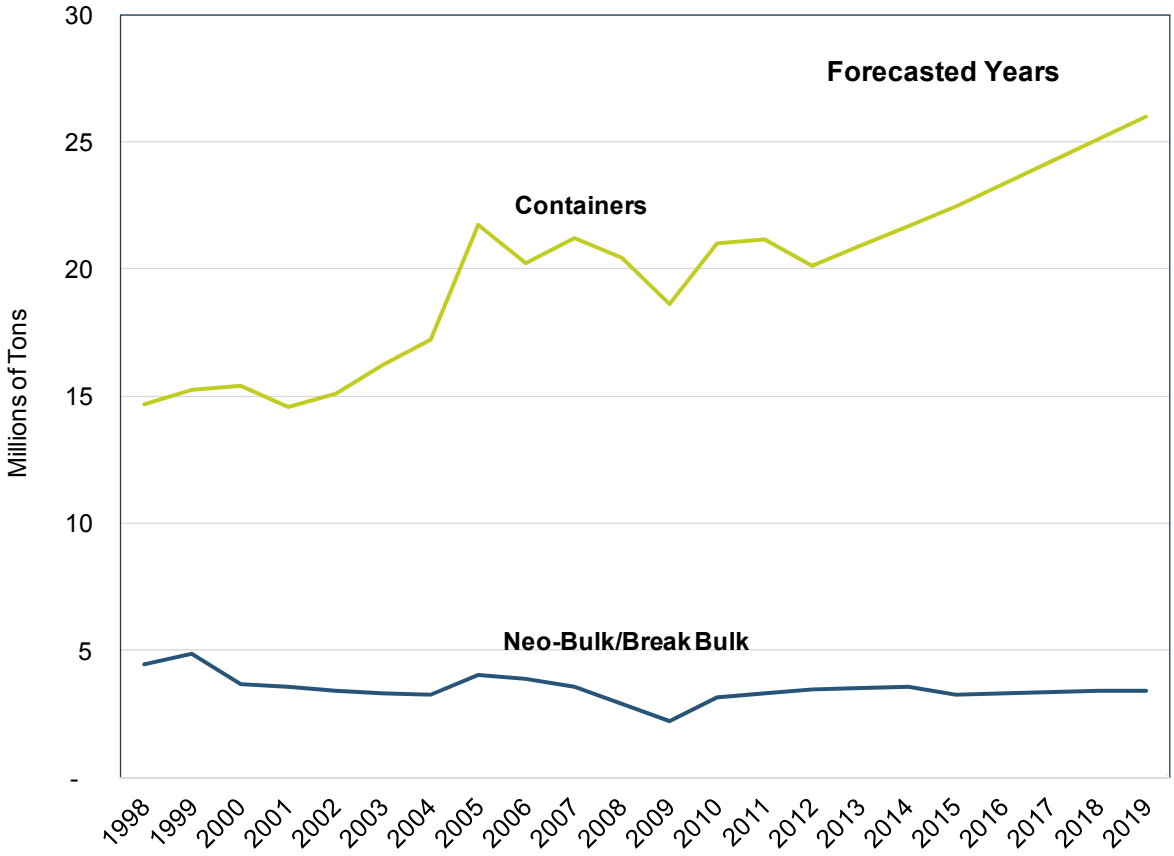

Figure 59 Container and neo bulk/break bulk commodity volumes, 1998-2019, Reference 27 and Reference 108

Note: BST forecast is for Washington Ports and does not include cargo volumes transiting directly to/from Canada.

While neo bulk and break bulk volumes are forecast to remain static, container volumes are expected to increase sharply between 2010 and 2019.[31] As shown in Table 43, total vessel days within the study area are expected to rise by 10%, from 1,300 to 1,430, over this same period.

[31] The forecast includes an underlying increase in vessel size over time, which actually lowers the number of vessel calls (as compared to holding vessel size constant).

Table 43 General cargo traffic vessel days by subarea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
2010	556.1	325.4	111.6	33.2	165.3	2.9	105.7	1,300.2
2019 Case A	617.1	364.6	120.1	11.7	205.6	3.0	112.6	1,434.7
Percent Change (2010 to Case A)	11%	12%	8%	-65%	24%	5%	6%	10%

Few cargo vessels make direct port calls within the study area. Most transit through the study area en route to South Puget Sound or to Vancouver, BC. Figure 60 illustrates vessel day changes by subarea. The subarea with the largest absolute change is Strait of Juan de Fuca West, followed by Strait of Juan de Fuca East and Saddlebag. The large percentage drop in Guemes Channel for cargo/container vessels can be attributed to an abnormally high year in 2010.[32] The Case A number of vessel traffic days is quite close to the historical average. Most of the vessel traffic days in the Saddlebag subarea are spent at dock at the Port of Bellingham. General cargo and container vessels transit the Strait of Juan de Fuca en route to Seattle, Tacoma, Bellingham, or Vancouver, BC.

[32] The Marine Exchange recorded a single vessel at dock from 1/25/10-2/9/10 (much longer than normal). It was docked at 'Dakota Creek,' which is a shipbuilding and repair facility in Anacortes.

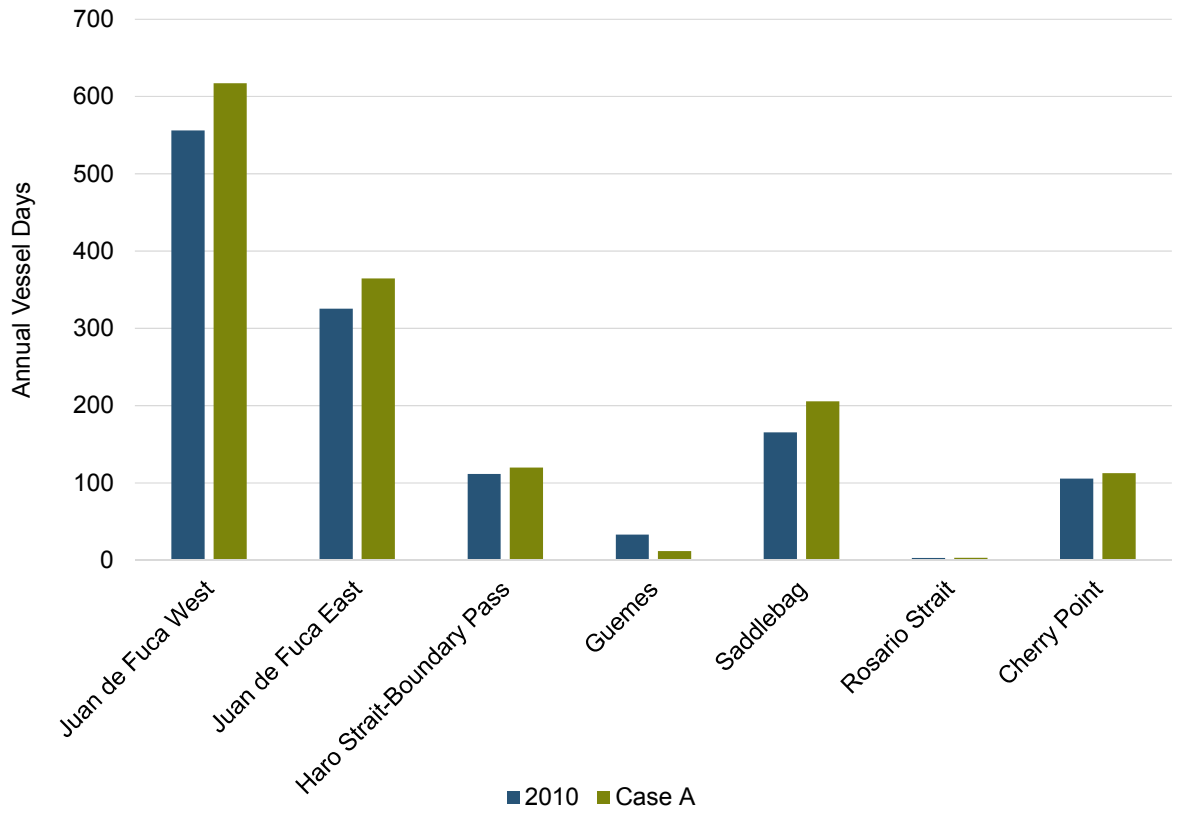

Figure 60 Cargo ship vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Tank Barges

Tank barge transits were forecast using the historical transits reported by WADOE. Similar to tanker forecasts, the study team used the pattern of growth expected for liquid bulk volumes to project future baseline tank barge numbers (Figure 61). In addition to baseline traffic, projects expected to significantly alter the volume of tank barges operating within the study area in Case A include the aforementioned expansions at the Neptune and Westshore terminals in Vancouver, BC. The additional tankers calling at the two Port Metro Vancouver terminals are expected to increase the demand for bunker from close-proximity refineries in the study area at Port Metro Vancouver. The WA DOE provided the number of tank barge roundtrips between Ferndale and Vancouver, BC. for 2008-2011 (Reference 35). If the current ratio of tank barge transits to vessel calls at the Vancouver, BC area remains constant, the 348 additional Kinder Morgan tankers are expected to generate seven additional tug and tank barge transits between the Cherry Point subarea and Port Metro Vancouver. A range of 0 to 15 calls were incorporated into Case A (Table 44).

Table 44 Tank barge vessel traffic days by subrea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
2010	87.6	310.7	27.1	340.8	103.0	62.1	354.9	1,286.2
2019 Case A	84.5	283.1	28.2	367.7	94.7	59.7	406.4	1,324.2
Percent Change (2010 to Case A)	-4%	-9%	4%	8%	-8%	-4%	15%	3%

Figure 61 summarizes the changes in tank barge volumes expected from the latest year of the historical traffic dataset, 2010, to the forecast year, 2019 Case A.

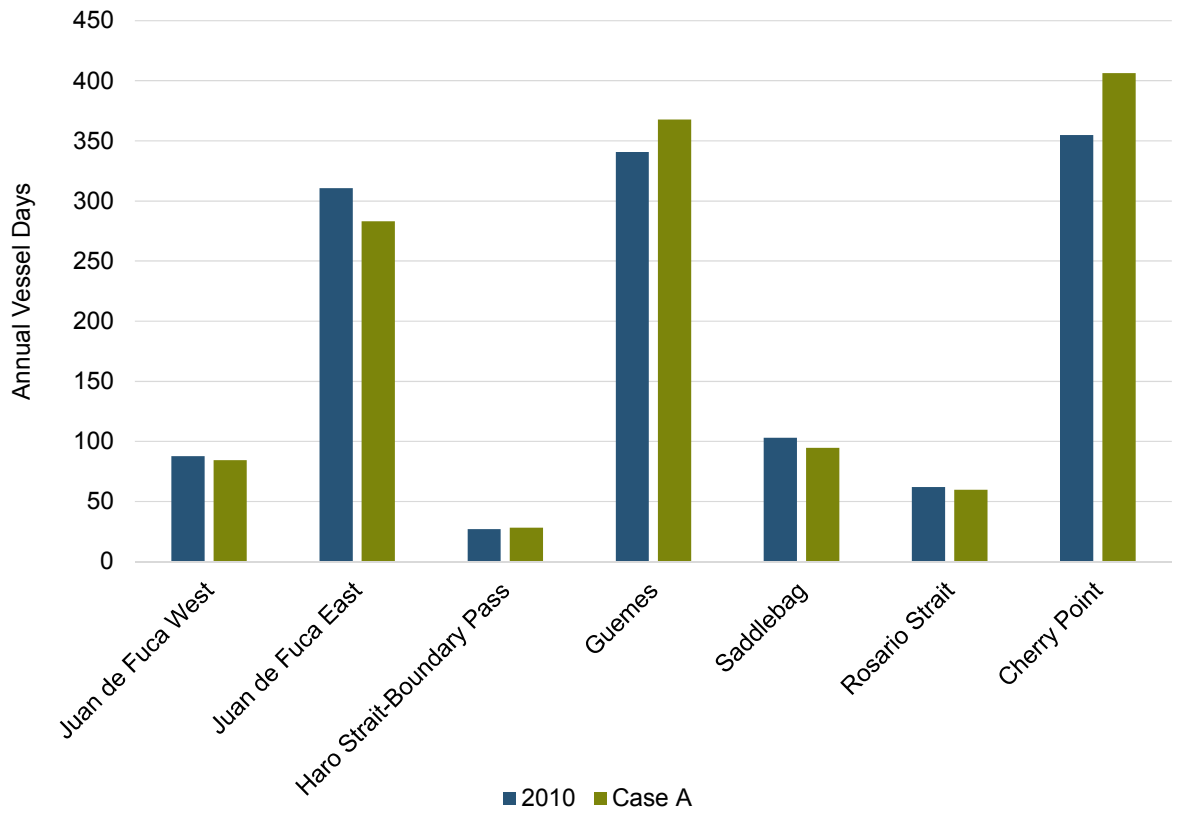

Figure 61 Tank barge vessel traffic days, by subarea, for all activity types, 2010 and Case A, 2019

Tugs

Tug volumes within the study area were forecast using total traffic volumes. As the number of non-tug vessel days spent in the subarea increases, so do the expected number of tug

days.[33] Case A projects expected to affect tug traffic beyond underlying trends include the rail facility expansions and the Port Metro Vancouver terminal expansions. As the number of tankers calling at Washington refineries decreases due to increased rail service, there will be a corresponding reduction in tug escort and assist time. This decrease dampens overall tug vessel days in the study area.

In the Cherry Point subarea, tugs moving tank barges between study area refineries and Port Metro Vancouver (to support bunkering of additional tankers) will generate an increase in tug vessel days compared to 2010, the latest year of the historical traffic dataset. Forecasted tug traffic days are summarized in Table 45 and Figure 62.

Table 45 Tug vessel traffic days, by subarea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
2010	346.9	1,072.1	105.7	866.2	431.8	353.8	1,134.6	4,311.1
2019 Case A	386.4	1,057.9	126.3	871.3	429.5	394.1	1,164.6	4,430.0
Percent Change (2010 to Case A)	11%	-1%	19%	1%	-1%	11%	3%	3%

[33] Tug activity time was calculated separately for oil tugs and non-oil tugs. Oil tug activity was calculated from the sum of trips with a tank barge and trips without a tank barge. Non-oil tug activity time was calculated using a ratio comparing historical non-oil tug trips to trips by other vessel types in the study area, equal to 1.36 for the 2006-2010 period. This ratio was applied to projected vessel activity in the study area to forecast future non-oil tug activity.

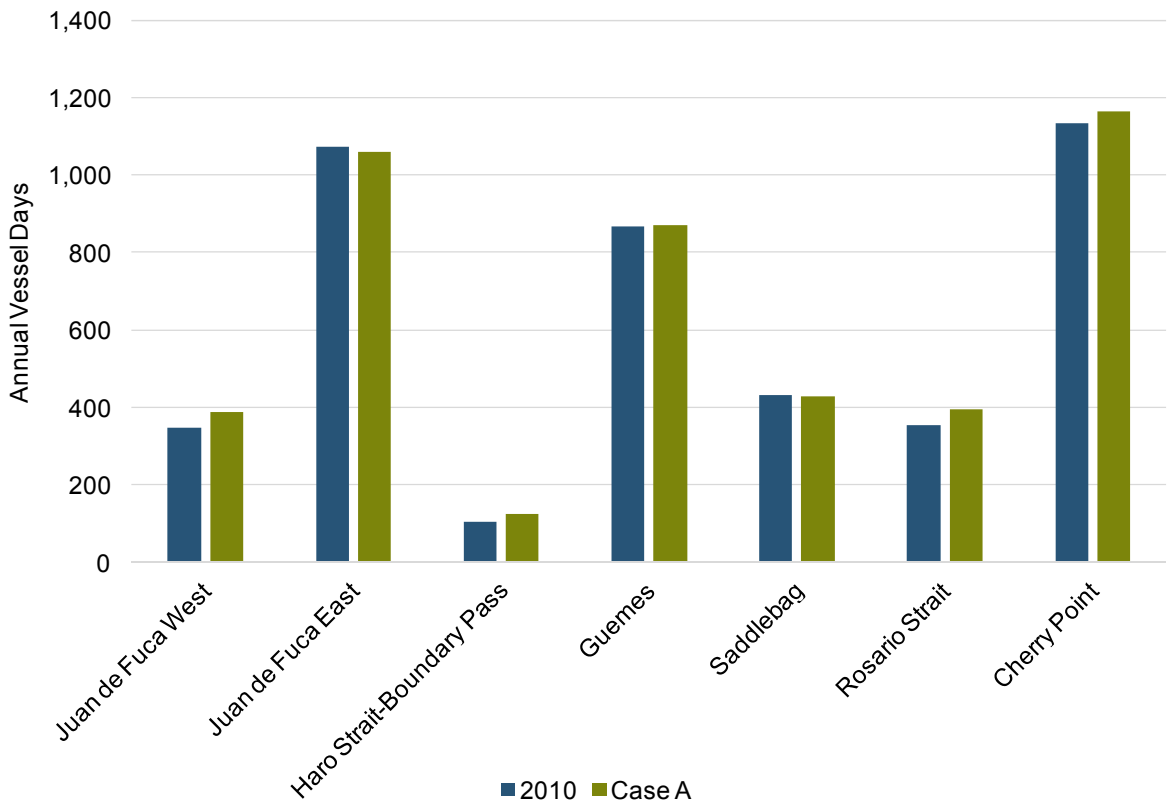

Figure 62 Tug vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Passenger and Fishing Vessels

Passenger vessels and fishing vessels collectively are expected to spend the most time in the study area in 2019. Much of this time is expected to be at-dock as both vessel types homeport in the study area. Between 2010 and 2019, passenger vessel days will increase due to forecasted growth in cruise vessel transits.[34] This growth will be offset by a reduction in large fishing vessel transits, which are forecast to decline in-keeping with recent trends. The historical reduction in fishing vessel transits is depicted in Figure 63.

[34] Cruise vessel forecasted growth is based on an analysis of historical trends completed by the study team.

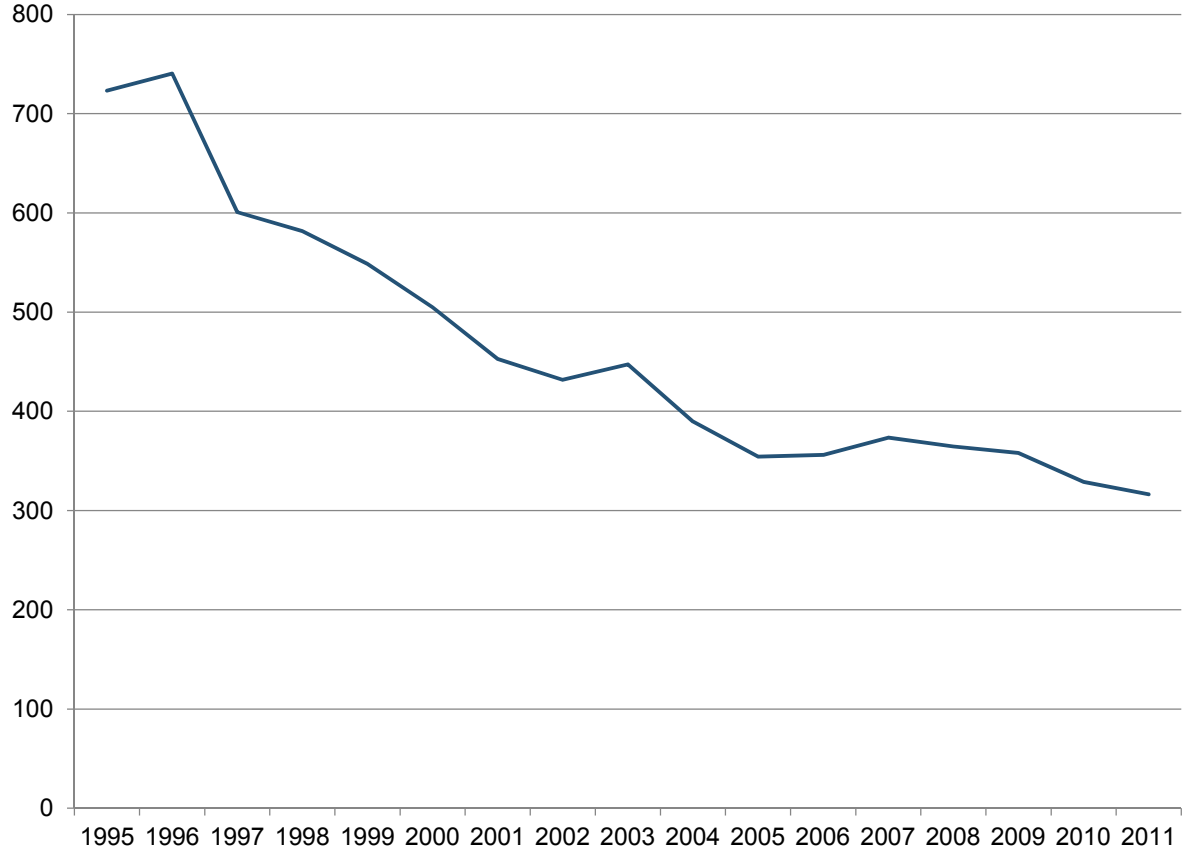

Figure 63 Study area fishing vessel transit days, 1995-2011

The last year of the historical traffic dataset (2010) and the forecasted passenger and fishing vessel traffic days are summarized in Table 46 and Figure 64.

Table 46 Passenger and fishing vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait - Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
2010	321.1	1,013.5	293.7	2,099.1	2,094.2	33.8	315.9	6,171.4
2019 Case A	293.4	1,065.3	307.2	2,129.8	2,145.7	33.7	335.8	6,310.9
Percent Change (2010 to Case A)	-9%	5%	5%	1%	2%	0%	6%	2%

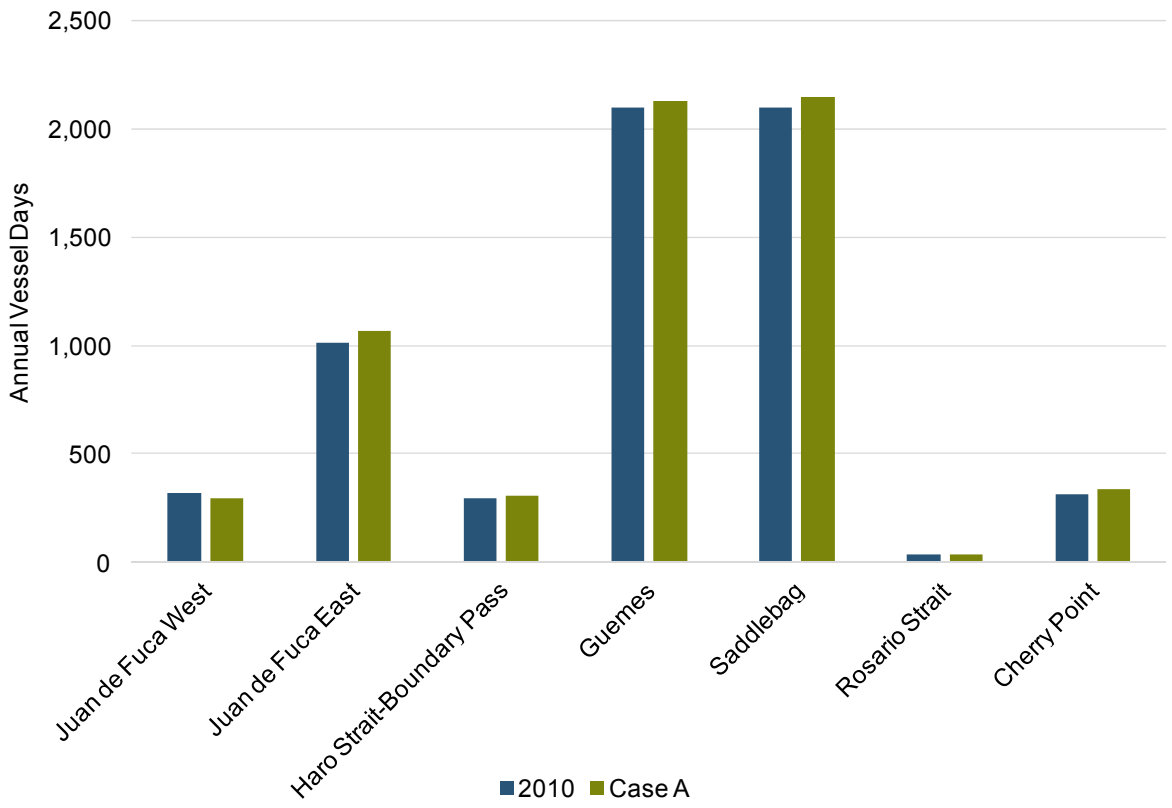

Figure 64 Passenger and fishing vessel traffic days by subarea, for all activity types, 2010 and Case A, 2019

3.2.4.2 Case B

Case B is the combination of the baseline traffic estimates generated in Case A and the forecast GPT 2019 traffic volumes (Table 47 and Figure 65). The proposed GPT will introduce a new source of vessel traffic to the regional traffic flow. This vessel traffic study is designed to predict and analyze the risk posed by vessels bound to or departing from the proposed GPT (GPT-calling vessels) and bunkering activity associated with these GPT calling vessels. GPT-calling vessels were mapped separately from other bulker traffic (in Case A) so that the change in potential risk with the proposed GPT could be isolated.

Table 47 Case B vessel traffic days by subarea and by component, for all vessel and activity types, 2019

Component	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
2010	2,363.7	3,927.3	777.1	3,952.2	3,088.7	515.8	2,624.0	17,248.5
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4
GPT	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Percentage Change: Case A to Case B	12%	27%	1%	3%	6%	21%	33%	15%

Note: Includes maneuvering time.

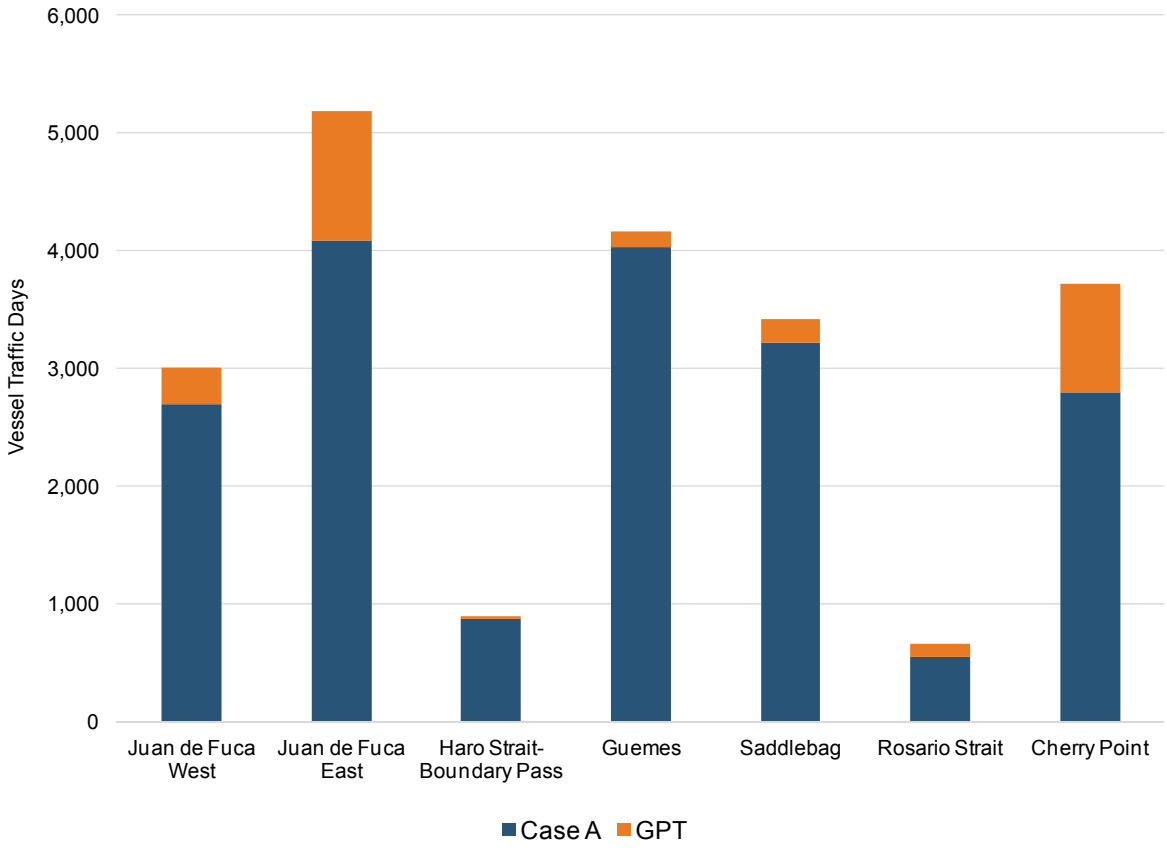

Figure 65 Case B vessel traffic days by subarea and component, for all vessel and activity types, 2019
Note: Case B is sum of Case A and GPT

GPT Vessel Traffic

The study team projected GPT traffic volumes at full capacity in 2019. In addition to bulkers, GPT traffic includes tugs assisting with docking and undocking of vessels, as well as tugs and tank barges expected to supply bunker for the GPT-calling bulkers. At full operational capacity, 487 vessels per year are expected to call at the proposed GPT

(Reference 114). All of these bulkers will require tug assists on arrival and departure, and a portion of them will also require tug and tank barge support to facilitate bunkering.

The study team mapped GPT vessel activity into the model for the year 2019. 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 in 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, and either Haro strait-Boundary Pass or Rosario Strait. Puget Sound Pilots currently estimate that 95% of bulkers use Rosario Strait, while only 5% use Haro Strait-Boundary Pass. Due to increased traffic by 2019, it was assumed that 85% will use Rosario Strait, and 15% will use Haro Strait-Boundary Pass.
3. GPT bulkers will travel between 12 and 13 knots, in line with the bulker speeds currently observed in the study area.
4. We assumed 2 movements (in and out) if vessels go straight to a berth and 3 movements (to anchor, to dock, and out) if they must wait. Bulker vessels currently make 2.6 transits (or moves) per arrival into the study area. Two of these moves are accounted for by arrival at and departure from the berth. Additional moves are accounted for by anchoring activity. Based on the queuing analysis, GPT-bulkers are expected to make 2.8 transits per call.
5. GPT bulker anchorage time was distributed to four subareas based on availability and order of assignment, as per USCG feedback (See Section 2.4.2). GPT bulkers are expected to spend 88% of their at-anchor time in Strait of Juan de Fuca East and 12% in Saddlebag.
6. GPT bulkers are expected to take between 1 and 2 hours to maneuver to anchor or berth.
7. Each bulker call at GPT will require two assist tugs, each making two transits – to and from the homeport. Assist tugs will homeport in either Anacortes (Crowley) or Bellingham (Foss), 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. A portion (between 50% and 100%) of GPT bulkers will bunker within the study area.
9. Bunker fuel will generally be supplied to Port Angeles via tank barges from the Tesoro refinery in Anacortes. These tug and tank barge movements have been included as GPT-related vessel traffic. Section 2.5.3.2 discusses the likelihood of a tug assist at Port Angeles and the activity time per assist.

Using the scenario parameters outlined, the study team estimated the GPT-bulker, tug, and tank barge time by activity type and subarea. Table 48 summarizes GPT vessel time by vessel type and subarea.

Table 48 GPT bulker, tug, and tank barge transit time by vessel type and subarea

Vessel	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Bulker	311.8	898.3	12.2	8.5	101.3	75.6	680.8	2,088.6
Tug	0.0	123.3	0.0	69.7	101.2	33.1	237.8	565.1
Tank Barge	0.0	82.9	0.0	61.8	0.0	6.8	0.0	151.5
Total	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2

Note: Includes maneuvering time.

In 2019, GPT bulkers are expected to spend about 2,100 vessel days within the study area. Tug and tank barges associated with GPT traffic will add another 700 vessel days, for a total of 2,800 GPT-related vessel traffic days in 2019. The queuing analysis[35] found that standard operational wait time would mean that the majority of bulker vessel time in the study area will be spent at anchor. GPT bulker days by activity type are summarized in Figure 66.

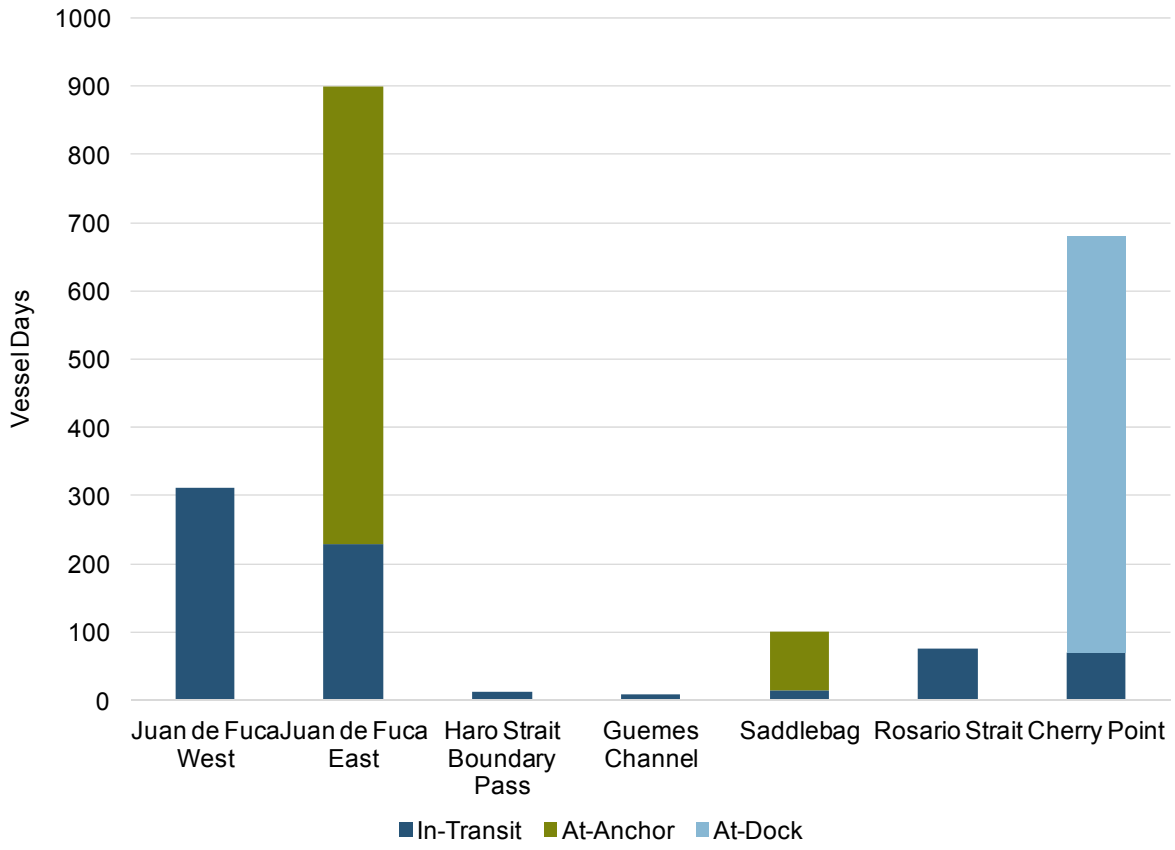

Figure 66 GPT bulker days by activity type and subarea, 2019

[35] The queuing analysis is discussed in more detail in Section 2.4.

3.2.4.3 Case C

Case C is the combination of Case B and the cumulative projects outlined in Table 49. Cumulative projects are defined as those which may be currently permitted, in the permitting process, or have been publicly announced.

Table 49 Case C components

Case C Forecast Assumptions
Case B traffic plus the following cumulative projects:
Tankers
Planned expansion of crude by rail offloading facilities at Shell (60,000 bopd); adjusting for practical throughput capacity and assuming price spreads are attractive half of the year, approximately 13 fewer fully laden tankers would be required
Expansion of Kinder Morgan (TransMountain Pipeline) export terminal adds 348 additional export tankers by 2019.
Tug and tank barges
Expansion at Kinder Morgan is expected to increase tug and tank barge bunker supply roundtrips between Ferndale and PMV by 15.

Note: bopd = barrels of oil per day.

Case C assumptions both increase and decrease Case B vessel volumes. The Kinder Morgan pipeline expansion adds vessel traffic days to the subareas transited by tankers and escort tugs going to and from Canada (Strait of Juan de Fuca West, Strait of Juan de Fuca East, Haro Strait-Boundary Pass, and Cherry Point). The expansion also adds tug and tank barge underway vessel traffic days to the Cherry Point subarea. The Phillips 66 refinery at Ferndale, WA is expected to support increased bunker demand. The planned rail terminal expansion at the Shell refinery will lower demand for tankers travelling to Anacortes, which will also reduce the number of escort and assist tug movements required. Consequently, there is a negative change in vessel traffic numbers in Rosario Strait, Guemes Channel, and Saddlebag (Table 50 and Figure 67).

Table 50 Case C vessel traffic days by subarea and component, for all vessel and activity types, 2019

Compo-nent	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Cumulative	150.2	176.4	148.7	-37.7	-7.5	-4.1	130.4	556.3
Case C	3,154.0	5,359.9	1,037.7	4,127.2	3,412.9	661.9	3,845.2	21,599.0

Note: Includes maneuvering time.

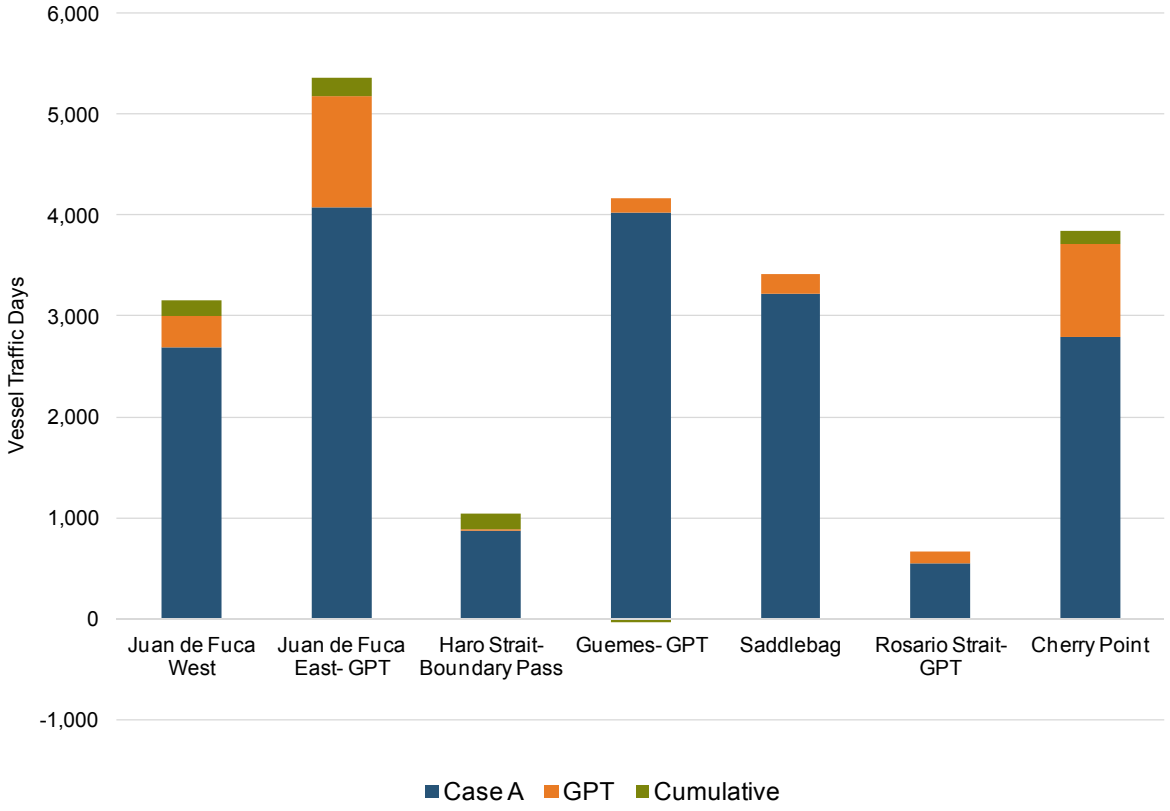

Figure 67 Case C vessel traffic days by subarea and component, for all vessel and activity types, 2019

Note: Case A + GPT + Cumulative = Case C.

Kinder Morgan

Kinder Morgan has applied for permits to expand its existing Trans-Mountain Pipeline that originates in Edmonton, Alberta and terminates at the Burnaby Terminal in the Greater Vancouver, BC area. There is a spur line from the Burnaby Terminal to the Westridge Marine Terminal that currently exports crude oil and also receives jet fuel for the Vancouver International Airport. Currently, five vessels per month, on average, are loaded with crude oil at the Westridge Marine Terminal. The expanded system would be capable of serving 34 vessels per month, depending on market conditions, for an average increase of 29 tankers per month (Reference 65). The planned expansion of the pipeline and the marine terminal would occur in 2017, according to the current project schedule, and result in an additional 348 export tankers calling annually (29 tankers per month) at the Westridge Marine Terminal.

The additional tankers resulting from the Trans-Mountain Pipeline expansion will increase the demand for bunker at Port Metro Vancouver. Assuming the current ratio of tank barge transits to vessel calls at the Vancouver, BC area remains constant, the 348 additional Kinder Morgan tankers are expected to generate 15 additional tug and tank barge transits from the study area. A range of 0 to 30 additional calls have been incorporated into Case C.

Shell Rail Terminal Construction

Shell has announced plans and filed for permits to build a 60,000 bopd rail unloading terminal at its Puget Sound refinery in Anacortes, Washington. This terminal will serve to

bring in crude oil from North Dakota and eventually replace declining Alaska North Slope production. The facility would have an initial capacity to unload one unit train (comprised of 102 tank cars) per day and current plans call for about six trains per week. The 60,000 bopd capacity would supply about 40% of the refinery's 145,000 bopd rated capacity.

3.2.4.4 Data Sources and Methodology

The forecasting cases were derived using the methodology described in Figure 68. The study team delineated the case components using years. Case A includes traffic expected in the study area by 2019. Case B expands on Case A by including GPT-related traffic. Case C includes projects that have been permitted or announced, but are not yet under construction and will not contribute traffic volumes until after 2019. Projects that have not been permitted and are considered to be speculative at this time were excluded from the analysis.

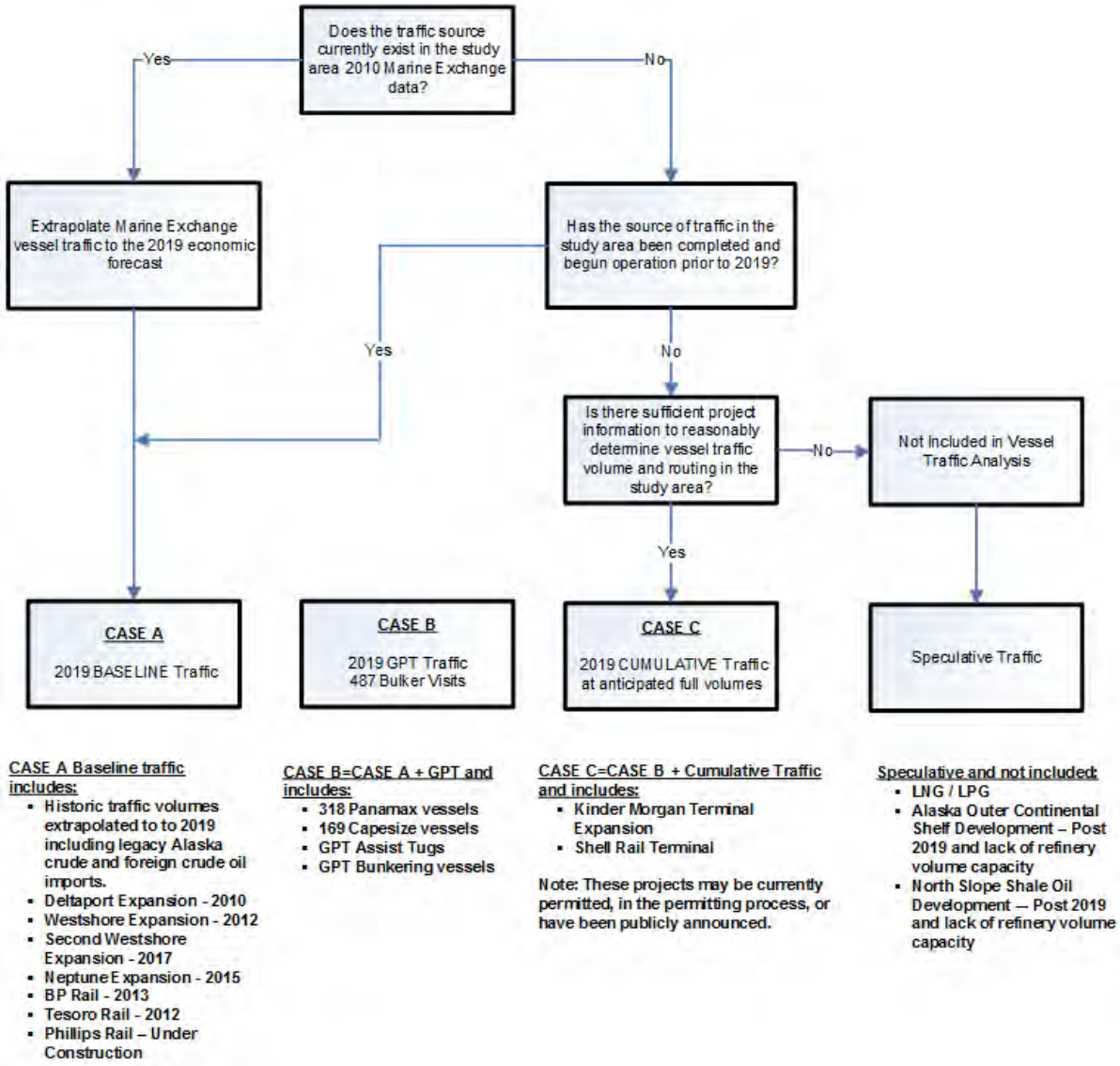

Figure 68 Forecasting case methodology

The study team's vessel traffic forecast relies heavily upon a commodity-based economic forecast generated by BST Associates, as well as historical trends and patterns of vessel

activity. 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 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,"* (Reference 26).

The GPT study team used both the 2009 Marine Cargo Forecast and the 2011 Update as the basis for our initial estimates of vessel traffic in the study area in 2019[36] (Figure 69).

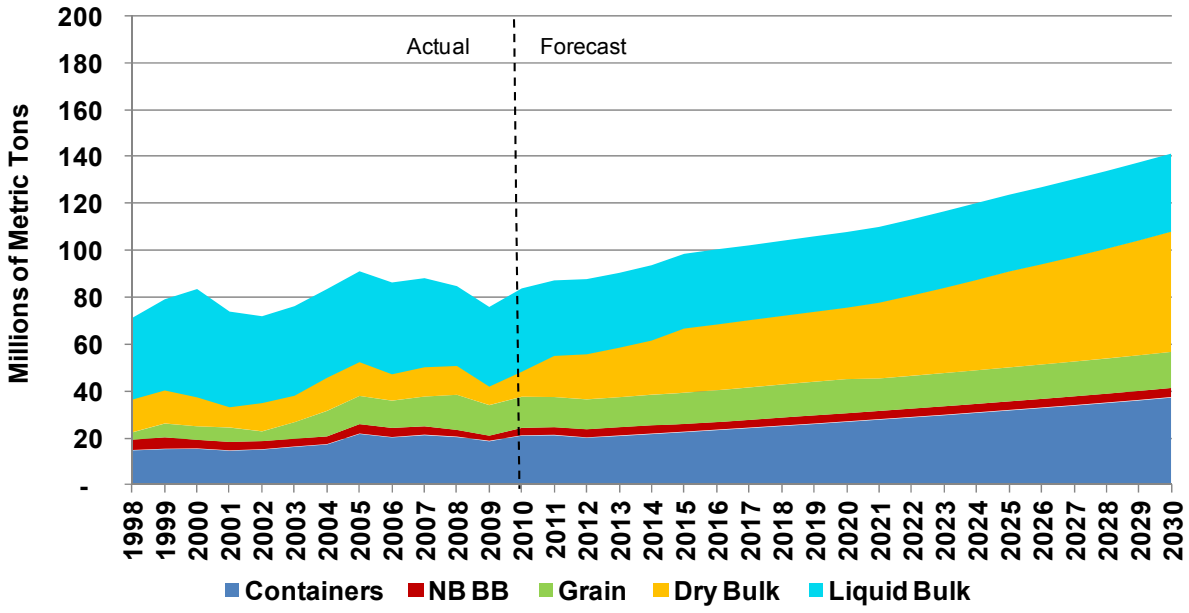

Figure 69 Puget Sound and Washington coast moderate commodity forecast, Reference 27
Note: NB=Neobulk; BB = Breakbulk.

To derive a relationship between cargo volumes and vessel trips, the study team used historical data. Combining historical cargo volumes[37] with average annual vessel size, the number of 'unique' vessel trips within the study area (Reference 75), and an adjustment for carrying capacity, the study team generated a formula for estimating 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 DWT of these bulkers over that same period. The study then generalized the relationship between the three variables to derive a formula for estimating the number of grain bulker trips into the study area using the total volume of BST forecasted grain exports.

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[36] BST's 2011 report was both the most recent forecast and the most recent complilation of actual cargo volume data available at the time this report was written.
[37] Actual commodity volumes from 1998–2008 were published in the 2009 Marine Cargo Forecast (Reference 65)

It should be noted that trends in vessel size were accounted for in this analysis. As shown in Figure 70, 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.

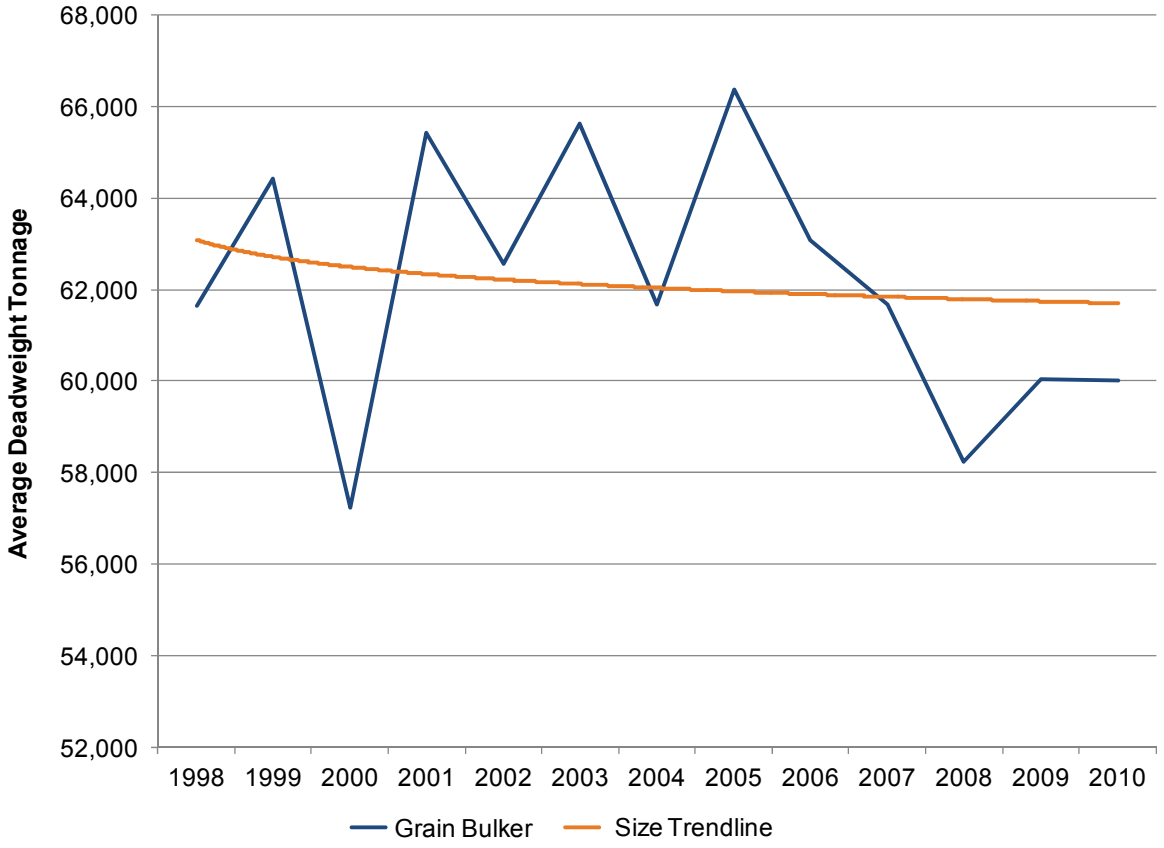

Figure 70 Grain bulker average DWT, 1998-2010, Reference 75

The study team compared its estimates to the actual data available from the Marine Exchange of Puget Sound to check the accuracy of this approach. Table 51 summarizes the results for Grain Bulkers. The equation for grain bulker trips generates estimates within a 15% average of actual trips. The standard deviation of the study's results is 8%.

Table 51 Actual to estimated trip comparison, grain bulkers, 2006-2010, Reference 75

Vessel Type	Year				
	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%

The only vessel types for which neither the MX data nor the BST forecast were used to forecast are non-oil tugs, ferries and fishing vessels. Each of these is discussed in more detail in the following sections.

Assist and Escort (Non-oil) Tugs

There is no single commodity or cargo type forecast by BST that would suffice as an indicator for future tug traffic volumes. Tugs, used for ship assist/escort 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 forecast increases in non-oil tug transits proportional[38] to total growth in study area vessel activity.

Ferry Component of Passenger Vessels

Ferry transit data show that between 1995 and 2010, underway and at-berth time remained within a 30-day window each year. Of the 15 years included in the study data, ferry vessel traffic days ranged from a high of 2,600 traffic days to a low of 2,570 traffic days. The study team held ferry traffic days constant at 2010 levels for 2019.

Fishing Vessels

Fishing vessel transits were forecast using historical trends. Between 1995 and 2010, the number of active fishing vessels in the study area dropped significantly. The study team forecast a continued, although slower, decline in fishing vessel transits.

Canadian Forecast

Vessels calling at Port Metro Vancouver were forecast using historical traffic patterns. The study team projected forward the historical trends seen for each vessel and activity type, and mapped this activity into the analysis. It should be noted that incremental increases in vessel traffic by type were forecast separately from specific terminal expansions.

3.2.4.5 Building in Uncertainty

Forecasting is, by nature, an inexact science. While the study team forecast 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 incorporate such uncertainty, the study team built variation into the model using Palisade Corporation's @RISK software. @RISK allowed the study team to model a range of values for specific variables, which in turn generated 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 analysis used the most-likely vessel traffic days as a basis for presentation; however, it is worth noting that the values used for the downstream risk analysis were actually ranges of values. The variables for which ranges were used are those that present the most uncertainty, and are described in detail below.

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[38] Tug activity time was calculated separately for oil tugs and non-oil tugs. Oil tug activity was calculated from the sum of trips with a tank barge and trips without a tank barge. Non-oil tug activity time was calculated using a ratio comparing historical non-oil tug trips to trips by other vessel types in the study area, equal to 1.36 for the 2006-2010 period. This ratio was applied to projected vessel activity in the study area to forecast future non-oil tug activity.

Economic Forecast

Each of the commodity forecasts developed by BST Associates and used in the model included annual commodity volumes for 2011 through 2026, 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.[39] 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.[40] 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. In other words, the study incorporated a high and a low value, with the average of the two being most likely.

Tug Maneuvering and At-Berth Time

Tug maneuvering time[41] was expected to range from 0.25 to 1.5 hours per call. For the purpose of modeling, the study team used a uniform distribution to represent this uncertainty, with 0.25 hours and 1.5 hours 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.

GPT-Fuel Demand

Between half and all (50 – 100%) of the 487 bulker vessels calling at the proposed GPT are expected to bunker in Port Angeles. The study team ranged the fuel demand estimate between these points. Assist tug, tug, and tank barge movements related to bunkering operations in Port Angeles vary with bunker demand.

Crude Prices

The cost differential between North Dakota crude and ANS crude oil may not cover the cost of rail transportation, which is estimated at about $10 per barrel (Reference 108). Figure 71

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[39] The years for which the MX data were available.

[40] Cruise vessels are the only passenger vessel type for which an @RISK forecast distribution was developed as ferry vessel days are held constant at 2010 levels.

[41] Maneuvering, for baseline tugs, is defined as the amount of time a tug (with or without a tow) will need to maneuver to and from a dock.

shows the historical crude oil price spreads between Brent crude (a global benchmark that is representative of crude oil imported into West Coast ports from foreign nations), ANS, and West Texas Intermediate (WTI), which is a benchmark for Mid-Continent crude oil prices.

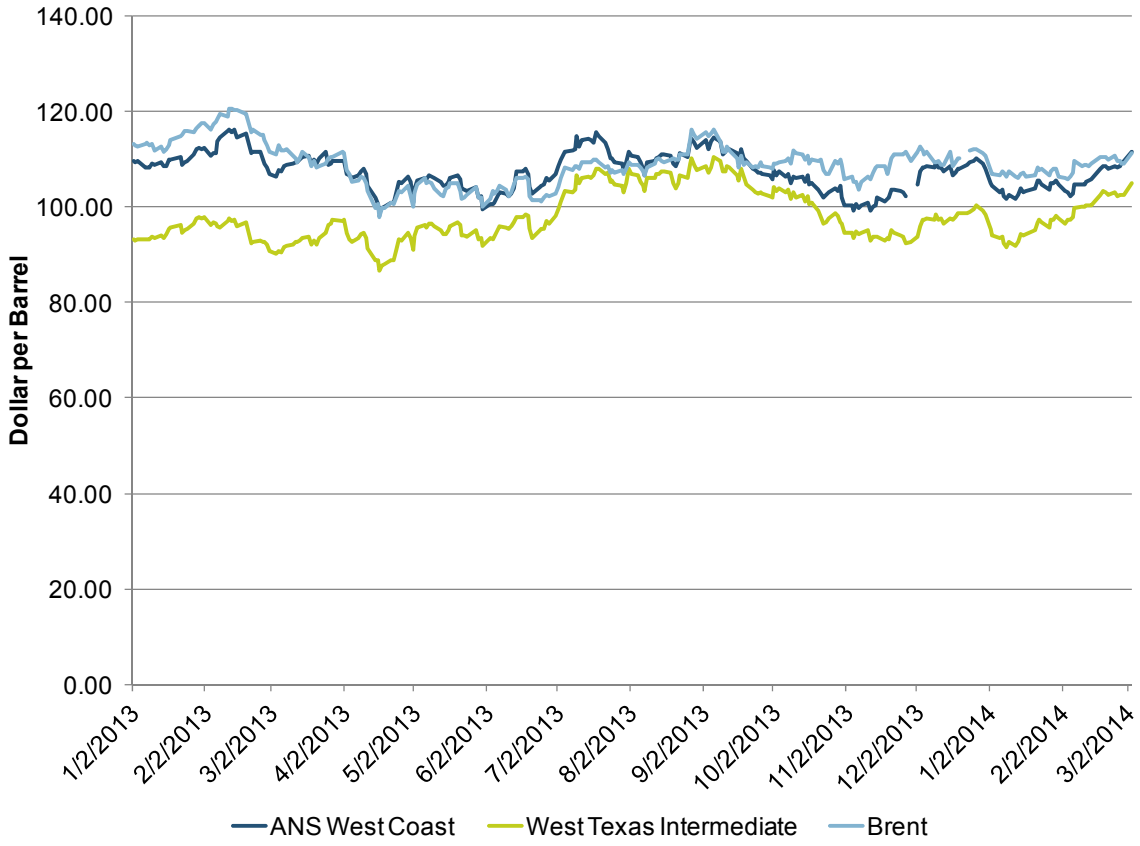

Figure 71 Historical crude oil prices, ANS, Brent, and WTI, Reference 12

As can be seen, the disparity between Brent and WTI has varied considerably over the past 16 months and at times ANS crude prices have exceeded the Brent price. Public databases with historical North Dakota crude pricing were not identified; but on April 2, 2014 crude oil prices for North Dakota crude oil traded at just under $96 per barrel at the Clearbrook Minnesota hub, which is a major delivery point for Bakken crude (Reuters 2014). On the same date ANS prices were estimated at $104.93, WTI at $99.62, and Brent at $104.79 (Reference 12).

It is generally known that North Dakota crude has been trading at large discounts to WTI and Brent due to the lack of sufficient "take-away" capacity via pipelines and rail transport. However, additional pipelines have come online or been re-purposed and a number of rail terminals have been built in the Bakken field to move crude to other markets that are not served by pipeline routes. As a result, the price differential has narrowed in recent months.

However, as Figure 71 shows, volatility in prices can change over time and forecasting future prices is very difficult. The analysis presented here assumed that in 2019 Bakken crude will enjoy a price advantage over ANS crude 50% of the time, with Bakken crude selling for at least $10 lower than ANS crude. Thus, about half of the time, North Dakota crude would displace ANS crude. Subsequently, on a daily basis, averaged over the year, and adjusting for practical throughput capacity of 90% of nameplate capacity, in Case A

about 63,000 bopd would be transported to study area refineries by rail displacing ANS crude by tanker.

Since there is a great deal of uncertainty regarding the volume of crude that may be transported by rail, the model used 50% as the mid-point, 25% as a high case (results in more tanker calls), and 75% as a low case (reduces the number of tanker calls).

3.3 Incident Probability Statistics

3.3.1 Introduction

This section presents incident probability statistics, termed Incident Rates. An Incident Rate (IR) quantifies the probability that an incident will occur on any given vessel traffic day. IR is expressed in the units of number of incidents per vessel traffic day, and IRs were calculated with respect to the parameter values: *v*, *a*, *i*, and *l*. Thus, IRs are presented in this section for every scenario. As described in Section 3.1.1 (Equation 3-1), there are 1,008 total scenarios.

This section reviews the quantitative formulation of IR used in this study, which was initially developed from historical baseline data. This formulation included reducing the number of studied scenarios by grouping together study subareas with very low historical baseline data. Additionally, some adjustments were made to the developed IR (to result in adjusted IR, or AIR) for scenarios with no historical baseline data.

Section 3.3.2 places this IR study into the context of the overall vessel traffic study. Section 3.3.3 of this report describes the IR input data and formulation, and introduces both Appendix E and Appendix D in Section 3.3.3.2. Section 3.3.4 addresses scenarios that do not occur in the study area and have an IR with value 0 (or "zero-IR"). Section 3.3.5 addresses scenarios with zero historical incidents and formulates an adjusted, non-zero IR. Resulting IR used in the statistical analysis in Section 3.4 are presented in Section 3.3.6, and a summary of incident rates calculated with respect for only one and two scenario parameters is presented in Section 3.3.7. Discussion of formulated IRs is provided in Section 3.3.8.

3.3.2 Vessel Traffic Context

3.3.2.1 Principles of Incident Probability

Incident probability statistics were formulated and are presented as IRs. IRs are numerical representations of the likelihood of incidents. Historical incident counts and historical traffic were used to derive IR. The historical baseline is the 16 years between 1995 and 2010. Incident Rates (IR) were calculated by dividing the number of incidents (*NI*) by the number of vessel traffic days (*TD*) (Equation 3-2):

$$\mathrm{IR} = \frac{\mathrm{NI}}{\mathrm{TD}} \qquad 3\text{-}2$$

where incident and traffic data are from the same time period, vessel type, activity, and subarea or from the same grouping of these parameters. IR were required input for methods employed in Section 3.4.

3.3.2.2 Incident Types

Refer to Section 3.1.1 for a full discussion of the six (6) incident types (*i*). For particular consideration in the IR analysis, note that drift and powered groundings were included as they occurred historically, but they are not differentiated in the IRs.

3.3.2.3 Activity Types

The four (4) activity types (*a*) are Underway, Maneuvering, Docked, and Anchored. All four activity types were included to model the total time in the study area. Incident types (*i*) that will not occur during a particular activity type (*a*) are called out in Section 3.3.4.1. IR formulations and results are presented by activity. Underway and maneuvering were treated similarly and together are referred to "in-transit" in the vessel traffic study. Docked and anchored are both stationery activity types and were treated similarly. IR formulation, adjustment, and results are presented in the following sections:

- Formulation and adjustment for underway and maneuvering: Sections 3.3.3.3 and 3.3.5.1.
- Results for underway IR: Section 3.3.6.1.
- Results for maneuvering IR: Section 3.3.6.2.
- Formulation and adjustment for docked and anchored: Sections 3.3.3.3 and 3.3.5.2.
- Results for anchored IR: Section 3.3.6.3.
- Results for docked IR: Section 3.3.6.4.

3.3.2.4 Vessel Types

Vessel traffic includes tankers, tank barges, bulkers, general cargo, tugs, passenger vessels, and large fishing vessels for the purpose of this analysis. The general cargo ship type includes container as well as break bulk and neo bulk vessels, as per Section 3.2. The tug vessel type includes towing oil and non-oil barges, escorting, and docking (whereas in Appendix C, tugs, passenger vessels, and large fishing vessels are grouped into one vessel type called 'Other,' and the tank barge vessel type is referred to as a tug and tank barge, reflecting that tank barges are towed by a tug. In this grouping, incidents attributed to tugs are counted in the 'Other' category and incidents attributed to tank barges are counted in the 'Tug and Tank Barge' category). 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 mostly due to their smaller size, they are assumed to represent relatively small quantities of potential contaminant outflow.

3.3.3 Approach to Incident Rates

3.3.3.1 Objective

The objective of developing incident probability statistics is to "determine the risk of accident involving GPT-calling vessels that may result in contaminant release" (Reference 116). Risk is interpreted in this report as the probability of an incident. An IR quantifies the probability of an incident in units of number of incidents per vessel traffic day. IRs were developed for every scenario. All 1,008 combinations (Equation 3-1, Section

3.1.1) are assumed to include all scenarios that could significantly contribute to the quantity of contaminants that may be spilled.

3.3.3.2 Inputs

IRs quantify the likelihood of an incident for a given scenario. For the purposes of this vessel traffic study, incident data were aligned with traffic data to define an IR with respect to vessel traffic, as opposed to defining the IR with respect to time. Both the incident data and the traffic data were characterized by the same scenario parameters and by the same set of possible values within each parameter.

Incident data were aligned with traffic data through two studies: an incident study, and a vessel traffic study. The number of incidents *NI* is characterized by vessel type (*v*), activity type (*a*), incident type (*i*), and locations (*l*) (Table 52) as $NI_{v,a,i,l}$. An incident study was performed to obtain values of $NI_{v,a,i,l}$ for every *v*, *a*, *i*, *l* combination (scenario) (Appendix C). Traffic days *TD* are characterized by vessel type (*v*), activity type (*a*), and locations (*l*) as $TD_{v,a,l}$. A vessel traffic study was performed to obtain values of $TD_{v,a,l}$ for every *v,a,l* combination (Appendix A). These aligned inputs allowed for the formulation of IRs in terms of number of incidents per traffic day. The following subsections describe the historical data used.

Table 52 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. Docked	3. Grounding	3. Rosario Strait
4. General Cargo	4. Anchored	4. Cargo transfer error	4. Haro Strait and Boundary Pass
5. Tug		5. Bunker Error	5. Cherry Point
6. Passenger and Fishing Vessel		6. Other Non-Impact Incident	6. Saddlebag 7. Guemes Channel Fidalgo Bay

<u>Study Period</u>

Incident and traffic data from a 16-year historical time period between 1995 and 2010 in the project study area were used to derive IRs. 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 are captured, lessening 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 introduced by 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 CCG MCTS Near Real Time traffic data and Department of Ecology traffic data (VTOSS and VEAT) were

published in the same, consistent historical format. Incidents and traffic occurring before and after 1995-2010 or outside the study area[42] are informative, but were not inputs to the IRs[43].

Historical Incidents (Appendix C)

Historical incidents are reported in Appendix C and in Appendix D by Environmental Research Consulting (ERC). 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 were 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.

A customized database is developed for each analytical project application to include only records relevant to the project. Incidents were categorized by project-specific scenario parameters, Table 52, to allow for matching with vessel traffic for the GPT VTS.

To develop the customized database for this study, a total of 1,116 vessel incident records for incidents that occurred in the study area during the years 1995 through 2010 were categorized and analyzed. The largest percentage (62%, 687 vessel incident records) of

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[42] 1972) 21,000 gallon spill at the BP Cherry Point facility
2012) Bulker allision at the Westshore Terminal, Port Metro Vancouver, BC.

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

vessels involved in these incidents did 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 are no traffic data available. 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), tank barges (36), and those classified as 'Other' vessels (238). 'Tugs' and 'Passenger and Fishing Vessels,' Vessel Types 5 and 6, respectively, are shown as the 'Other' Vessel Type in Appendix C. Included are fishing vessels longer than 60 feet. The 'Passenger' vessel type includes cruise ships and ferries. Vessels within these six types were called VTS (for Vessel Traffic Study) vessels for the purposes of these analyses.

Each of the 429 incidents involving VTS vessels were characterized by the project-specific scenario parameters and by historical year y, $I_{v,a,i,l,y}$. The numbers of incidents (NI) were 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 Appendix C and in Appendix D show incident locations within subareas by incident type and vessel type on subarea maps. The incident database was organized by the project-specific scenario parameters to align with the formatting of the traffic database. 'Cargo Transfer Error' and 'Bunker Error,' Incident Types 5 and 6, respectively, were grouped into one incident type called 'Transfer Error' in Appendix C. However, Appendix D addresses these two incident types individually. IRs 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 C. Spill probability and outflow percentage is discussed further in Appendix E.

Historical Traffic

The number of traffic days for the six (6) VTS vessel types were categorized by activity type and location combination for every year in the historical baseline period 1995-2010. The numbers of traffic days are tabulated by vessel type, location, and year ($TD_{v,l,y}$) within the report by Northern Economics, Inc. (Section 3.2). Vessel days by activity and year ($TD_{v,a,y}$) are shown in figures. The entire dataset of $TD_{v,a,l,y}$ was organized by the project-specific scenario parameters and provided directly from NEI to Glosten for input to the IRs.

3.3.3.3 Incident Rate Formulation

IRs are calculated by dividing number of incidents by number of vessel traffic days (Equation 3-2, where incident and traffic data share the same time period, vessel type, activity, and subarea). Equation 3-3 shows this formulation with subscripts indicating scenario parameters, summed over the 16-year baseline. Each IR is with respect to the selected scenario combination of parameter values: v, a, i, and l.

$$IR_{v,a,i,l} = \frac{\sum_{y=1995}^{2010} NI_{v,a,i,l,y}}{\sum_{y=1995}^{2010} TD_{v,a,l,y}} \qquad 3\text{-}3$$

IRs may also be calculated for a group of scenarios. While an IR is needed for each of the 1008 scenarios, there are relatively few historical incidents over the 16 year baseline. The 429 incidents in the project database were classified into only 125 of the 1,008 scenarios. That left 883 scenarios (88%) with zero historical incidents. 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 Strait of Juan de Fuca West, so IRs for bulk carriers docked in Juan de Fuca West should be zero. However, after zeroing these no traffic scenarios, scenarios still remained that pose an incident risk to the system but that do not have historical data to assign them their own unique IRs.

Scenarios with similar risk profiles were grouped, rather than defining a zero IR or an IR from only very few incidents. The numbers of incidents were summed in the numerator, and the corresponding numbers of vessel traffic days were summed in the denominator. This maintained alignment between incidents and traffic. The IR 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, bulkers) were explicitly left ungrouped. All vessel types, activity types, and incident types were maintained ungrouped. IRs were only grouped over subarea. Grouping over subarea was done by activity.

Grouping by Subarea for Underway and Maneuvering

Subareas with similar geography and traffic patterns were grouped. Traffic activity by subarea is discussed in Section 3.2. For underway and for maneuvering scenarios, three subarea groups (*l_group*) were 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 IR formulation for underway scenarios is given as Equation 3-4. The IR formulation for maneuvering scenarios is equivalent and given as Equation 3-5.

$$IR_{v,a=underway,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} NI_{v,a=underway,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} TD_{v,a=underway,l,y}} \qquad 3\text{-}4$$

$$IR_{v,a=maneuvering,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} NI_{v,a=maneuvering,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} TD_{v,a=maneuvering,l,y}} \qquad 3\text{-}5$$

Grouping by Subarea for Anchored and Docked

Anchored and docked scenarios were grouped over all seven subareas (*l*). The IR at an anchorage is independent of the subarea where anchorage is located. Similarly, the IR at a dock was averaged over all dock locations[44]. Equations 3-6 and 3-7 give the IR formulation for the anchored and docked activity types, respectively.

$$IR_{v,a=anchored,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} NI_{v,a=anchored,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=anchored,l,y}} \qquad 3\text{-}6$$

$$IR_{v,a=docked,i,l} = \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} NI_{v,a=docked,i,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=docked,l,y}} \qquad 3\text{-}7$$

Formulation Refinements

The total number of unique IRs to derive was reduced from 1,008 to 288 by grouping. After reducing the number of locations (*l*) by grouping into *l_group*, there were 216 unique IRs for underway and maneuvering scenarios (Equation 3-1; $a = 2$, $l = l_group = 3$), and 72 unique IRs for anchored and docked scenarios ($a = 2$, $l = l_group = 1$).

The combined 288 IRs were reviewed and adjusted for insufficient historical data, statistical anomalies, and appropriate conservatism (appropriate in the authors' professional opinion). These IR formulations still produced IRs 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.

[44] In reality, docks and anchorages more susceptible to weather influence, tight maneuvering room, potential for anchor dragging or other factors would be expected to have a higher incident rate than another sheltered dock or anchorage. A uniform incident rate applied across all docks and anchorages will be over or under the estimate for a given subarea and will give an average estimate for the whole study area.

A zero IR was accepted if there is zero probability of the scenario's combination of incident type and activity; for example, a transfer error while moving for all vessel types.

When there were zero traffic days in a particular subarea, an IR of zero was assumed. The IR 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 IRs of all the subareas together. Consequently, the IRs for zero traffic day subareas were explicitly defined as zero. These accepted and adjusted zero IRs are further described in Section 3.3.4.

A zero IR was not accepted where a combination of vessel type, activity type, incident type, and subarea group (or entire study area, for anchored and docked) had zero historical incidents, but non-zero historical traffic. The IR was adjusted under this condition. This was necessary to capture the non-zero probability of an incident that has not yet occurred. These adjustments to define non-zero IRs are described in Section 3.3.5.

3.3.4 Zero Incident Rates

This section reviews the four types of scenarios that can have a true zero-IR. In other words, there is zero risk that these incidents will occur in the future. A zero IR was 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 IR may be zero for one or more of the described zero probability combinations following. There is overlap in the given number of scenarios applicable within following subsections.

3.3.4.1 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 cargo transfer error or bunker error while underway or maneuvering. For all vessel types in all subareas, scenarios of cargo transfer or bunker error while underway or maneuvering have a zero IR. This applies to 168 scenarios (Equation 3-1; $a = 2$, $i = 2$).

3.3.4.2 Incident Type and Vessel Type Combination

Vessels that do not carry a contaminant cargo do not have a cargo transfer error. Cargo transfer error contributing to spilled oil volume is only relevant for tankers and for tank barges. Cargo transfer error contributing to spilled dry bulk commodities is only relevant for bulkers. General cargo, tug, passenger, and fishing vessels have a zero IR for cargo transfer error. This applies to 84 scenarios (Equation 3-1; $v = 3$, $a = 4$, $i = 1$).

3.3.4.3 Vessel Type, Activity Type, Incident Type and Subarea Combination

There is zero bunkering at the proposed GPT or at other docks in the Cherry Point Subarea for Bulkers. The IR for bulkers' bunker error at dock is zero in the Cherry Point subarea.

Historically, there are no ship bunkering locations in the subareas: Haro Strait – Boundary Pass, Rosario Strait, and Juan de Fuca West, and it was assumed that no ship bunkering will occur in these areas in 2019 as well. Only the smaller vessel types (Tugs, Passenger and Fishing Vessels) may refuel and potentially have a bunker error in these subareas.

3.3.4.4 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 (Appendix C and Appendix D). Where there is zero historical traffic in the formula denominator, the IR is undefined. These scenarios are assigned IRs of zero.

Zero-traffic scenarios do not add incidents to the calculated IRs when grouped with nonzero-traffic scenarios. The IR for the group of scenarios is still valid for the other nonzero traffic scenarios. For, example, there is no anchoring traffic in Strait of Juan de Fuca West, but there is anchoring around Port Angeles in Strait of Juan de Fuca East. The IR calculated by Equation 3-6 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 were assigned an IR of zero.

An average number of annual traffic days from the 1995-2010 is shown in Table 53 (Appendix C and Appendix D) for all 6 × 4 × 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 51 combinations for vessel type, activity type, and location with zero-traffic; with 6 incidents types, the zero IR applies to 306 scenarios (including 15 combinations for maneuvering which are assumed zero IRs for the 90 scenarios with transfer and bunker error, as described in Section 3.3.4.1).

Table 53 Average annual traffic days by vessel type, activity type, and subarea, 1995-2010

Vessel Type	Strait of Juan de Fuca West	Strait of 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	86.9	114.8	27.3	11.3	1.6	62.2	103.3
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	354.7	530.7	96.0	53.8	41.6	338.4	501.0
Passenger and Fishing	427.5	338.3	82.3	124.3	104.6	36.3	143.1
			Maneuvering				
Tanker	0.0	26.3	0.0	25.3	6.2	0.0	43.3
Tank Barge	0.1	7.8	0.2	23.7	4.9	0.0	26.2
Bulker	0.0	4.5	0.0	1.0	0.3	0.0	1.4

Vessel Type	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point
Cargo	0.0	3.8	0.0	0.5	0.1	0.0	0.0
Tug	0.2	14.9	0.6	33.6	10.96	0.8	33.3
Passenger and Fishing	0.0	0.4	0.0	0.7	2.1	0.0	0.0
Anchored							
Tanker	0.0	497.2	0.0	300.5	305.8	0.0	16.2
Tank Barge	0.0	168.1	0.0	146.1	55.3	0.0	0.0
Bulker	0.0	32.5	0.0	4.2	0.6	0.0	1.4
Cargo	0.0	33.1	0.0	2.6	0.0	0.0	0.0
Tug	1.3	229.1	2.8	203.1	125.4	4.9	0.0
Passenger and Fishing	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Docked							
Tanker	0.0	162.6	0.0	232.6	0.0	0.0	486.9
Tank Barge	1.0	4.1	1.8	201.9	36.8	0.0	279.0
Bulker	0.0	6.9	0.0	51.7	21.2	0.0	39.8
Cargo	0.0	20.0	0.0	13.2	160.0	0.0	0.0
Tug	5.5	270.4	19.7	621.5	253.9	31.6	618.1
Passenger and Fishing	0.0	855.3	220.5	2852.0	3190.2	0.0	180.0

3.3.5 Adjusted Incident Rates

This section explains the adjustment performed on scenarios with no historical incidents, but that could possibly occur in the future. In other words, the risk that incidents will occur in these scenarios in the future is non-zero. The dataset of 429 incidents (Section 3.3.3.2) distributes into 125 of the 1,008 scenarios. There are zero historical incidents for the remaining 883 (88%) scenarios. After grouping subareas into 288 scenario groups (Section 3.3.3.3), there were still zero historical incidents for 221 (77%) of the 288 scenario groups. The zero-IRs were accepted in 101 of the 221 scenario groups with zero historical incidents, discussed above in Section 3.3.4. The IRs were adjusted to be non-zero in the 120 remaining scenario groups with zero historical incidents, to capture the non-zero risk of an

incident occurring in these scenario groups. This section presents the approach to adjust the IRs for these scenarios to be non-zero.

The general approach for these scenarios is to assume that one (1) incident occurred in 17 years. The one artifically added incident is distributed across a group of scenarios. The sum of traffic days (*TD*) over the 16-year database from the group of scenarios is multiplied by 17/16 to add a year of average traffic days to the denominators of Equation 3-3 through Equation 3-7. When this formulation is applied to a smaller group of scenarios, fewer traffic days are in the denominator, and a higher, more conservative adjusted IR (AIR) is predicted. This approach introduces an acceptable percentage (4.3%) of artificial incidents to the dataset of 429, as per discussion in Section 3.3.6.5. It was selected for its acceptable conservatism and simplicity.

3.3.5.1 Adjustment for Underway and Maneuvering

After subtracting transfer and bunker errors from the 144 IRs calculated for underway and maneuvering (Equation 3-1; $v = 6$, $a = 2$, $i = 4$, $l = l_group = 3$), there were 44 remaining zero-IRs for underway, and 55 remaining zero-IRs for maneuvering. These zero-IRs and the AIRs are noted in the tables presented in Section 3.3.6.

As previously stated, the AIR method for underway scenarios was 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 was scaled from 16 to 17 years. This IR was 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 3-8. The formulation for maneuvering is equivalent and shown in Equation 3-9.

$$AIR_{v,a=underway,i,l} = \frac{1}{\frac{17}{16} \times \sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=underway,l,y}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} TD_{v,a=underway,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=underway,l,y}} \qquad 3\text{-}8$$

$$AIR_{v,a=maneuvering,i,l} = \frac{1}{\frac{17}{16} \times \sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=manuevering,l,y}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_group} TD_{v,a=maneuvering,l,y}}{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=maneuvering,l,y}} \qquad 3\text{-}9$$

IRs while underway, including adjustments, for tankers, tank barges, bulkers, cargo ships, tugs, and the passenger and fishing vessel types, are given in Section 3.3.6.1, Table 54 through Table 58. Maneuvering IRs are given in Section 3.3.6.1, Table 60 through Table 64.

3.3.5.2 Adjustment for Anchoring and Docked

Adjustment for Impact Incidents

There were zero historical incidents for the 210 scenarios with allisions, collisions, or groundings (i = impact) at an anchorage or dock (Equation 3-1; $v = 5$, $a = 2$, $i = 3$, $l = 7$). An impact incident while not moving is possible due to a dragged anchor or a breakaway.

As stated previously, the AIR method for anchored scenarios was 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 was scaled from 16 to 17 years. This IR was 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 3-10. The formulation for docked is equivalent and shown in Equation 3-11.

$$AIR_{v,a=anchored,i=impact,l} = \frac{1}{\frac{17}{16}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=anchored,l,y}}{\left(\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} \sum_{v=1}^{v_all} TD_{v,a=anchored,l,y} \right)^2} \qquad 3\text{-}10$$

$$AIR_{v,a=docked,i=impact,l} = \frac{1}{\frac{17}{16}} \times \frac{\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} TD_{v,a=docked,l,y}}{\left(\sum_{y=1995}^{2010} \sum_{l=1}^{l_all} \sum_{v=1}^{v_all} TD_{v,a=docked,l,y} \right)^2} \qquad 3\text{-}11$$

Adjustment for Cargo Transfer Error

Cargo transfer error is only relevant for tankers, tank barges, and bulkers, as described in Section 3.3.4.2. 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 cargo transfer errors from tank barges at an anchorage. Thus, the IR for tankers at anchor was assigned to tank barges.

Spills of bulk commodities are not reported under the same regulation as oil spills. Bulkers only transfer cargo at dock, and no bulk cargo transfer spills at-dock have been reported over the baseline time period in the study area. Therefore, data from coastal and inland US waters were used to predict an incident rate. Over the sixteen year baseline, there were four (4) reported bulk cargo transfer incidents and an estimated 9,700 port visits (Reference 45). Assuming each port visit is equal to one (1) vessel traffic day (24 hours) at dock, this gives an AIR = 4 / 9,700 = 0.000026 incidents per day at dock (also see Appendix E Table 21). As discussed in Appendix E, the lack of accurate historical data reduces the confidence levels in risk statistics derived from this estimated adjusted IR.

Had the formula in Equation 3-11 been assumed rather than using nationwide data, the resulting AIR would be twenty times more conservative. There were 1,914 days for bulkers at dock throughout the study area across the 16 year baseline, 1995-2010. Assuming one (1)

incident in 17 years of bulker days at the dock would give an IR of 0.00049 (= 1/ (17/16 x 1,914 days). This IR is overly conservative, considering that the estimate using nationwide data is already based on conservative assumptions. The modelled adjusted dry bulk cargo transfer error rate is 0.000026 incidents per day at dock.

The IRs 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 66 and Table 67, respectively.

Adjustment for Bunker Error at Anchor

IRs for bunker error were calculated for the anchoring and docked activities grouped over all subareas, as in Section 3.3.3.3. All vessel types had a prior bunker error at dock; no adjustment was needed to define a nonzero bunkering error rate at dock. There were only two vessel types with zero historical bunker errors at anchor. The IR for bunker error at anchor was adjusted for tank ships and for bulkers as per Equation 3-10.

3.3.6 Result Incident Rates

Number of incidents, number of traffic days, and the adjusted IRs are presented below in Table 54 through Table 67. Data are shown grouped, calculated, and adjusted, as discussed in previous sections. Adjusted IRs are italicized with light grey highlight.

3.3.6.1 Underway

Number of incidents by incident type, number of traffic days, and the adjusted IRs for the underway activity type are presented below in Table 54 through Table 59, for tanker, tank barge, bulker, cargo, tug, and for the passenger and fishing vessel type, respectively. Underway IRs were calculated by Equation 3-4. Adjusted underway IRs were calculated by Equation 3-8 and are shown italicized with light grey highlight.

Table 54 Tanker underway incident rates by incident type

Incident Type	Strait of 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
Cargo 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
Adjusted Incident Rate - Tanker Underway (incidents/traffic day)			
IR Collision	0.000146	*0.000014*	*0.000015*
IR Grounding	0.000146	*0.000014*	0.000651
IR Allision	*0.000066*	*0.000014*	*0.000015*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.002183	0.000665	0.007807
Sum	*0.002539*	*0.000708*	*0.008487*

Table 55 Tank barge underway incident rates by incident types

Incident Type	Strait of 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
Cargo 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)			
	3,228	1,433	1,859
Adjusted Incident Rate – Tank Barge Underway (incidents/traffic day)			
IR Collision	0.000310	*0.000032*	0.000538
IR Grounding	*0.000071*	*0.000032*	*0.000041*
IR Allision	*0.000071*	*0.000032*	*0.000041*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.000620	*0.000032*	0.001614
Sum	*0.001072*	*0.000127*	*0.002234*

Table 56 Bulker underway incident rates by incident type

Incident Type	Strait of 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
Cargo 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
Adjusted Incident Rate - Bulker Underway (incidents/traffic day)			
IR Collision	0.000055	*0. 000006*	*0. 000004*
IR Grounding	*0.000029*	*0. 000006*	*0. 000004*
IR Allision	0.000055	*0. 000006*	*0. 000004*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.000166	*0.000006*	0.001150
Sum	*0.000305*	*0.000022*	*0.001162*

Table 57 Cargo underway incident rates by incident type

Incident Type	Strait of 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
Cargo 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
Adjusted Incident Rate - Cargo Underway (incidents/traffic day)			
IR Collision	*0.000039*	*0.000005*	*0.000004*
IR Grounding	*0.000039*	*0.000005*	*0.000004*
IR Allision	*0.000039*	*0.000005*	*0.000004*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.001833	*0. 000005*	0.002328
Sum	*0.001949*	*0.000020*	*0.002340*

Table 58 Tug vessels underway incident rates by incident type

Incident Type	Strait of 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
Cargo 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)			
	14,165	6,950	9,543
Adjusted Incident Rate – Tug Vessels Underway (incidents/traffic day)			
IR Collision	*0.000014*	*0.000007*	*0.000010*
IR Grounding	0.000141	*0.000007*	*0.000010*
IR Allision	0. 000071	*0.000007*	*0.000010*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.001624	0.000576	0.001467
Sum	0.001371	0.000508	0.001250

Table 59 Passenger and fishing vessels underway incident rates by incident type

Incident Type	Strait of 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
Cargo 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	5,952
Adjusted Incident Rate – Passenger and Fishing Vessels Underway (incidents/traffic day)			
IR Collision	0.000082	*0.000004*	*0.000014*
IR Grounding	0.000571	*0.000004*	0.000672
IR Allision	*0.000029*	*0.000004*	0.000168
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.001551	0.003689	0.004536
Sum	*0.002232*	*0.003705*	*0.007026*

3.3.6.2 Maneuvering

Number of incidents by incident type, number of traffic days, and the adjusted IRs for the underway activity type are presented below in Table 60 through Table 65, for tanker, tank barge, bulker, cargo, tug, and for the passenger and fishing vessel type, respectively. Maneuvering IRs are calculated by Equation 3-5. Adjusted maneuvering IRs are calculated by Equation 3-9 and are shown italicized with light grey highlight.

Table 60 Tanker maneuvering incident rates by incident types

Incident Type	Strait of 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
Cargo 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)			
	421	0	1,197
Adjusted Incident Rate - Tanker Maneuvering (incidents/traffic day)			
IR Collision	*0.000151*	0.00	*0.000430*
IR Grounding	*0.000151*	0.00	*0.000430*
IR Allision	0.002377	0.00	0.000835
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.011887	0.00	0.001670
Sum	*0.014567*	0.00	*0.003367*

Table 61 Tank barge maneuvering incident rates by incident type

Incident Type	Strait of 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
Cargo 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)			
	126	3	876
Adjusted Incident Rate – Tank Barge Maneuvering (incidents/traffic day)			
IR Collision	*0.000117*	*0.000002*	0.002283
IR Grounding	*0. 000117*	*0.000002*	*0.000818*
IR Allision	*0. 000117*	*0.000002*	0.001142
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	*0.000117*	*0.000002*	0.001142
Sum	*0.000469*	*0.000010*	*0.005384*

Table 62 Bulker maneuvering incident rates by incident type

Incident Type	Strait of 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
Cargo 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
Adjusted Incident Rate - Bulker Maneuvering (incidents/traffic day)			
IR Collision	*0.005129*	0.00	*0.003058*
IR Grounding	*0.005129*	0.00	*0.003058*
IR Allision	*0.005129*	0.00	*0.003058*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	*0.005129*	0.00	*0.003058*
Sum	*0.020516*	0.00	*0.012231*

Table 63 Cargo maneuvering incident rates by incident type

Incident Type	Strait of 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
Cargo 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)			
	61	0	9
Adjusted Incident Rate - Cargo Maneuvering (incidents/traffic day)			
IR Collision	*0.011670*	0.00	*0.001754*
IR Grounding	*0.011670*	0.00	*0.001754*
IR Allision	0.016406	0.00	*0.001754*
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.065623	0.00	0.109170
Sum	*0.105368*	0.00	*0.114431*

Table 64 Tug maneuvering incident rates by incident type

Incident Type	Strait of Juan de Fuca	Haro Strait Boundary Pass Rosario Strait	Guemes Channel Saddlebag Cherry Point
Number of Incidents 1995-2010 – Other Maneuvering (incidents)			
Collision	0	0	0
Grounding	0	0	0
Allision	0	2	2
Cargo 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)			
	241	22	1,247
Adjusted Incident Rate - Tug Maneuvering (incidents/traffic day)			
IR Collision	*0.000100*	*0.000009*	*0.000515*
IR Grounding	*0.000100*	*0.000009*	*0.000515*
IR Allision	*0.000100*	0.090499	0.001604
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.012445	0.000009	0.002406
Sum	*0.012744*	0.090527	*0.005040*

Table 65 Passenger and fishing vessels maneuvering incident rates by incident type

Incident Type	Strait of 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
Cargo 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)			
	6	0	46
Adjusted Incident Rate - Passenger and Fishing Vessels Maneuvering (incidents/traffic day)			
IR Collision	*0.002123*	0.00	*0.016084*
IR Grounding	*0.002123*	0.00	*0.016084*
IR Allision	*0.002123*	0.00	0.153285
IR Cargo Transfer Error	0.00	0.00	0.00
IR Bunker Error	0.00	0.00	0.00
IR Other Non-Impact Incident	0.165914	0.00	0.153285
Sum	*0.172282*	0.00	*0.338737*

3.3.6.3 Anchored

Number of incidents by incident type, number of traffic days, and the adjusted IRs for the anchored activity type are presented below in Table 66. Anchored IRs were calculated by Equation 3-6. The IR for tank barge transfer errors at anchor was adjusted to be equal to the tanker transfer error rate, as per Section 3.3.5.2. Other adjusted anchored IRs were calculated by Equation 3-10. Adjusted rates are shown italicized with light grey highlight.

Table 66 Anchored incident rates by vessel type and incident type

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
Cargo 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)			
	17,915	5,912	618	572	9,066	0
			Adjusted Incident Rate - Anchored (incidents/traffic day)			
IR Collision	*0.0000145*	*0.0000048*	*0.0000005*	*0.0000005*	*0.0000073*	0.0
IR Grounding	*0.0000145*	*0.0000048*	*0.0000005*	*0.0000005*	*0.0000073*	0.0
IR Allision	*0.0000145*	*0.0000048*	*0.0000005*	*0.0000005*	*0.0000073*	0.0
IR Cargo Transfer Error	0.0001675	*0.0001675*	0.0	0.0	0.0	0.0
IR Bunker Error	*0.0000145*	0.0	*0.0000005*	0.0017478	0.0002206	0.0
IR Other Non-Impact Incident	0.0001675	0.0003383	0.0016179	0.0034955	0.0002206	0.0
Sum	*0.0003930*	*0.0005201*	*0.0016199*	*0.0052446*	*0.0004632*	0.0

3.3.6.4 Docked

Number of incidents by incident type, number of traffic days, and the adjusted IRs for the docked activity type are presented below in Table 67. Docked IRs were calculated by Equation 3-7. The IR for bulker transfer errors at dock was adjusted for bulk commodity spills, as per Section 3.3.5.2. Other adjusted docked IRs were calculated by Equation 3-11. Adjusted rates are shown italicized with light grey highlight.

Table 67 Docked incident rates by vessel type and incident type

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
Cargo 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)			
	14,113	8,394	1,914	3,091	29,130	116,768
			Adjusted Incident Rate – Docked (incidents/traffic day)			
IR Collision	*0.0000004*	*0.0000003*	*0.0000001*	*0.0000001*	*0.0000009*	*0.0000037*
IR Grounding	*0.0000004*	*0.0000003*	*0.0000001*	*0.0000001*	*0.0000009*	*0.0000037*
IR Allision	*0.0000004*	*0.0000003*	*0.0000001*	*0.0000001*	*0.0000009*	*0.0000037*
IR Cargo Transfer Error	0.0016296	0.0010722	*0.0000258*	0.00	0.00	0.00
IR Bunker Error	0.0000709	0.0003574	0.0010450	0.0006470	0.0005149	0.0001285
IR Other Non-Impact Incident	0.0014171	0.0020899	0.0020899	0.0019411	0.0005493	0.0004539
Sum	*0.0031189*	*0.0027409*	*0.0031609*	*0.0025885*	*0.0010669*	*0.0005933*

3.3.6.5 Incidents Added from Adjusted IRs

Adjusted IRs to non-zero rates added the equivalent of 17.00 incidents (4.0%) to the dataset of 429 incidents. The distribution of these artificial incidents by activity type, incident type, and vessel type is given in Table 68, Table 69, and Table 70, respectively. An addition of 4.0% incidents is a reasonable conservatism considering that 77% of scenarios had zero historical incidents.

Table 68 Incidents added from AIRS by activity type

Activity	Historical Incident Count	Incidents added from the adjusted historical rates	Sum Number of Incidents
Underway	189	4.98	193.98
Maneuver	44	8.27	52.27
Anchor	16	2.32	18.32
Docked	180	1.44	181.44
Total	429	17.00	446.00

Table 69 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	5.23	12.23
Grounding	15	6.48	21.48
Allision	18	3.39	21.39
Cargo Transfer Error	35	1.04	36.04
Bunker Error	41	0.26	41.26
Other, Non-Impact	313	0.59	313.59
Total	429	17.00	446.00

Table 70 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	2.78	92.78
Tank Barge	36	2.65	38.65
Bulker	15	2.69	17.69
Cargo	50	3.38	53.38
Tug	89	2.25	91.25
Pass & FV	149	3.24	152.24
Total	429	17.0	446.00

3.3.7 Incident Rate Summaries

A summary of number of incidents, traffic days, and IRs grouped by one parameter is presented. Statistics by incident type, vessel type, activity type, and location are presented in Table 71, Table 72, Table 73, and Table 74, respectively. IRs are unadjusted; they are a simple division of the number of incidents by traffic days. Traffic days presented in this section are consistent with Table 53, Section 3.4, and with Section 3.2.

Table 71 Average incident rate by incident type

	Collision	Grounding	Allision	Transfer Error	Bunker Error	Other, Non-Impact
Number of Incidents	7	15	18	35	41	313
Traffic Days	322,805	322,805	322,805	322,805	322,805	322,805
Incident Rate	0.000022	0.000056	0.000046	0.000108	0.000127	0.000970

Table 72 Average incident rate by vessel type

	Tanker	Tank Barge	Bulker	Cargo	Tug	Pass & FV
Number of Incidents	90	36	15	50	89	149
Traffic Days	43,561	21,829	26,790	23,339	70,364	136,921
Incident Rate	0.002066	0.001649	0.000560	0.002142	0.001265	0.001088

Table 73 Average incident rate by activity type

	Underway	Maneuvering	Anchored	Docked
Number of Incidents	189	44	16	180
Traffic Days	110,943	4,369	34,083	173,410
Incident Rate	0.001704	0.010072	0.000469	0.001038

Table 74 Average incident rate by subarea

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
Number of Incidents	53	103	4	108	67	11	83
Traffic Days	40,897	67,081	12,918	78,887	69,215	8,874	44,933
Incident Rate	0.001296	0.001535	0.000310	0.001369	0.000968	0.001240	0.001847

The distribution of IRs by incident type is the same as the distribution of incident counts by type, since all incident types are normalized by the same traffic days. Distribution, counts, and trends by incident type are presented in Appendix C.

IRs calculated from all incidents and all traffic in the 1995-2010 baseline are shown in Figure 72 through Figure 75 by vessel type, activity type, incident type, and subarea, respectively. These figures visually represent the IR information (last row) in Table 71

through Table 74. IRs in these figures are unadjusted; they are a simple division of the number of incidents by traffic days.

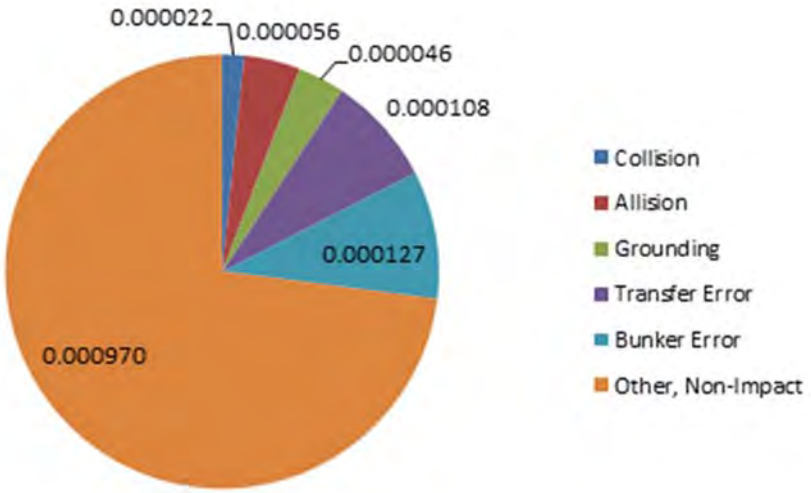

Figure 72 Overall incident rates (number of incidents per vessel traffic day) by incident type, 1995-2010

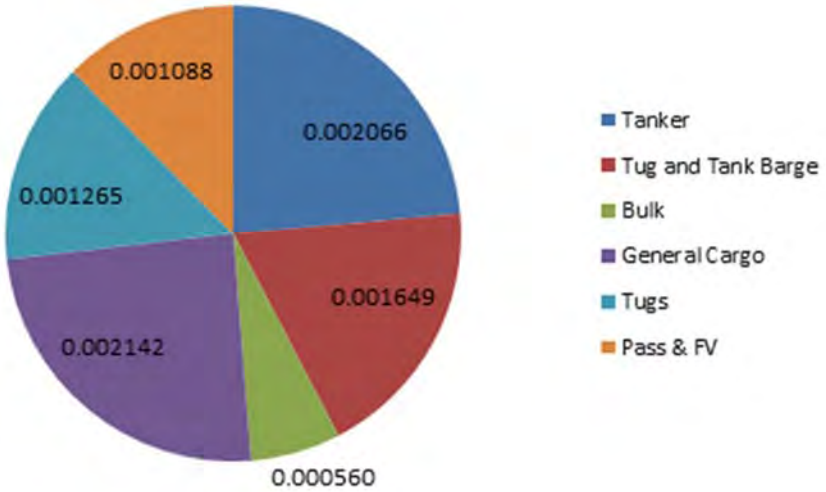

Figure 73 Overall incident rates (number of incidents per vessel traffic day) by vessel type, 1995-2010

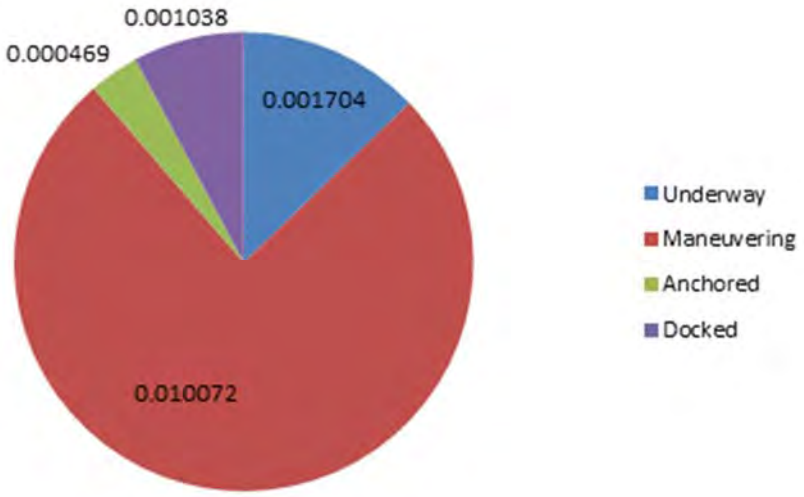

Figure 74 Overall incident rates (number of incidents per vessel traffic day) by activity, 1995-2010

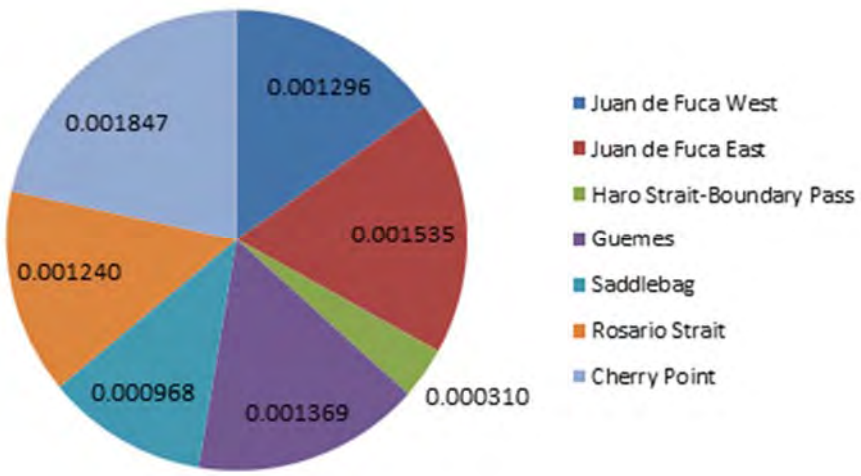

Figure 75 Overall incident rates (number of incidents per vessel traffic day) by subarea, 1995-2010

A summary of number of incidents, traffic days, and IRs grouped by two parameters is presented. Statistics by activity type and subarea are presented in Table 75. Statistics by vessel type and activity are presented in Table 76.

Table 75 Unadjusted average incident rates for all activity types and subareas

Subarea	Underway	Maneuvering	Anchored	Docked
Number of Incidents 1995-2010 – by Activity Type (incidents)				
Juan de Fuca West	48	0	1	4
Juan de Fuca East	59	15	8	21
Haro Strait-Boundary Pass	3	0	0	1
Guemes Channel	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	40,768	5	21	104
Juan de Fuca East	29,690	922	15,361	21,109
Haro Strait-Boundary Pass	8,989	12	45	3,872
Guemes Channel	3,459	1,356	10,503	63,568
Saddlebag	2,432	395	7,794	58,594
Rosario Strait	8,278	12	79	505
Cherry Point	17,327	1,666	280	25,659
Unadjusted Incident Rate – by Activity Type (incidents/traffic day)				
Juan de Fuca West	0.0012	0.0000	0.0000	0.0385
Juan de Fuca East	0.0020	0.0163	0.0005	0.0010
Haro Strait-Boundary Pass	0.0003	0.0000	0.0000	0.0003
Guemes Channel	0.0072	0.0059	0.0002	0.0011
Saddlebag	0.0086	0.0304	0.0004	0.0005
Rosario Strait	0.0011	0.1613	0.0000	0.0000
Cherry Point	0.0014	0.0042	0.0071	0.0019

A tank barge was recorded for an 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 76 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	1,618	17,915	14,113
Tank Barge	6,519	1,004	5,912	8,394
Bulker	24,143	115	618	1,914
Cargo	19,606	70	572	3,091
Tug	30,659	1,510	9,066	29,130
Pass & FV	20,102	52	-	116,768
Unadjusted Incident Rate – by Activity Type (incidents/traffic day)				
Tanker	0.003127	0.005563	0.000335	0.003118
Tank Barge	0.001074	0.003983	0.000338	0.002740
Bulker	0.000331	0.000000	0.001618	0.003135
Cargo	0.001683	0.085574	0.005243	0.002588
Tug	0.001435	0.006623	0.000441	0.001064
Pass & FV	0.003283	0.290170	0.000000	0.000582

3.3.8 Conclusion

3.3.8.1 Summary

Incident rates were formulated from a 16-year (1995-2010) historical baseline of incident and traffic data from within the study area. There were 429 incidents in the baseline dataset. The 429 incidents distributed into 125 scenarios, which left many (88%) scenarios with no data on past incidents.

The total number of unique incident rates to derive was reduced from 1,008 to 288 by grouping locations. After grouping subareas, there were still zero historical incidents for 221 (77%) of the 288 scenario groups. The incident rates were adjusted to be non-zero in 120 of the scenario groups with zero historical incidents. Adjustment was necessary to capture the non-zero probability of an incident occurring in the future. Adjusting incident rates to non-zero rates added the equivalent of 17.00 incidents (4.0%) to the dataset of 429 incidents. Many scenarios and scenario groups had zero probability of incident from the selected combination of scenario parameter values. These were assigned a zero incident rate. A zero incident rate was assigned in 101 of the 288 scenario groups. Additionally, zero incident rates were assigned to specific scenarios, such as a bulker bunker error at dock in Cherry Point. Of the 1,008 scenarios, 332 had adjusted or actual incident rates equal to or greater than 0.00001 incidents per traffic day, leaving 639 (67%) scenarios with a zero incident rate or an IR with a return period longer than 100,000 vessel traffic days.

3.3.8.2 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.

The number of incidents is expected to increase in direct, linear proportion with increased number of traffic days. To test this hypothesis, yearly statistics for number of traffic days and incident rates were compared to look for a correlation between increased traffic and increased IRs. Such a correlation would indicate that the number of incidents increases nonlinearly with increasing traffic days, or that congestion in the system increases the number of incidents. Behavior in individual subareas and in the overall study area was studied. Guemes Channel, Cherry Point, and Port Angeles (Strait of 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 with increased traffic. Thus, the IR results follow the expected trend of a linear increase in number of incidents with number of traffic days, and IRs are assumed constant through 2019 and with the addition of the proposed terminal.

It must be noted that congestion (higher traffic density) would primarily affect collision rates while underway. Other impact incident types may also be affected. However, there were too few data points to interpret a trend in rate of collisions with respect to congestion. There were seven (7) collisions in the baseline records: two (2) in Strait of Juan de Fuca West, two (2) in Strait of 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. Given the lack of potentially congestion-related data points, a further study could refine the boundaries in which to calculate traffic density.

Beyond the lack of data discussed above, the available data do 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 particularly 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.

In addition to waterway congestion, 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. However, these factors were not reliably recorded, if at all, within the incident records. Therefore, these factors cannot be explicitly modeled with the same IR formulation presented. These factors are represented in the IRs at the rate that they were present and contributed to the historical incidents in the 16-year baseline. The available data make 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).

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. Papers on the modeling and effect of traffic congestion are listed in the Reference List (References 16, 17, 10, 25, 43, 48, 63, 78, 81, 82, 101, 127, 130, and 131). The alternative methods, however, were not applicable with the approach presented and data available for this project. In the authors' professional opinion, the increase in vessel traffic in the forecast years is within the range that traffic density in local areas can be effectively managed by VTS to prevent an increase in collision frequency rate.

The IRs presented were compared to worldwide statistics for validation. Historical Accident Frequencies for Oslofjord, Norway, the North Sea area, and worldwide, were found to be in alignment with comparable units for tankers, bulkers, and general cargo ships with collisions, groundings, and Other Non-Impact Incidents (Reference 126) in the GPT study area. IRs between regions were within a wide, but acceptable range.

A confidence level on IRs is not defined in this report. The historical incident database was developed and checked as described in Section 3.3.3.2. Yet, the primary sources and processed data may still have human errors from transcription and interpretation. All quoted traffic vessel days are predicted mean values. There is a range of uncertainty about the mean. This uncertainty is modeled in Section 3.4.

3.4 Characterization of Incidents and Spills

3.4.1 Introduction

This section quantitatively examines the potential contaminant outflow due to GPT operations. A computational model was developed to estimate the potential contaminant outflow (bunker oil, cargo oil, and dry bulk) in the study area, with and without GPT operations. The difference in these outflow results is the predicted contaminant outflow due to the addition of the proposed GPT.

A contaminant outflow model was developed to quantify the effects of the proposed terminal. The model used historical incident and traffic data to predict the rate at which incidents that may result in contaminant outflow occur in the forecasted years. Traffic volumes by vessel type were projected for different geographic regions throughout the system, and the composition of vessels that make up each vessel type were projected in terms of size and structural integrity (i.e., single- or double-hulled). Because of uncertainty in projections and variability in historical data, a Monte Carlo simulation was employed to generate a probabilistic set of potential contaminant outflow outcomes. The Monte Carlo

algorithm calculated the number of incidents, number of spills, and volume of outflows for 10,000 stochastic results, each of which models the total annual traffic activity. The results were then post-processed so that comparisons could be made between forecast contaminant outflow with and without operation of GPT.

Vessel traffic days were input to a Monte Carlo Analysis to predict a range and probability distribution for:

1. Annual number of potential incidents.
2. Annual number of potential spills.
3. Annual potential oil outflow.
4. Annual potential dry bulk outflow.

Total annual potential spills throughout the system for each traffic volume case were output as a cumulative distribution function. The simulation results predict that there is a 95% likelihood that the number of total annual spills will be less than or equal to 21 in the largest traffic volume case (Case C). The cumulative probability range for 12 spills is 49% to 60% for Case A. This means that 11% (60% - 49%) of the model predictions, or approximately 1,100 of 10,000, predicted 12 spills. In Case A, the predicted average annual number of spills is 11.78, and in Case B, the average annual number of spills is 13.92. The difference of 2.14 spills is an 18% increase, attributable to the additional traffic from the proposed GPT.

Total annual potential spill volumes throughout the system for each traffic volume case were output as cumulative distribution functions. The simulation results predict that in Case A, the median spill size is 837 gallons, and in Case B, the median spill size is 1,044 gallons. The difference of 207 gallons is a 25% increase, attributable to the additional traffic from the proposed GPT. The addition of cumulative traffic in Case C further increases the median total annual oil outflow by another 13% to 1,178 gallons.

The magnitude of the increase in total annual potential oil and bulk outflow is predicted to be proportional to the quantity and size of the vessel traffic introduced into the system by GPT, which are Panamax and Capesize bulk carriers, assist tugboats and tank barge-towing tugboats, and tank barges. The outflow contaminant model predicts an 18% increase in the average number of spills and a 25% increase in the median oil outflow throughout the study area in 2019. The outflow contaminant model predicts an increase in median total annual bulk cargo outflow from a negligible amount to a small amount (15 cubic feet) with the addition of the proposed GPT.

Section 3.4.2 describes the Monte Carlo contaminant outflow model in detail. Section 3.4.3 describes the data that were used by the model. Section 3.4.4 presents the results of the simulation, which are summarized in Section 3.4.5.

3.4.2 Contaminant Outflow Model

3.4.2.1 Objective

The objective of the contaminant outflow model was to determine the quantities and locations of potential oil and dry bulk outflow for the three forecast cases in (Section 3.2.1). Traffic sources additional to the existing baseline traffic are included in the forecasts to 2019. The traffic contribution of other additional projects is discussed in Appendix A.

Oil outflow is from petroleum cargos and bunkers. Dry bulk outflow is from all dry bulk commodity types. The amounts of potential oil and dry bulk outflow were quantified separately. A flow chart of the contaminant outflow model is given as Figure 77.

3.4.2.2 Methodology

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

Total potential contaminant outflow for a given year was determined by summing all the individual spills that occur in that year. Determination of the quantity and volume of individual spills was accomplished by breaking the system into scenarios that represent each potential occurrence of oil and bulk outflow, and sampling each scenario to determine if that scenario results in any spills of oil cargo, bulk cargo, bunker fuel, or some combination thereof. As discussed in Section 3.1.1 and Equation 3-1, scenarios are defined by six (6) vessel types (v), four (4) activity types (a), six (6) incident types (i), and seven (7) locations (l) . Thus, there are 1,008 scenarios for each traffic volume case (). These 1,008 scenarios were assumed to include all combinations of the scenario variables that may significantly contribute to the quantity of contaminants 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 potential contaminant outflow is defined by the summation of potential spill volume for each scenario ($SV_{v,a,i,l}$), as shown in Equation 3-12.

$$Total\ Annual\ Outflow = \sum_{v=1}^{6}\sum_{a=1}^{4}\sum_{i=1}^{6}\sum_{l=1}^{7} SV_{v,a,i,l} \qquad 3\text{-}12$$

Spills may or may not occur as the result of incidents that have the potential to result in a spill. It was necessary, therefore, to determine the rate at which incidents occur and the probability that a spill occurs, given an incident, for each scenario. Historical incident rates per vessel traffic day for each scenario ($IR_{v,a,i,l}$) were developed as detailed in Section 3.3. Spill probabilities for each (vessel type, incident type) combination ($SP_{v,i}$) are described in Section 3.4.3.4.

The total annual outflow information provided by Equation 3-12 must be linked with information about the number of incidents that occur each year. A key assumption of the contaminant outflow model was that the numbers 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 was assumed that an event occurring on one vessel will not affect the time before another event occurs on another vessel. Therefore, the Poisson distribution was assumed to be a representative distribution of, and was used to sample, the number of shipping incidents that occur for each scenario. Equation 3-13 defines the Poisson distribution for the number of incidents ($NI_{v,a,i,l}$) that will occur for a forecasted yearly average incident rate ($\lambda_{v,a,i,l}$).

$$P(NI) = \frac{\lambda^{NI} e^{-\lambda}}{(NI)!} \qquad 3\text{-}13$$

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. The model was concerned with yearly contaminant outflow, as opposed to daily contaminant outflow, so it was necessary to determine the forecasted yearly average incident rate ($\lambda_{v,a,i,l}$). This was accomplished by multiplying the historical incident rate by the forecast number of traffic days for the given scenario, as defined by Equation 3-14. Forecast traffic days ($TD_{v,a,l}$) for the three traffic volume cases were developed as detailed in Section 3.2.

$$\lambda = IR \times TD \qquad 3\text{-}14$$

For each incident that occurs, the probability that it results in a spill is given by the Spill Probability ($SP_{v,i}$). By generating a random number between 0 and 1 and comparing it with ($SP_{v,i}$), it is determined whether or not a spill occurs.

If a spill does occur, it is necessary to determine the spill volume ($SV_{v,a,i,l}$). Spill volume is the product of Outflow Percent ($OP_{v,i}$) and Vessel Capacity (VC_v), as defined in Equation 3-15.

$$SV = OP \times VC \qquad 3\text{-}15$$

Outflow percentages ($OP_{v,i}$) for each combination of vessel type and incident type are developed and presented in this section. Vessel Capacities (VC_v) are described in Section 3.4.3.3.

Scenario and Case Parameters

The variables described in the previous section are dependent on parameters for each scenario. The project scenarios taxonomy is summarized in Table 77.

Table 77 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. Docked	3. Grounding	3. Rosario Strait
4. General Cargo	4. Anchored	4. Cargo transfer error	4. Haro Strait and Boundary Pass
5. Tug		5. Bunker Error	5. Cherry Point
6. Passenger and Fishing Vessel		6. Other Non-Impact Incident	6. Saddlebag 7. Guemes Channel Fidalgo Bay

An example of a Case 3 traffic volume scenario is as follows:

> *Considering a baseline, GPT, and cumulative vessel traffic volume, a general cargo vessel, while maneuvering, has the potential for grounding in Strait of Juan de Fuca East. The parameters that define the variables used to determine whether a spill occurs in this scenario are identified by the following indices, as given in Table 77: c = 3, v = 4, a = 2, i = 3, l = 2.*

Monte Carlo Simulation

The variables used to determine total contaminant outflow ($v, a, i, l, c, SV_{v,a,i,l}$) 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[45]. Therefore, one summation across all scenario outflows ($\sum SV_{v,a,i,l}$) will result in *one stochastic result* of total contaminant 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 contaminant outflow many times. The Monte Carlo method was thus employed to build a probability distribution of possible solutions of total annual contaminant outflow.

Each solution of total contaminant outflow is called a stochastic result. Each of the 1,008 scenarios were calculated for 10,000 stochastic results, for a total of 1,008 × 10,000 = 10,080,000 (10.08 million) calculations of scenarios potentially resulting in spills, for each traffic volume case. The Monte Carlo simulation cycled through each case parameter and project scenario parameter, building a database of incidents and spills identified by these parameters, as detailed in Figure 77. For each scenario in each case, the Monte Carlo simulation generated random numbers to determine (i.e., randomly sample) the values of the variables summarized in Table 78. The next subsection details an example of randomly sampling.

Table 78 Summary of random variables generated by Monte Carlo Simulation

Variable	Definition
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 vessel type (*v*). Several other random numbers are sampled to determine the vessel capacity, depending on vessel type (*v*), as detailed in Section 3.4.3.3.
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, what percentage of the vessel capacity is spilled.

[45] 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.

Example of Random Variable Sampling

Figure 76 shows an example of a graphed cumulative distribution function for the variable Outflow Percentage (OP). The cumulative distribution function for outflow percentage was based on historical vessel traffic data (Section 3.2). To sample this cumulative distribution function, a random number was generated between zero (0) and one (1) and designated as the sampled probability. The outflow percentage was then determined by interpolating the outflow percentage at this sampled probability. In the case of the example in Figure 76, the random number generated was 0.7, resulting in a sampled outflow percentage of 0.0001%.The likelihood that the sampled outflow percentage will be less than any given magnitude is dependent on the shape of the outflow percentage curve.

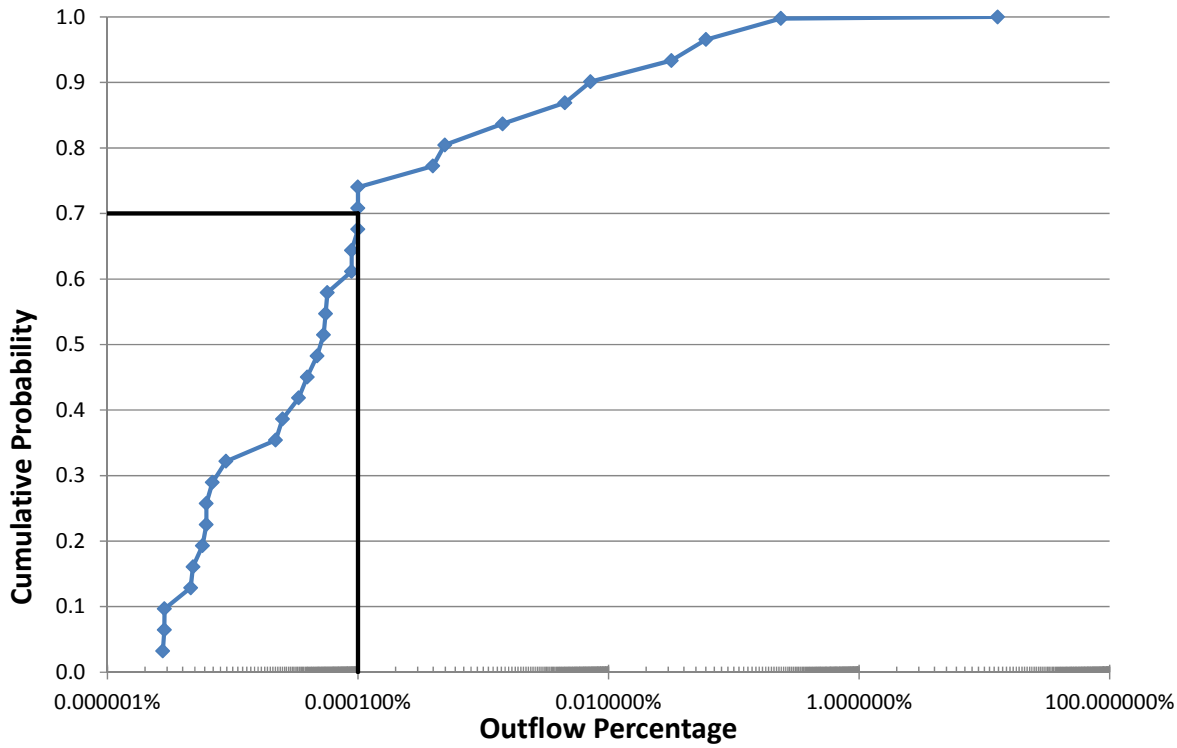

Figure 76 Example outflow percentage cumulative distribution function[46]

[46] Throughout this section, most cumulative distribution functions and probability distribution functions are plotted on logarithmic scales, due to risk statistic reasons discussed in Section 3.4.4.1.

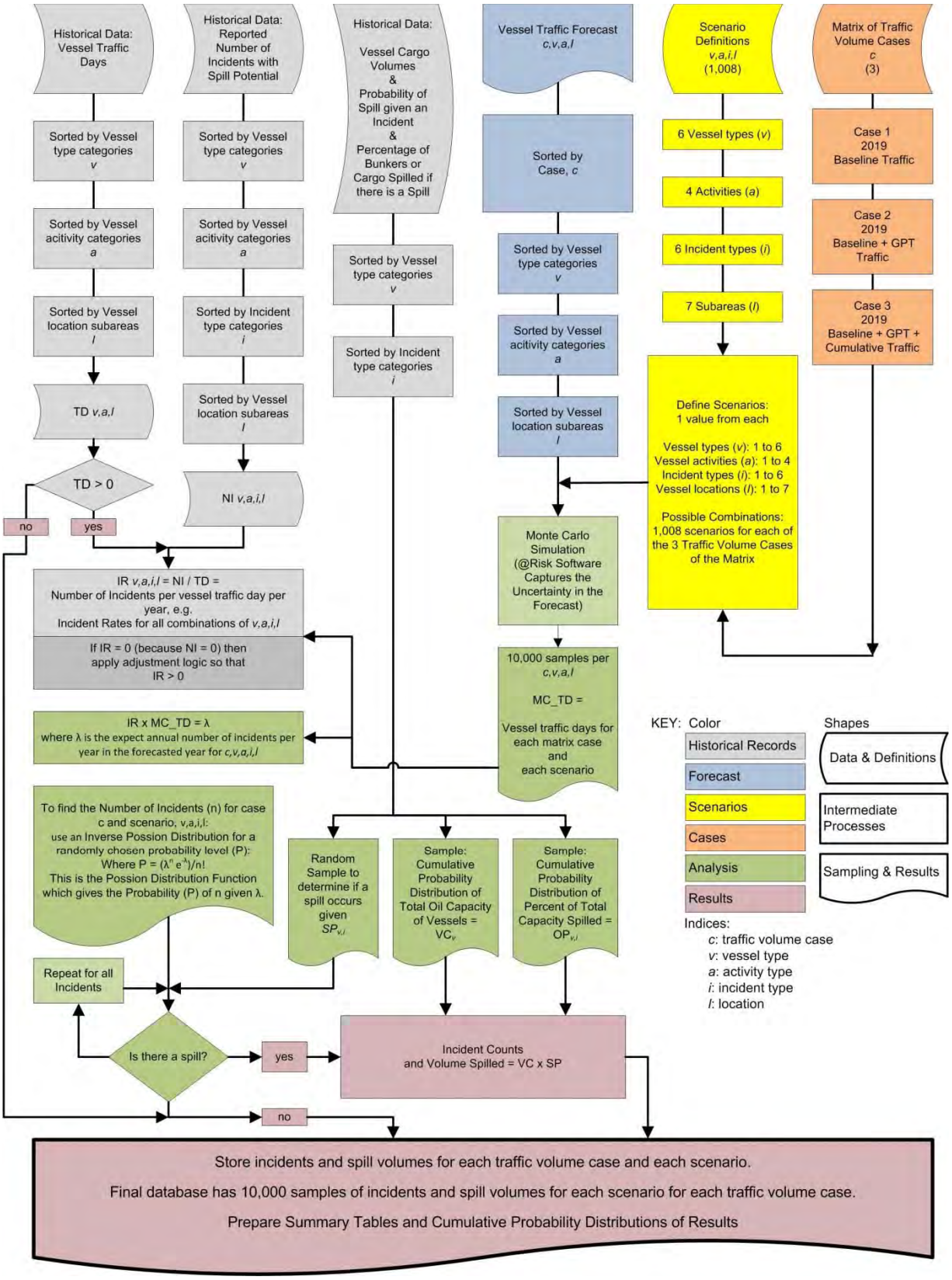

Figure 77 Monte Carlo Simulation flow diagram

Post-Processing Monte Carlo Simulation Data

Changes in the forecasted quantity of contaminants spilled in the subject area with the addition of the proposed GPT were estimated by comparing the probability distributions of oil and bulk outflow for the three traffic volume cases. Because the model is set up so that all incidents and spills are stored in a database with their respective case and scenario parameters, the data can be post-processed in any number of ways.

Cumulative distribution functions (CDFs) are created to show the probability that quantities of a given phenomenon will happen. By creating a CDF of annual oil outflow in Cherry Point, for instance, the 50th percentile (median) oil outflow volume in Cherry Point can be determined. By creating CDFs of potential oil outflow in Cherry Point for each of the three traffic volume cases, the median values for each traffic volume case can be extracted, allowing for a quantitative comparison of median annual oil outflow in Cherry Point with and without the proposed GPT.

CDFs of outflow volume were created by summing all of the outflow volumes in each stochastic result, and sorting these totals by magnitude. This sorted array represents the CDF, where the index of each value, divided into the total number of stochastic results, represents the probability that the outflow volume will be that value or less. In an array of 10,000 stochastic results sorted from smallest to largest outflow volume, therefore, the 5,000th value represents the 50th percentile (median) outflow volume. This methodology can be applied to any combination of parameters that were tracked, such as number of incidents per subarea.

Results from the simulation are presented in 3.4.4.

Programming Environment

The Monte Carlo simulation was programmed using the Python(X,Y) distribution of the Python programming language, as given by Reference 107. 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 are read into the program with the Python module xlrd, as given by Reference 145. Random numbers are generated and cumulative distribution functions are interpolated using the Python module SciPy, as given by Reference 145. Results are plotted using MatPlotLib, as given by Reference 58.

3.4.3 Input Data

The contaminant outflow model forecast probability distributions for potential oil and bulk outflow in the study area based on historical data and projections of vessel traffic. The following sections describe how these data and projections were obtained and used by the model.

3.4.3.1 Traffic Days ($TD_{v,a,l}$)

Traffic days are the number of days spent, per year, for each combination of vessel type, activity type, and location. Northern Economics, Inc. (NEI) developed probability distributions of traffic days for every (vessel type, activity type, location) combination, for the three traffic volume cases. The results are presented in Section 3.2. NEI provided a database of 10,000 stochastic results of vessel traffic days for each *v, a,* and *l* combination, which are read into the contaminant outflow model.

3.4.3.2 Incident Rates ($IR_{v,a,i,l}$)

Incident rates are the rate at which incidents occur for each scenario; i.e., for each combination of vessel type, activity type, incident type, and location. Generally, the incident rate for each scenario was determined by dividing the number of incidents that occurred during the historical study period (1995-2010) by the traffic days for that vessel-activity-location combination, with exceptions for those scenarios for which there were insufficient data to support a non-zero incident rate. Incident rates are tabulated in an Excel spreadsheet, which is read in by the contaminant outflow model. A comprehensive discussion of incident rate formulation is given in Section 3.3.

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

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

Changes in the capacity distributions of certain vessel types are also anticipated between now and 2019. Various techniques were employed to account for trends and sudden 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.

<u>Tankers</u>

NEI provided deadweight tonnage (DWT) for all 1,382 tankers that transited through the system in 2010. Tankers were split into two sub-categories (product and crude) due to significant differences in size and transit frequency. Figure 78 shows the DWT distributions for tanker subtypes in the system in 2010.

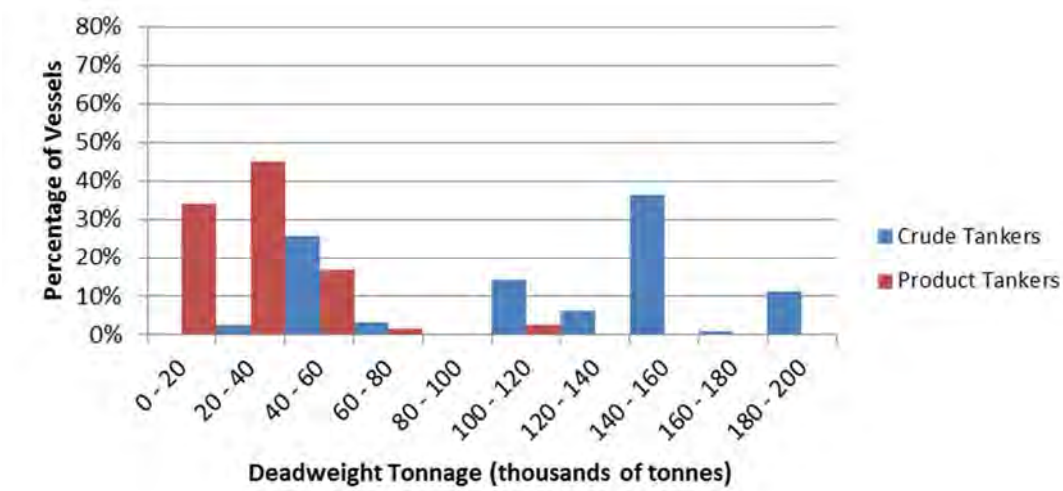

Figure 78 Tanker DWT distribution, 2010 (Appendix A)

As discussed in Section 3.2.2.2, tankers with a capacity larger than 125,000 DWT transit the study area, but while in the study area, they are limited to carrying a maximum of 125,000 tons of cargo. When the outflow contaminant model samples a tanker with a DWT exceeding 125,000, the model then adjusts the capacity down to 125,000 DWT. NEI

provided regression equations for the average DWT of product tankers (Equation 3-16) and crude tankers (Equation 3-17). Figure 79 illustrates the regression curve fit of average DWT as a function of year. NEI also provided forecast numbers of product and crude tanker vessel traffic days in the system, which were then converted to percentages (Table 79.) It is assumed that the breakdown of product versus crude tankers is consistent across all subareas, as the MX data used to compute these percentages shows a strong correlation between percentage of routes by tanker vessel type and percentage of routes by both tanker vessel types.

$$Average\ \ DWT\ (Product\ ) = -6{,}482 \times \ln(Year\ - 1998\ ) + 49{,}895 \qquad 3\text{-}16$$

$$R^2\ = 0.488$$

$$Average\ \ DWT\ (Crude\ ) = 5{,}685\ .4 \times \ln(Year\ - 1998\ ) + 105{,}505 \qquad 3\text{-}17$$

$$R^2\ = 0.294$$

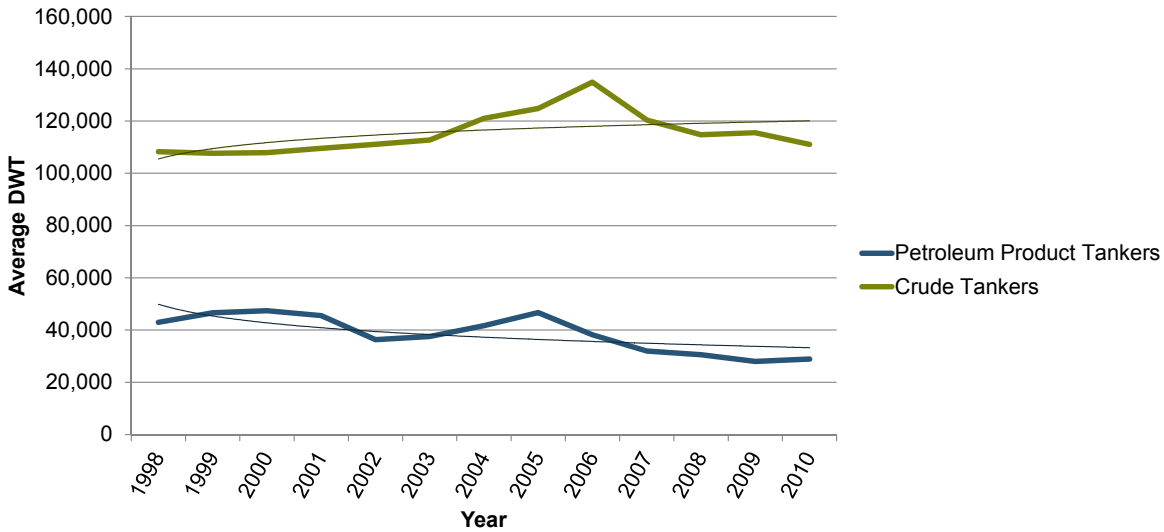

Figure 79 Regression curve fitting of product and crude tanker average DWT
Source: NEI, 2013

Table 79 Tanker traffic breakdown by subtype

	2010	2019
Product	56%	58%
Crude	44%	42%

Finally, Environmental Research Consulting (ERC) provided equations for estimating tanker bunker capacity (Equation 3-18) [47] and tanker cargo capacity (Equation 3-19) [48] in gallons, based on DWT (Appendix E).

$$Bunker\ Capacity(Tanker) = 5.086 \times DWT + 106{,}924 \quad \text{(gallons)} \qquad 3\text{-}18$$

$$R^2 = 0.958$$

$$Cargo\ Capacity(Tanker) = 285.4 \times DWT \quad \text{(gallons)} \qquad 3\text{-}19$$

To sample a tanker capacity for a given year, a random number was generated to determine the tanker subtype (product or crude), with probabilities of returning a given subtype in 2019 shown in Table 79. Another random number was generated to randomly select a deadweight tonnage of that tanker subtype from the database of tankers in the system in 2010. The DWT was then extrapolated to 2019 by multiplying the sampled DWT by the ratio of average 2010 DWT to average 2019 DWT using Equation 3-16 or 3-17, depending on the tanker subtype. Finally, the bunker and cargo capacities were derived from Equations 3-18 and 3-19.

Cargo Ships

NEI provided deadweight tonnage (DWT) for all 1,689 cargo ships that transited through the system in 2010. Cargo ships were split into two subcategories, container and general cargo, due to significant differences in size and transit frequency. Figure 80 shows the DWT distributions for cargo ship subtypes in the system in 2010.

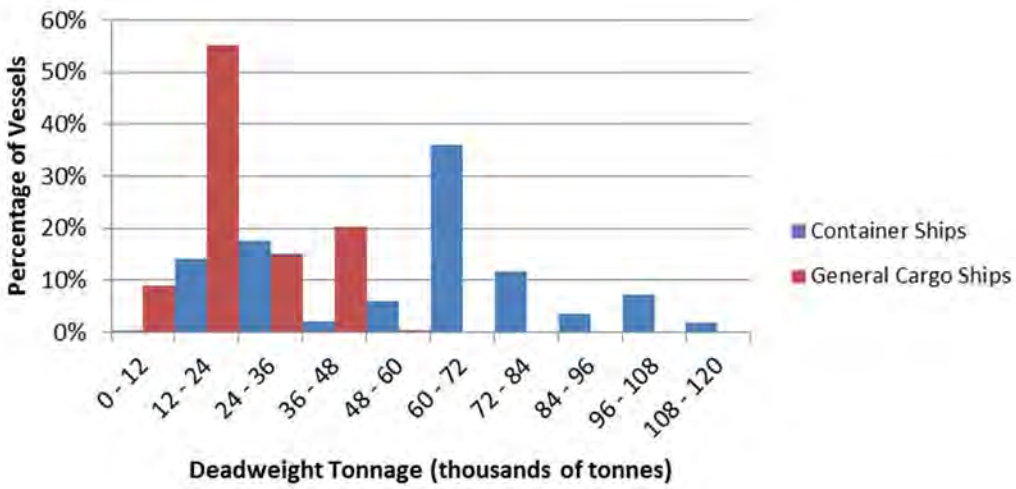

Figure 80 Cargo ship DWT distribution, 2010 (Appendix A)

As discussed in Section 3.2.2.2, tankers with a cargo-carrying capacity greater than 125,000 DWT are permitted to transit the study area, but may only carry 125,000 tons of cargo while in the study area. When the contaminant outflow model samples a tanker exceeding 125,000 DWT, the model then adjusts its capacity to 125,000 DWT.

[47] Based on adjustment for 70% bunker capacity, as noted in Appendix E.
[48] Based on adjustment for 98% cargo oil capacity and capped at 35,675-million gallons, as noted in Appendix E.

NEI provided regression equations for the average DWT of container ships (Equation 3-20) and general cargo ships (Equation 3-21). Figure 81 illustrates the regression curve fit of average DWT as a function of year. NEI also provided the forecast numbers of container and general cargo ships in the system, which were then converted to percentages (Table 80).

$$Average\ DWT(Container) = 6{,}534.9 \times \ln(Year - 1998) + 39{,}156 \qquad 3\text{-}20$$

$$R^2 = 0.893$$

$$Average\ DWT(General\ Cargo) = 740.35 \times \ln(Year - 1998) + 21{,}503 \qquad 3\text{-}21$$

$$R^2 = 0.199$$

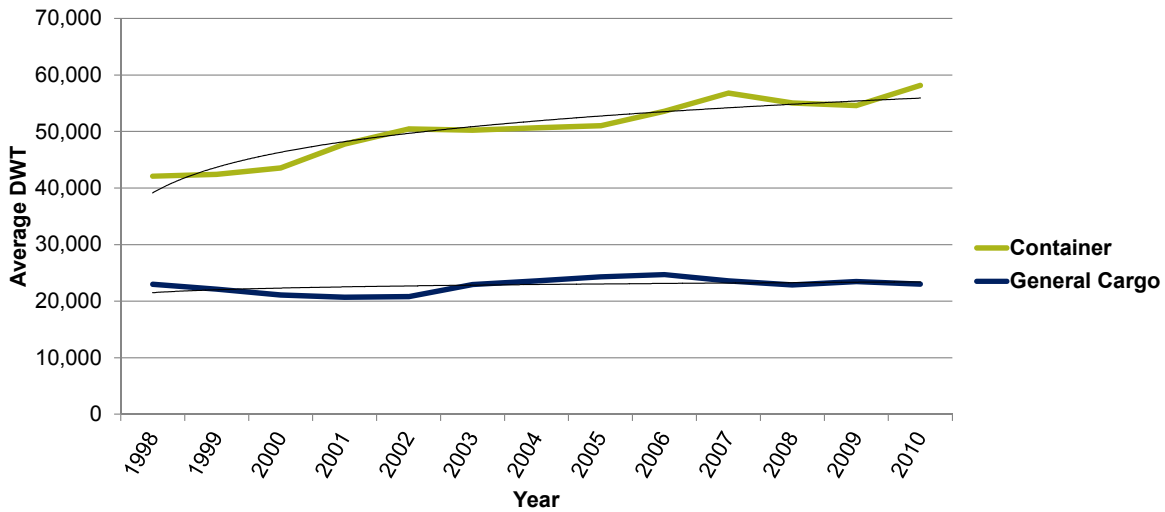

Figure 81 Regression curve fitting of container ship and general cargo vessel average DWT (Appendix A)

Table 80 Cargo ship traffic breakdown by subtype

	2010	2019
Container	87%	84%
General Cargo	13%	16%

Finally, ERC provided a regression equation for estimating cargo ship bunker capacity in gallons, based on DWT, Equation 3-22[49] (Appendix E).

$$Bunker\ Capacity(Cargo\ Ship) = 27.545 \times DWT - 64{,}922 \text{ (gallons)} \qquad 3\text{-}22$$

$$R^2 = 0.930$$

To sample a cargo ship bunker capacity for a given year, a random number was generated to determine the ship subtype, container or general cargo, with probabilities of returning a given subtype in 2019 as shown in Table 80. Another random number was generated to randomly select a DWT of that cargo ship subtype from the database of cargo ships in the system in 2010. The DWT was then extrapolated to 2019 by multiplying the sampled DWT by the ratio of average 2010 deadweight to average 2019 DWT, using Equation 3-20 or

[49] Based on adjustment for 70% capacity, as noted in Appendix E.

3-21, depending on the cargo ship subtype. Finally, the bunker capacity was derived from Equation 3-22.

United States Bulk Carriers

NEI provided deadweight tonnage (DWT) of all 739 bulk carriers (bulkers) that transited through and made port calls in the system in 2010. United States bulk carriers (US bulkers) were split into two sub-categories, grain and non-grain, due to significant differences in size and transit frequency. Grain US bulk carriers are classified herein as those that carry grain products, including wheat, corn, and barley. Non-grain US bulk carriers are those that carry all other products, including coal, potash, stone, and sand. Figure 82 shows the DWT distributions for US bulker subtypes in the system in 2010.

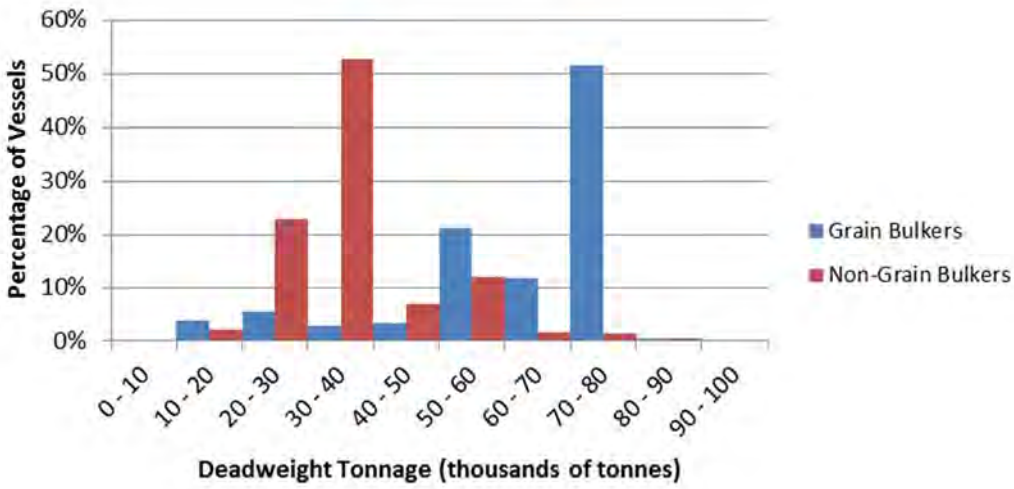

Figure 82 US bulk carrier DWT distribution, 2010 (Appendix A)

NEI provided regression equations for the average DWT of US grain bulkers (Equation 3-23) and non-grain bulkers (Equation 3-24). Figure 83 illustrates the regression curve fit of average DWT as a function of year. NEI also provided the forecast numbers of grain and non-grain US bulkers in the system, which were converted to percentages (Table 81).

$$Average\ DWT(Grain) = -541.4 \times \ln(Year - 1998) + 63{,}087 \qquad 3\text{-}23$$

$R^2 = 0.021$

$$Average\ DWT(Non\ Grain) = 1{,}597.8 \times \ln(Year - 1998) + 32{,}246 \qquad 3\text{-}24$$

$R^2 = 0.165$

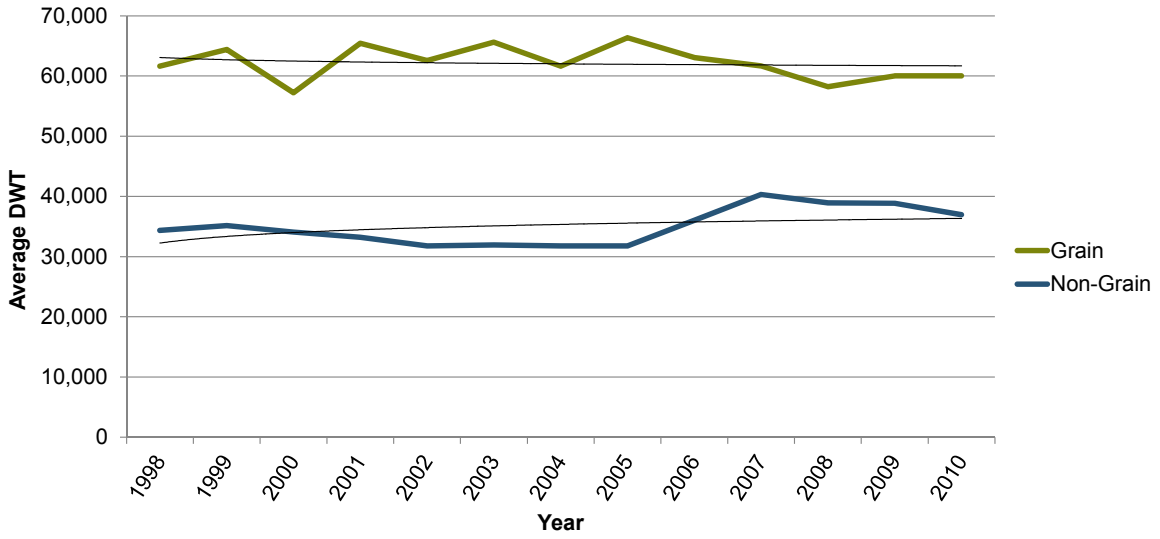

Figure 83 Regression curve fitting of grain and non-grain US bulker average DWT
Source: NEI, 2013

Table 81 US Bulker traffic breakdown by subtype

	2010	2019
Grain	43%	36%
Non-Grain	57%	64%

A regression equation for estimating US bulk carrier bunker capacity based on DWT was formulated using information from various sources of 21 bulkers of all sizes, including Capesize and Panamax vessels, as shown in Figure 84. 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 is because very few bulkers are built in this size range, for economic reasons. The least-squared regression line shown in Figure 84 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 E, so an adjustment factor of 70% was applied to the equation describing the least-squared regression line. The adjusted regression equation used in the model is shown as Equation 3-25.

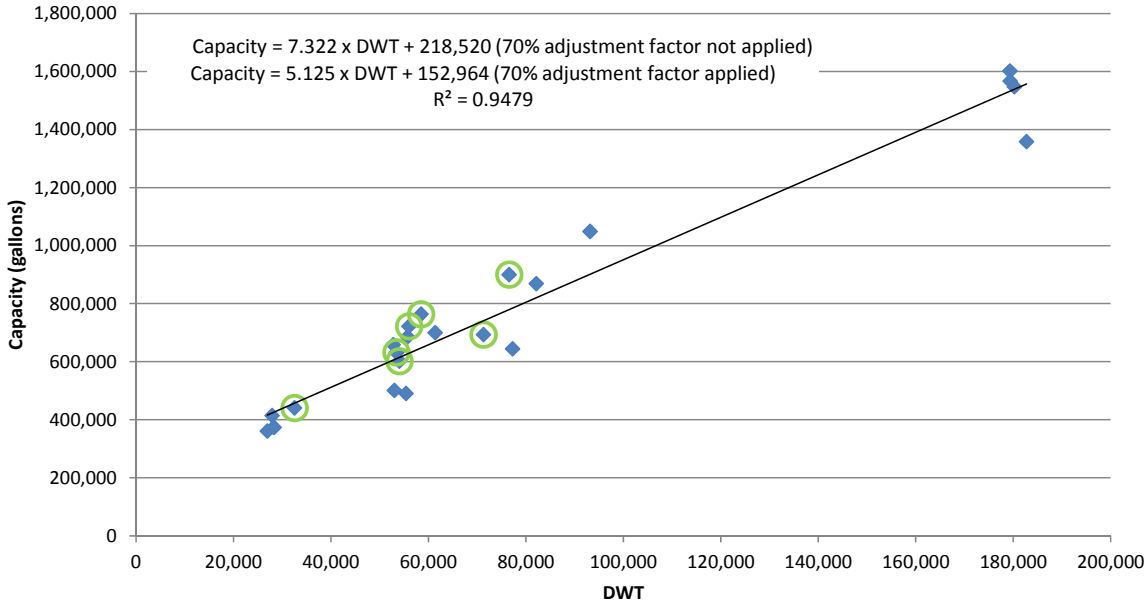

Figure 84 Bulker bunker capacity versus DWT

$$Bunker\ Capacity(Bulker) = 5.125 \times DWT + 152{,}964 \quad \text{(gallons)} \qquad 3\text{-}25$$

$R^2 = 0.948$

Finally, ERC provided an equation for estimating bulker cargo capacity in cubic feet, Equation 3-26, based on DWT (Appendix E).

$$Cargo\ Capacity(Bulker) = 40.047 \times DWT \quad (\text{ft}^3) \qquad 3\text{-}26$$

To sample a US bulker bunker or cargo capacity for 2019, a random number was generated to determine the US bulker subtype, grain or non-grain, with probabilities of returning a given subtype in 2019 shown in Table 81. Another random number was generated to randomly select a DWT of that US bulker subtype from the database of US bulkers in the system in 2010. The DWT was then extrapolated to 2019 by multiplying the sampled DWT by the ratio of average 2010 deadweight to the average 2019 DWT, using Equation 3-23 or 3-24, depending on the US bulker subtype. Finally, the bunker and cargo capacities were derived from Equations 3-25 and 3-26.

Canadian Bulk Carriers

In addition to US bulk carriers, there are Canadian bulk carriers, defined as those bulkers that transit through the system *but do not make any port calls*. Canadian bulkers were defined separately because they were not accounted for in the MX data used to define US bulkers. Instead, NEI used NRT data to provide a deadweight distribution of Canadian bulkers transiting through the study area in 2010, as summarized in Figure 85.

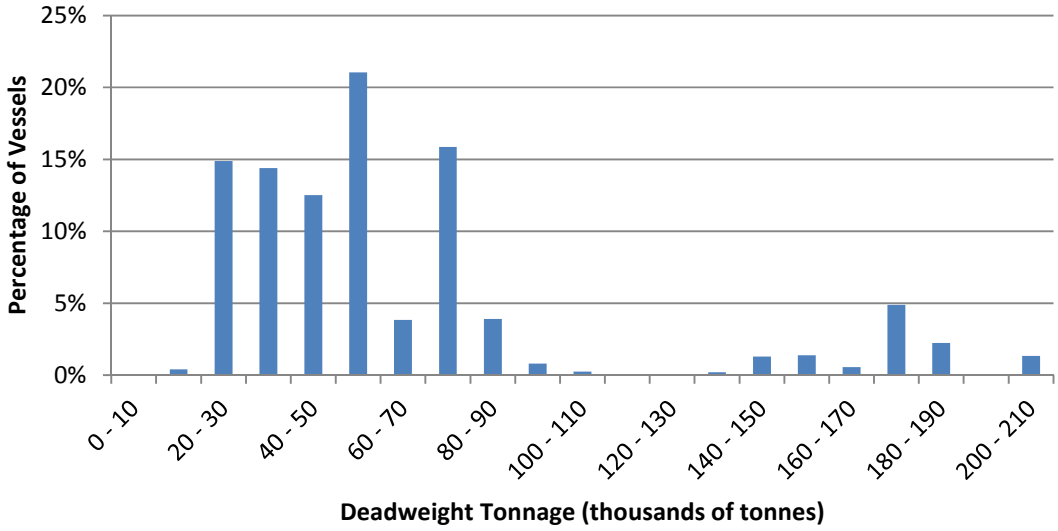

Figure 85 Canadian bulk carrier DWT distribution, 2010 (Appendix A)

To sample a Canadian bulker bunker or cargo capacity for 2019, a random number was generated to determine to select a DWT of that Canadian bulker from the database of Canadian bulkers in the system in 2010. The DWT was then extrapolated to 2019 by multiplying the sampled Canadian bulker DWT by the ratio of the average 2010 US bulker deadweight to the average 2019 US bulker DWT. It was assumed that the trend in Canadian bulker DWT will follow the trend in US bulker DWT, so the average of the forecast US bulker grain and non-grain subtypes was used to for this extrapolation. Finally, the bunker and cargo capacities were derived from Equations 3-25 and 3-26.

GPT-Calling Bulk Carriers

Data from Reference 114 were used to determine the DWT range of GPT-calling bulk carriers (GPT bulkers) in 2019. Reference 114 indicates that the proposed GPT facility is designed to accommodate bulkers up to 250,000 DWT, and also provides size ranges for typical modern day Panamax and Capesize bulkers. These ranges were used in the outflow contaminant model and are summarized in Table 82.

Table 82 GPT bulker traffic breakdown by subtype (Appendix A)

	Panamax	Capesize
Size Range (DWT)	65,000 – 80,000	160,000 – 180,000
2019 Calls (% of total)	318 (65%)	169 (35%)

To sample a GPT bulker bunker or cargo capacity, a random number was generated to determine the GPT bulker subtype (Panamax or Capesize), with probabilities of returning a given subtype equal to the percentage of calls shown in Table 82. Another random number was generated to randomly determine a DWT of that GPT bulker subtype within the size range given in Table 82 for that GPT bulker subtype. A uniform distribution was used for sampling the DWT of each GPT bulker subtype, to match the size ranges that were provided in Reference 114. A uniform distribution means that every value within the DWT range has an equal probability of being randomly selected. Finally, the bunker and cargo capacities were derived from Equations 3-25 and 3-26.

Tank Barges

A comprehensive study of 26 tank barges operating in the study area in 2012 was conducted, and a database of characteristics of those vessels was compiled. Total tank barge volume (length × beam × depth) was plotted against capacity for 18 tank barges with available capacity data. A least-squared regression line was fit to the data and the regression equation was used to estimate the capacities of the remaining eight tank barges based on their available volume data. An adjustment factor of 98% was applied to the tank barge capacities to match the convention in Appendix E. Based on expert judgment and interviews with tank barge owners, four tank barges were assumed to have a retirement date prior to 2019. The remaining 22 tank barges were therefore used to generate a capacity distribution for tank barges in the system in 2019, as summarized in Figure 86. This assumes that the capacity of any new tank barge within the study area by 2019 can also be characterized by the same distribution.

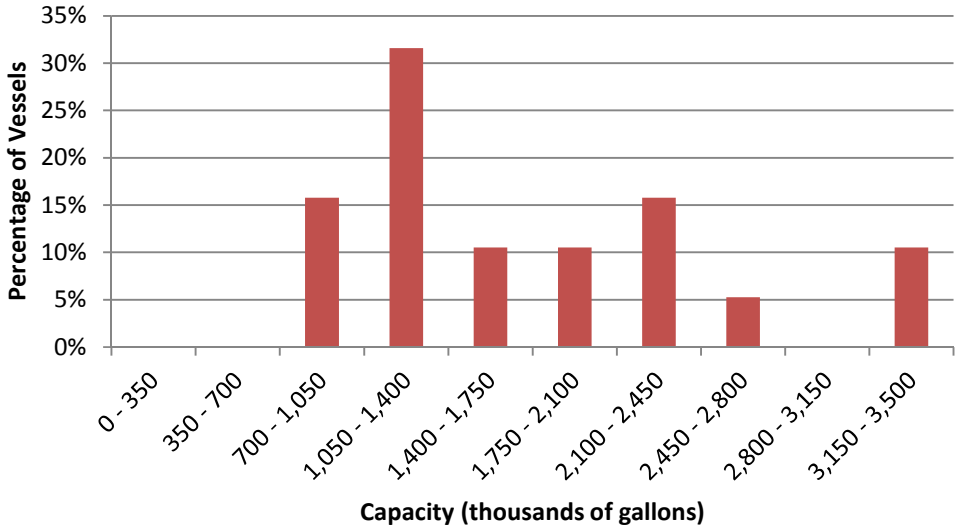

Figure 86 2019 tank barge cargo capacity distribution

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

GPT Tank Barges

Tank barges are defined as GPT tank barges during the time they are operating to refuel GPT-calling bulk carriers. It was assumed that the cargo capacities of GPT tank barges follow the same distribution of all tank barges in the system. The difference, as far as the contaminant outflow model is concerned, is that additional tank barges transit the system as a result of operations of the proposed GPT.

Tugboats

As part of their vessel traffic study (Section 3.2), 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 (24%) of the 2007-2010 tugboat traffic. The tug bunker capacity distribution of this representative database is summarized in Figure 87, which illustrates that the wide range of study area tug sizes, and not just a subset of tug sizes that operate at a higher frequency, were captured in the analysis.

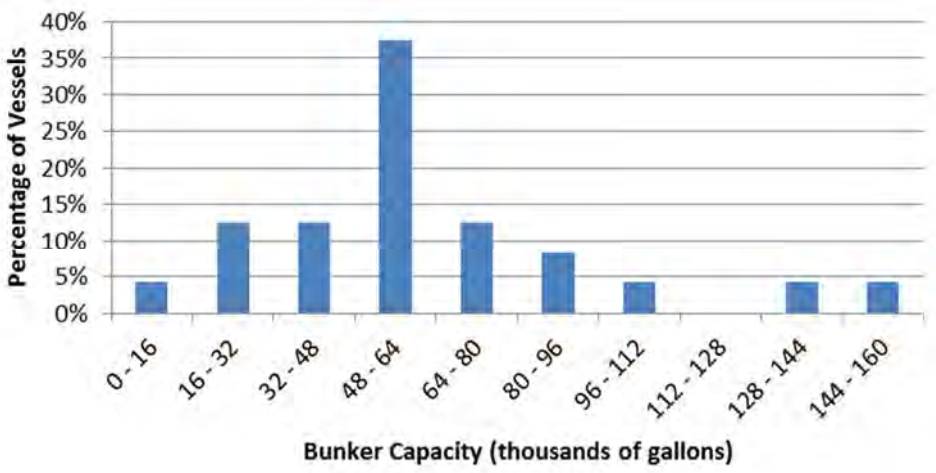

Figure 87 Tugboat bunker capacity distribution (Appendix A)

To obtain a tugboat bunker capacity, the capacity of one of the tugs in the representative database was randomly selected.

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 2019, including the proposed GPT. It was therefore assumed that there will be no change in the capacity distribution of tugs between 2010 and 2019.

GPT Tugboats

Tugboats are defined as GPT tugboats during the time they are assisting and docking GPT-calling vessels. It was assumed that the bunker capacities of GPT tugboats follow the same distribution of all tugboats in the system. The difference, as far as the contaminant outflow model is concerned, is that additional tugboats transit the system as a result of the proposed GPT operations.

Passenger and Fishing Vessels

Passenger and Fishing Vessels are composed of three vessel subtypes:

(1) Cruise Ships.

(2) Passenger Ferries.

(3) 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 was generated to determine the Passenger and Fishing Vessel subtype (cruise, ferry, or fishing vessel), with probabilities of returning a given subtype in 2019 shown in Table 83, as provided by NEI as part of their vessel traffic study (Section 3.2).

Table 83 Passenger and fishing vessel traffic breakdown by subtype (Section 3.2)

	2010	2019
Cruise Ship	6.1%	7.6%
Passenger Ferry	41.5%	40.8%
Fishing Vessel	52.5%	51.7%

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

Cruise Ships

NEI provided DWT for all 1,044 cruise ships that transited through the system in 2010. Figure 88 shows the DWT distribution for cruise ships in the system in 2010.

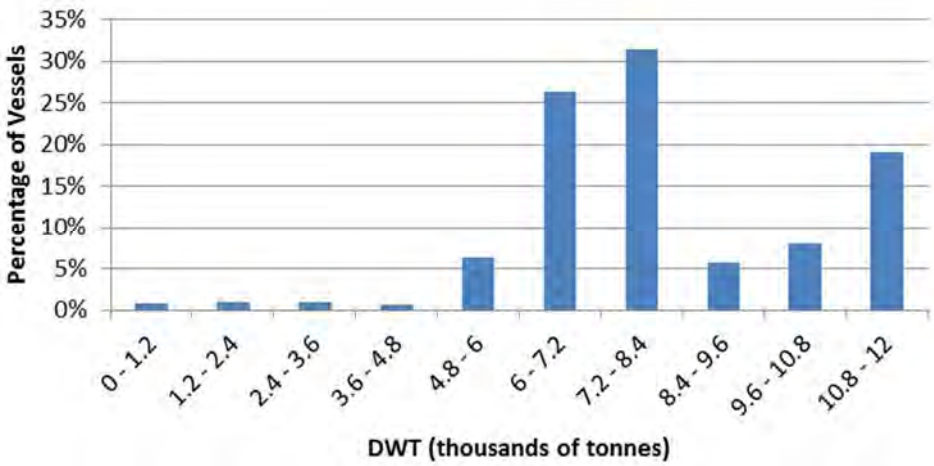

Figure 88 Cruise ship DWT distribution, 2010 (Appendix A)

The yearly periodical *Significant Ships* (Reference 119) 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 89. The data points circled in green are vessels that actually transited through the system in 2010. The regression equation is shown as Equation 3-27.

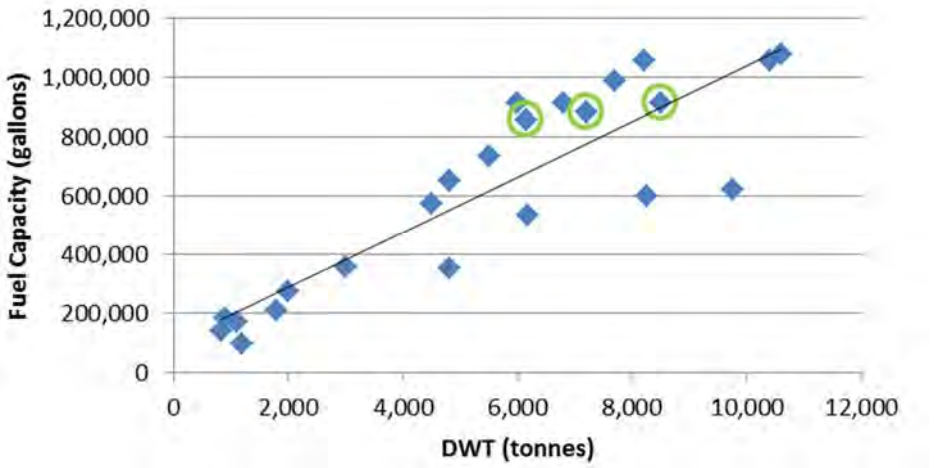

Figure 89 Cruise ship bunker capacity versus DWT (Appendix C and Appendix D)

$$Bunker\ Capacity\ (CruiseShip) = 93.976 \times DWT + 99{,}871 \quad \text{(gallons)} \qquad 3\text{-}27$$

$$R^2 = 0.782$$

To obtain a cruise ship bunker capacity, the DWT of one of the cruise ships in the NEI database of 2010 cruise ship transits was randomly selected. The bunker capacity was then derived using Equation 3-27. It was assumed that there will be negligible changes in the DWT distribution and relationship between DWT and bunker capacity of cruise ships between 2010 and 2019.

Passenger Ferries

To establish a bunker capacity distribution of passenger ferries, bunker capacities were obtained for a sampling of ferries that describe the majority of passenger ferry activity in the study area. Annual ferry schedules were used to estimate the amount of time spent underway in the study area for each ferry, which were converted to relative percentages of time spent in the study area. Ferries included in the analysis are shown in Table 84.

Table 84 Vessels composing passenger ferry fuel capacity distribution

Vessel Name	Owner/Operator	Route(s)	Fuel Capacity (gal)	Relative percent of time in study area
M/V Chelan	Washington State Ferries	Anacortes – Sydney, BC Anacortes – San Juan Islands	125,850	9.7%
M/V Salish	Washington State Ferries	Port Townsend – Coupeville	21,304	8.1%
M/V Kennewick	Washington State Ferries	Port Townsend – Coupeville	21,304	13.6%
M/V Kaleetan	Washington State Ferries	Anacortes – San Juan Islands	80,522	11.6%
Hyak	Washington State Ferries	Anacortes – San Juan Islands	80,522	11.1%
Evergreen State	Washington State Ferries	Anacortes – San Juan Islands	29,378	14.5%
Elwha	Washington State Ferries	Anacortes – San Juan Islands	64,840	11.1%
Victoria Clipper[50]	Clipper Vacations	Seattle – Victoria	3,000	2.7%
Victoria Clipper III	Clipper Vacations	Seattle – San Juan Islands	1,940	3.3%
Victoria Clipper IV	Clipper Vacations	Seattle – Victoria	3,100	2.7%
Guemes Island Ferry	Washington State Ferries	Anacortes – Guemes Island	6,000	5.3%

[50] Actual capacity is 5,800 gallons, but conversation with Clipper Navigation, Inc. administration revealed that tanks are never filled to more than 3,000 gallons.

Vessel Name	Owner/Operator	Route(s)	Fuel Capacity (gal)	Relative percent of time in study area
M/V Coho	Black Ball Ferry Line	Port Angeles – Victoria	94,574	5.5%
M/V Malaspina	Alaska Marine Highway System	Bellingham – Alaska	118,877	0.7%

The bunker capacities of the vessels in Table 84 and the relative percentage of time each spends in the system represent the bunker capacity distribution of passenger ferry vessels in the study area, as illustrated in Figure 90.

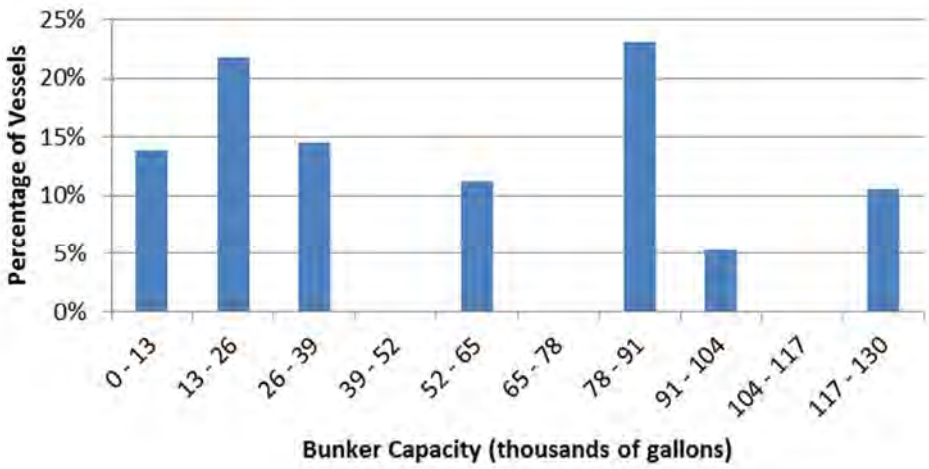

Figure 90 Passenger ferry bunker capacity distribution

To obtain a passenger ferry bunker capacity, the capacity of one of the ferries in the representative database was randomly selected, with a probability of selection equal to the relative percentage of time spent in the study area. It was assumed that there will be negligible change in the bunker capacity distribution of passenger ferries between 2010 and 2019.

Fishing Vessels Greater than 60 Feet

NEI provided a database of 6,710 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 91.

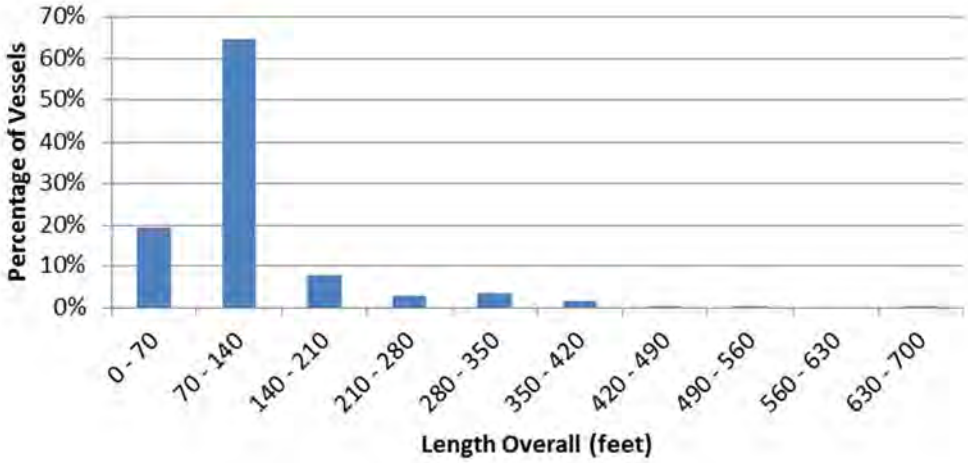

Figure 91 Fishing vessel greater than 60 feet length overall distribution (Appendix A)

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 92. 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 3-28.

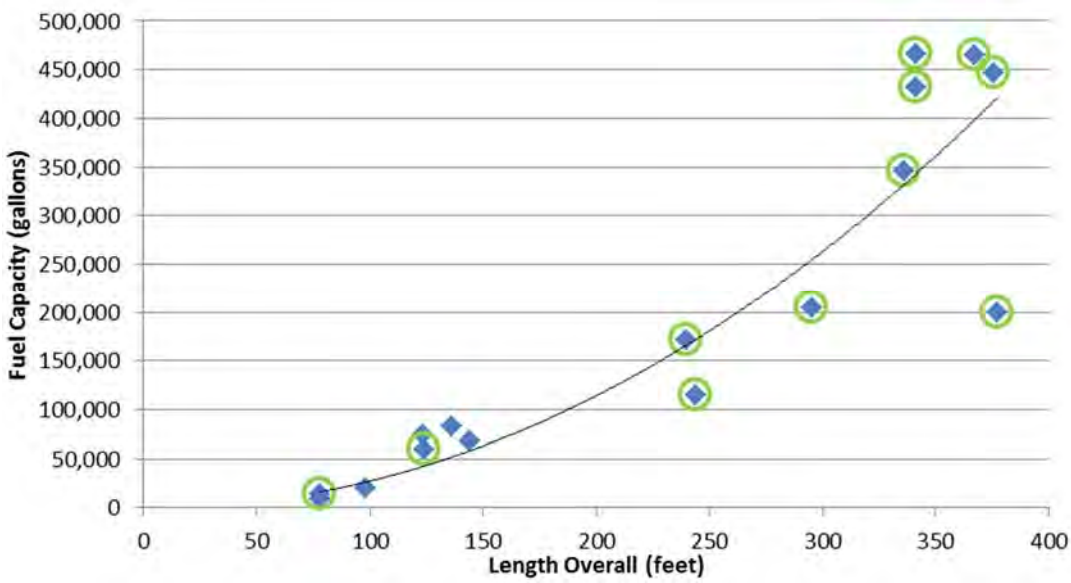

Figure 92 Fishing vessel bunker capacity versus LOA

$$Bunker\ \ Capacity\ \ (Fishing\ \ Vessel) = 2.109 \times LOA^{2.057} \quad \text{(gallons)} \qquad 3\text{-}28$$

$$R^2 = 0.918$$

To obtain a fishing vessel bunker capacity, the LOA of one of the fishing vessels in the NEI database of 2008-2010 fishing vessel transits was randomly selected. The bunker capacity was then derived using Equation 3-28. It was assumed that there will be negligible changes in the LOA distribution and relationship between LOA and bunker capacity of fishing vessels between 2010 and 2019.

3.4.3.4 Spill Probabilities ($SP_{v,i}$)

When an incident occurs, it is necessary to determine whether the incident results in a spill. The method for determining if an incident results in a spill is summarized in Figure 93. This method was accomplished by assigning a spill probability to each vessel type, incident type (v,i) combination, and sampling for a spill with a random number. ERC provided spill probabilities for the project vessel types based on vessel type, incident type, and an additional factor, which is number of hulls, either single or double. ERC also provided the probabilities of having a single or double hull for each vessel type for 2019. By randomly sampling the number of hulls of a vessel for 2019 based on hull type probability, the appropriate spill probability could then be randomly sampled for the given vessel type and incident type, thus returning the result of either a spill or no spill for a given (v,i) combination.

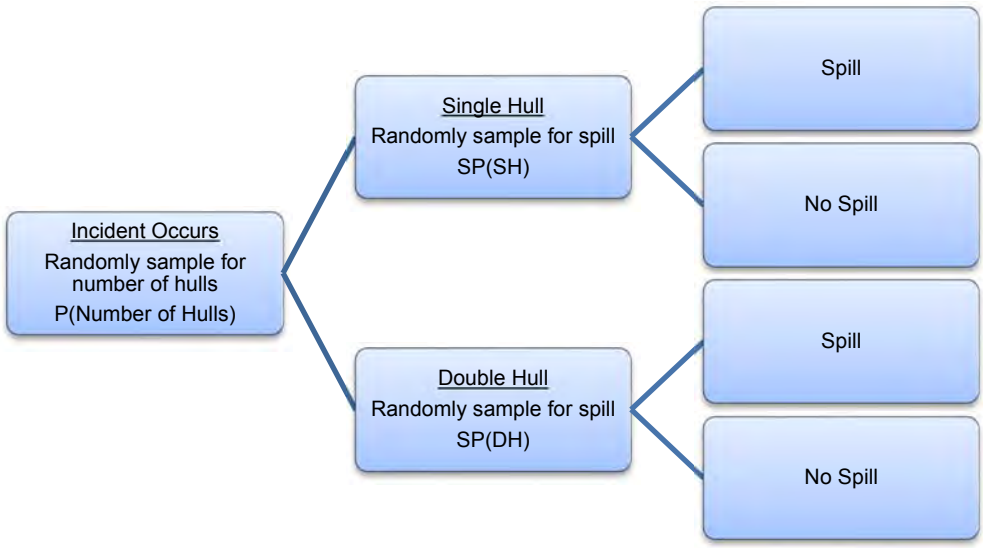

Figure 93 Flow diagram for determination of whether a spill occurs given an incident

Spill probability data for most (v,i) combinations are presented in Appendix E. Due to a lack of historical data, the development of spill probabilities for bulk carriers with dry bulk cargo was not possible. Therefore, it was conservatively assumed that, except for groundings, the dry bulk spill probabilities of bulk carriers equal the oil cargo spill probabilities of single-hull tankers, as given in Appendix E, since the majority of bulk carriers are single-sided. Since the majority of bulk carriers are double-bottomed, it was assumed that for groundings the spill probability equals that of double-hull tankers. These probabilities are shown in Table 85.

Table 85 Bulk carrier dry bulk cargo spill probabilities

Incident Type (v)	Spill Probability (SP)
Collision	0.68
Allision	0.68
Grounding	0.18
Other Non-Impact	0.40
Transfer Error	0.92

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

3.4.3.5 Outflow Percentage Probabilities ($OP_{v,i}$)

When a spill occurs, it is necessary to determine the quantity of oil or bulk outflow. When a spill occurred for a given vessel type, incident type (v,i) combination, a cumulative distribution function (CDF) was randomly sampled to return a percentage of outflow for the (v,i) combination. The capacity of the vessel type (v) was then randomly sampled using the appropriate method from Section 3.4.3.3. The spill volume ($SV_{v,i}$) for a given spill equals the product of outflow percentage and vessel capacity (Equation 3-15).

Based on historical spill records, ERC developed CDFs of bunker and cargo outflow as percentages of vessel bunker and cargo capacities for vessel type and incident type (v,i) combinations (Appendix E). The outflow percentage curves from Appendix E that were used in the contaminant outflow model are listed in Table 86.

Table 86 Outflow percentage curves from Appendix E used in contaminant outflow model

Vessel Type(s), (v)	Commodity	Incident Type(s), (i)	Appendix E Table No.
Bulker	Dry Bulk	Transfer Error	24
Bulker	Dry Bulk	Other Non-Impact	25
Double Hull Tanker	Cargo Oil	Impact Incidents	8
Double Hull Tank Barge	Cargo Oil	Impact Incidents	10
All Vessel Types	Bunker Oil	Impact Incidents	14

Additional CDFs were developed for prediction of oil or bulk outflow for (v,i) combinations not listed in Table 86, as described in the following subsections.

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 were provided by ERC in Appendix E, Tables 12 and 13, based on United States spill data. However, it was 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 and 2010 were used to construct transfer error cargo outflow CDFs for tankers and tank barges. The tail of each CDF was then extended to capture the maximum transfer error outflow derived by ERC in Appendix E, Tables 12 and 13. The maximum outflow in Appendix E 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 outflow for their respective CDFs. Probabilities of these maximum outflows are equal to the probabilities provided by ERC in Appendix E, Tables 12 and 13. The resultant CDFs of oil outflow volume for tanker and tank barge transfer error spills are presented in Figure 94 and Figure 95, respectively.

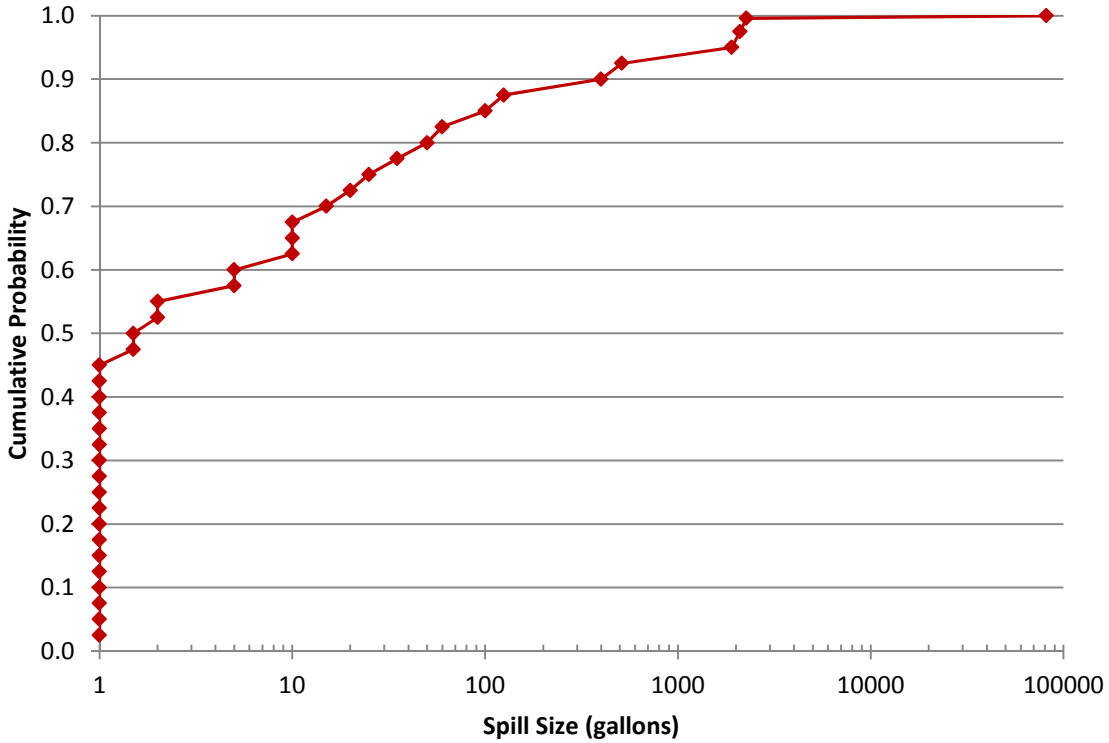

Figure 94 Cumulative distribution function of cargo oil outflow volume for tanker transfer error spills

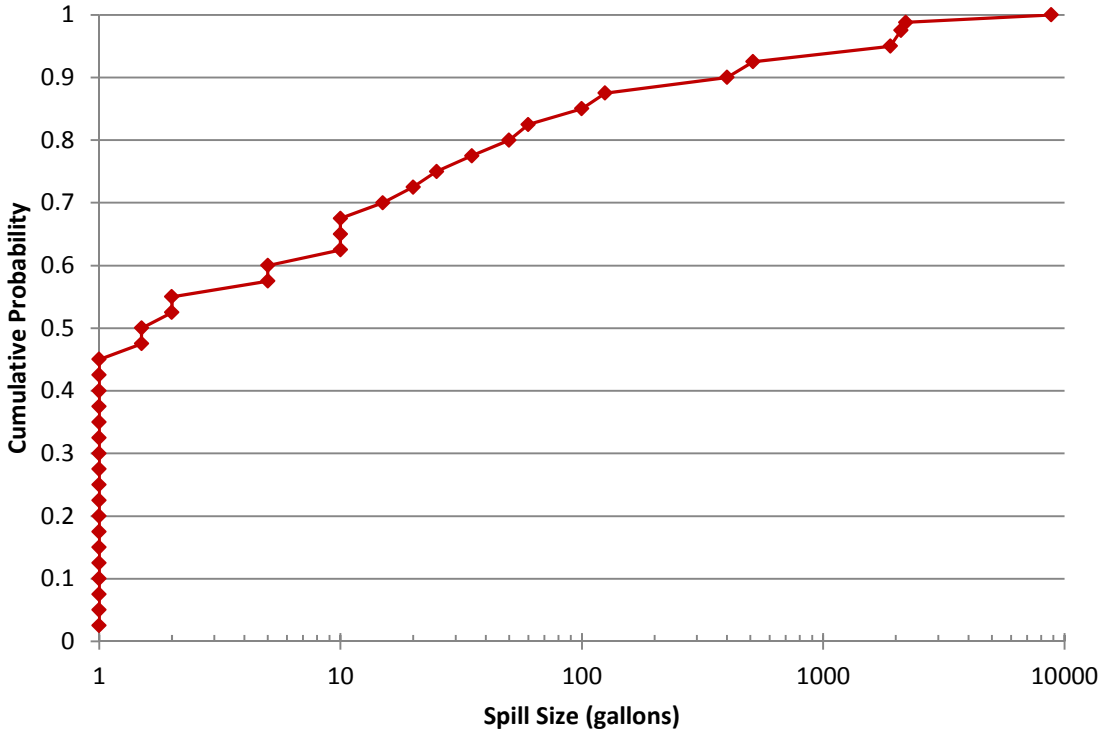

Figure 95 Cumulative distribution function of cargo oil outflow volume for tank barge transfer error spills

Oil Outflow Volume for Bunker Error Spills

Bunker oil outflow percentage cumulative distribution functions for bunker errors are provided by ERC in Appendix E, Tables 14 and 15, based on United States spill data. However, it was 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 were used to construct bunker error outflow CDFs for large VTS vessels (tankers, tank barges, bulkers, cargo ships, and cruise ships) and small VTS 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 was then extended to capture the maximum bunker error outflow derived in by ERC in Appendix E, Tables 14 and 15. The maximum theoretical outflows are presented as percentages of total capacity, so the average capacities of all large VTS vessels and all small VTS 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 E. The resultant CDFs of oil outflow volume for large VTS vessel and small VTS vessel bunker error spills are presented in Figure 96 and Figure 97.

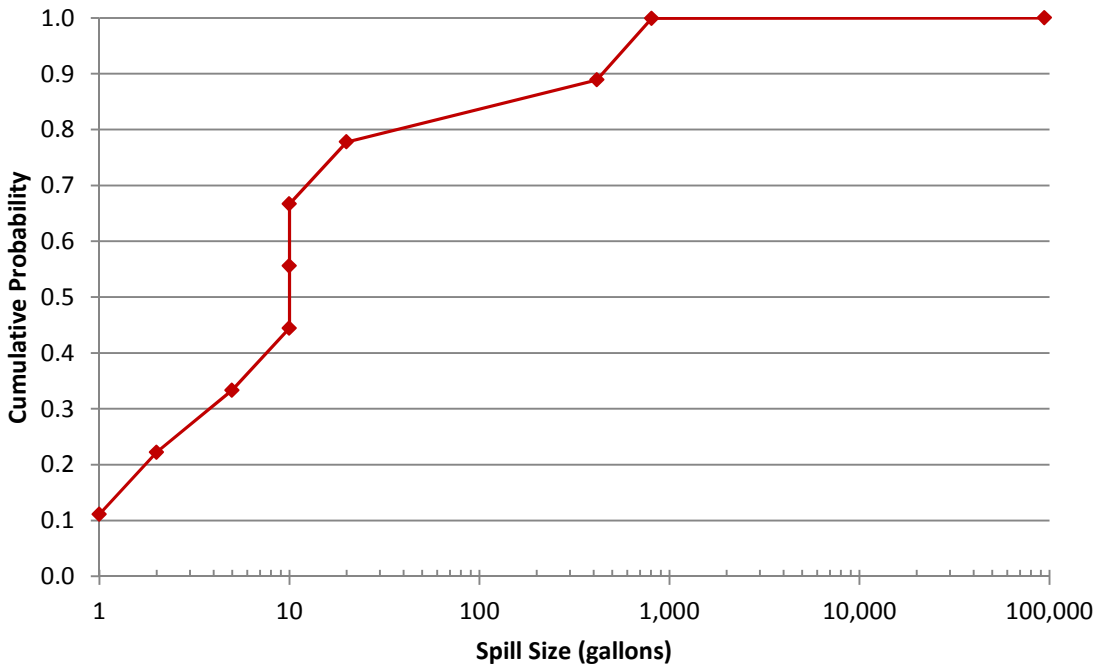

Figure 96 CDF of bunker outflow volume for tanker, tank barge, bulker, and cargo vessel bunker error spills (Appendix E)

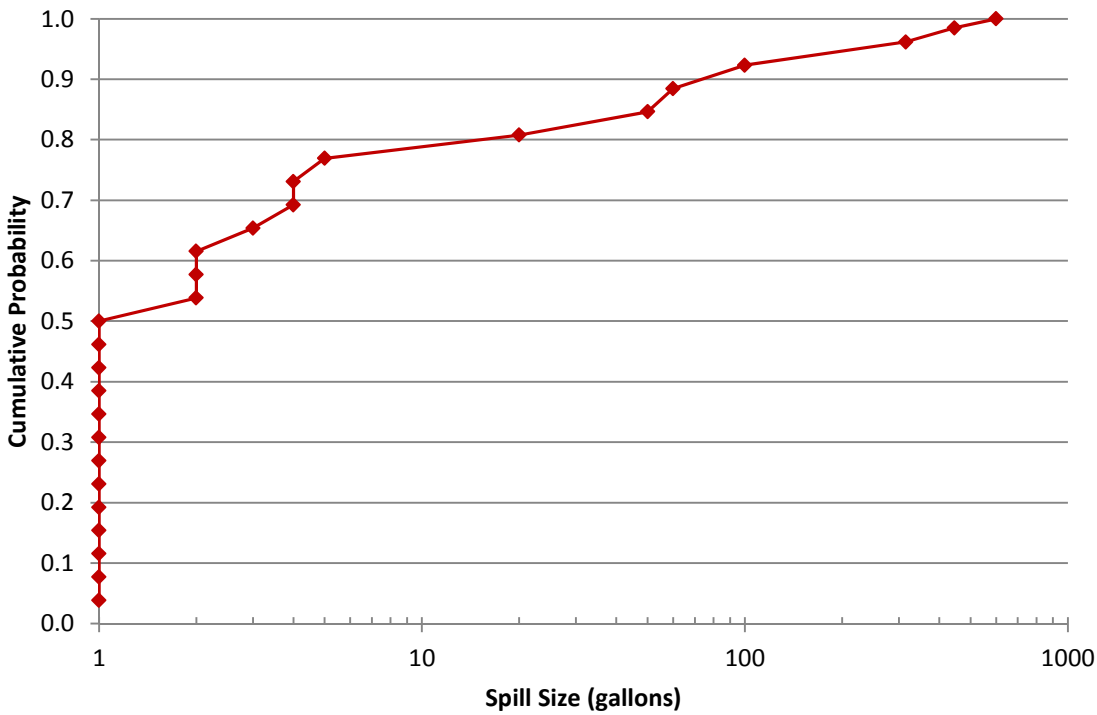

Figure 97 Cumulative distribution function of bunker outflow volume for fishing vessel, passenger ferry, and tugboat bunker error spills (Appendix E)

Bunker Outflow Percentage for All Vessel Other Non-Impact Spills

A bunker outflow percentage cumulative distribution function for all vessel types and the other non-impact spill category is provided by ERC in Appendix E, based on worldwide spill data. However, it was found that outflow percentages in this curve drastically exceed historical spill percentages in the study area. An alternative CDF curve was developed using historical incident data from the study area provided by ERC (Section 3.3). 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 was 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 was 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 98.

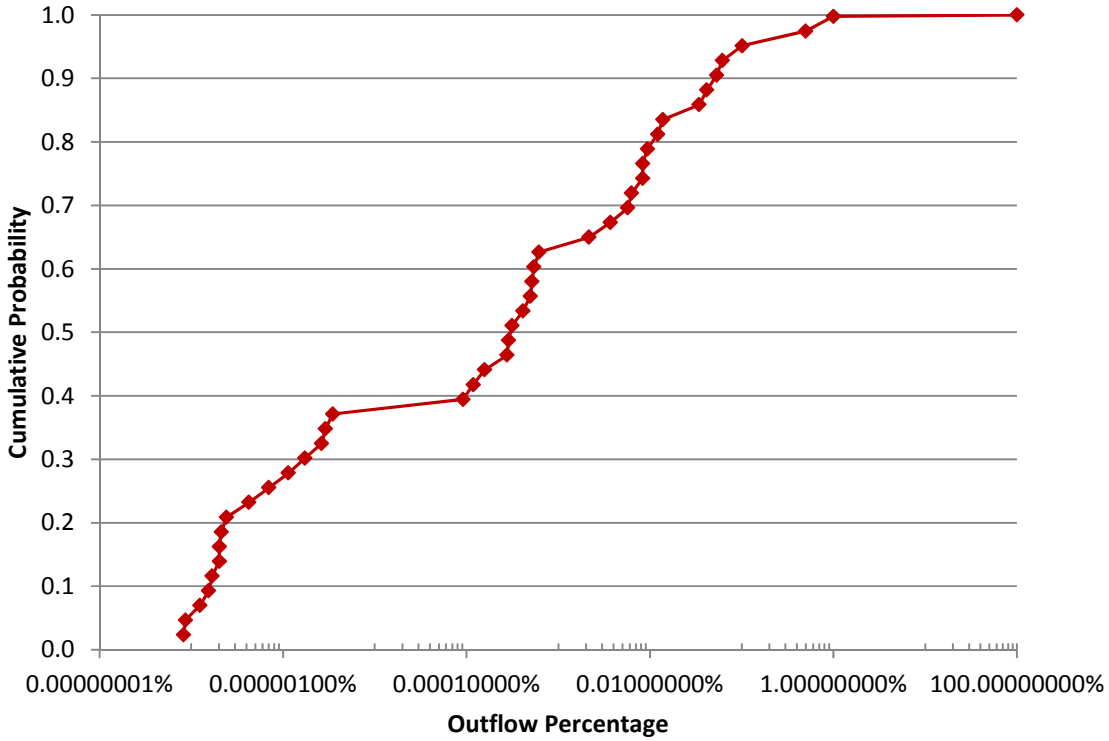

Figure 98 Cumulative distribution function of bunker outflow percentage for all vessel other non-impact spills (Appendix E)

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 E, Tables 9 and 11, 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 (Section 3.3). 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 show 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 E, Tables 9 and 11). 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 was 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 99 and Figure 100, respectively.

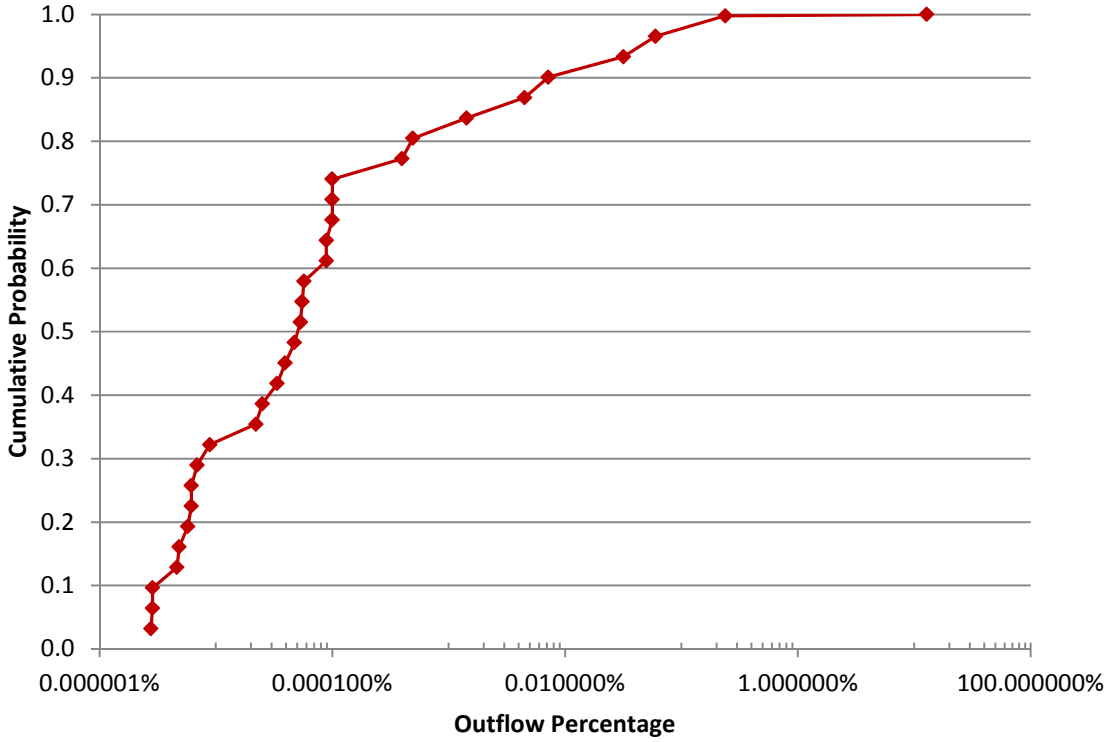

Figure 99 Cumulative distribution function of cargo oil outflow percentage for tanker other non-impact spills (Appendix E)

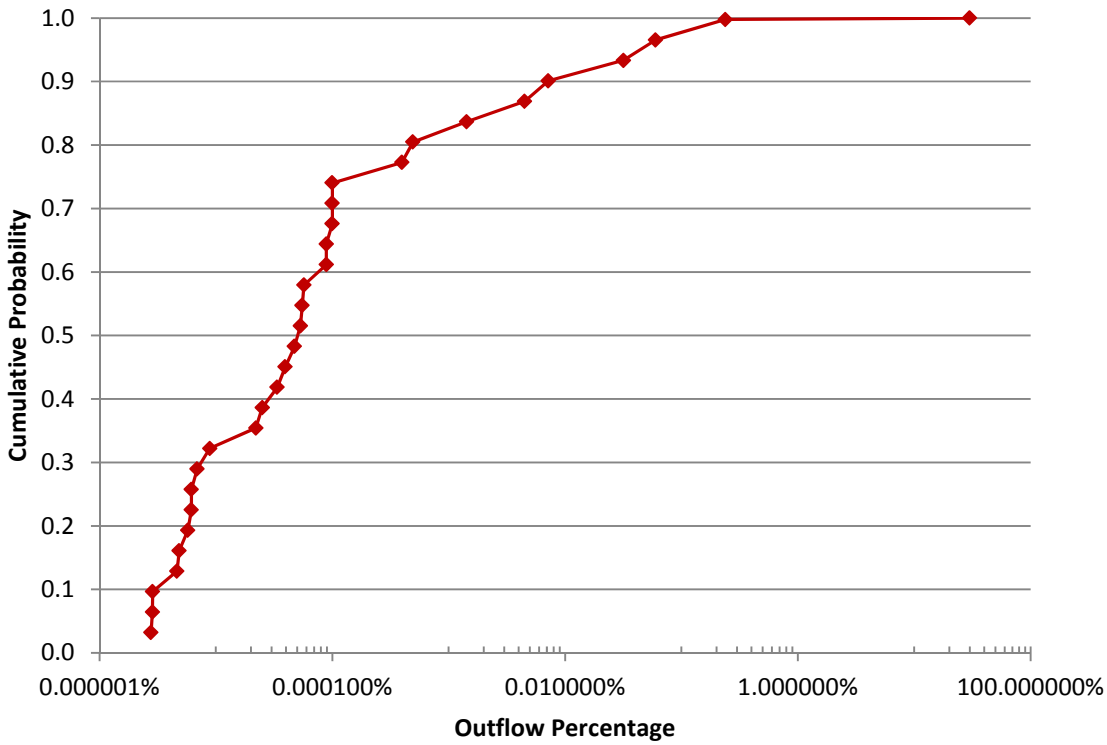

Figure 100 Cumulative distribution function of cargo oil outflow percentage for tank barge other non-impact spills (Appendix E)

Dry Bulk Outflow Percentage for Bulk Carriers due to Impact Incidents

Outflow due to impact incidents (collisions, allisions, and groundings) is assumed to be a possibility, but there were extremely limited historical data on dry bulk outflow due to impact incidents. Therefore, several assumptions were made. It was assumed that the maximum outflow is one quarter (¼) of one cargo hold. The average bulk carrier has five cargo holds, so the worst-case dry bulk outflow due to an impact incident was assumed to be $\frac{1}{4} \times \frac{1}{5} = \frac{1}{20} = 5\%$. The distribution was assumed to have a cumulative probability of zero at zero percent (0%) outflow, and a cumulative probability of one at maximum cargo outflow, so an elliptical distribution shape was assumed. The dry bulk outflow percentage curve for bulk carriers in collision spills is described by Equation 3-29 and shown in Figure 101.

$$P\left(OP_{v=3,i=2}\right) = \sqrt{1 - 400\left(OP - 0.05\right)^2} \qquad 3\text{-}29$$

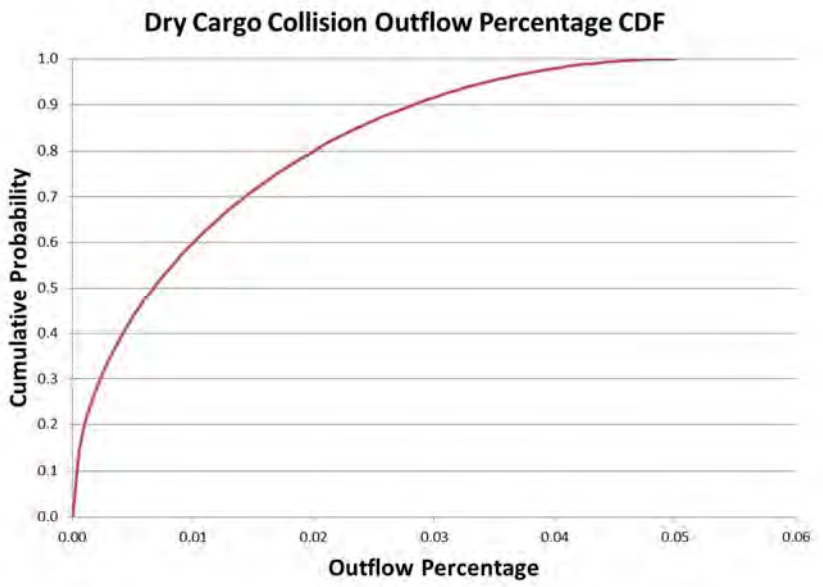

Figure 101 Cumulative distribution function of dry bulk outflow percentage for bulk carrier spills due to collision, allision, or grounding

3.4.4 Results

3.4.4.1 Representative Risk Statistics

This section presents the predictions of the contaminant outflow model. Prediction results are plotted as cumulative probability distributions. Statistics of the distributions are tabulated for four risk prediction parameters:

1. Predicted annual number of incidents.
2. Predicted annual number of spills.
3. Predicted annual oil outflow.
4. Predicted annual dry bulk 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 for the number of spills. With respect to volume of contaminant outflow (oil and dry bulk 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. Different statistics are used to represent different risk parameters in this VTARAS report.

The choice of using either the average prediction or a percentile of the prediction parameter is a result of the mathematical detail of the Monte Carlo simulation. As described in Section 3.4.2, the methodology for sampling contaminant 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 fraction of a spill. A Poisson sampling method predicts the integer number of incidents, including the possibility of zero incidents, in each of the 10,000 predictions 2019.

The average of 10,000 integers may not be an integer. A percentile value of a distribution of 10,000 integers (e.g., the value of the 50th percentile or 95th percentile), many of which are zeroes, may also 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 1 incident, 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 0.25 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 statistic to compare contaminant outflow is not the average of the 10,000 predictions, but rather percentiles; e.g., the median (50th percentile) or the 95th percentile. This is because percentile values are more robust than averages against extreme values in the distribution. Unlike predictions of the number of incidents, which because of the Poisson method resemble a normal distribution, 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 2019 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 contains a very large oil outflow and the other of which does 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 percentile statistic of the contaminant outflow distribution. When producing 10,000 predictions of what will happen in 2019, 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 statistic 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.

3.4.4.2 Statistical Accuracy, Uncertainty, and Comparisons

The reported distribution statistics should be interpreted as a measure of risk. The average values are not absolute statements of the average number of incidents or spills in 2019. Rather, the average values are the average of 10,000 attempts to predict the number of incidents and spills in 2019. 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 2019.

The statistics of the probability distributions are a measure of the accuracy of the predicted parameters. They are not a prediction of the statistics of the distribution of incidents, spills,

and volumes that will occur in 2019. If there are no uncertainties in the prediction parameters, 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. For example, if there are no uncertainties in any of the following:

- The forecast of vessel traffic movement,
- The volumes of oil they will be carrying,
- The forecast of incident rates,
- The rate at which a spill occurs as a result of an incident,
- 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 contaminant outflow that will occur in 2019. The prediction will be that there are a particular number of incidents, a particular number of spills, and a particular volume of oil and dry bulk 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 2019, with and without the proposed GPT, it is only appropriate to compare common statistical measures of the prediction sets. Comparison between the three 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 102, for instance, all three cases are shown. The predicted increase in total annual number of incidents in 2019 due to the addition of GPT traffic at any given probability level is the difference between the curves for Case A and Case B. The graph shows that the 95th percentile annual number of incidents under these conditions is predicted to increase from 38 incidents without the proposed GPT to 44 incidents with the proposed GPT. Similarly, the cumulative probability range for 28 incidents is 46% to 53% for Case A. This means that 7% (53% - 46%) of the model predictions, or approximately 700 of 10,000, predicted 28 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 representative risk statistics are given for the three cases in the CDF figure legends.

3.4.4.3 Most Likely Geographic Location Where Spills May Occur

Total Number of Incidents

Figure 102 shows the cumulative distribution function of total yearly incidents for the entire study area for each traffic volume case, summed across all vessel types, activity types, incident types, and subareas. Because the Poisson distribution was used to sample for the number of incidents in each scenario, the number of annual incidents is always returned as an integer value. Annual average number of incidents is a non-integer. The simulation results show that in 2019 an increase in the average number of incidents of 21% is predicted throughout the system with the addition of the proposed GPT (percentage difference between Case B average, 34.31 incidents, and Case A average, 28.31 incidents). The addition of cumulative traffic further increases the average number of incidents by another 4% (percentage difference between Case C average, 35.68 incidents, and Case B average, 34.31 incidents).

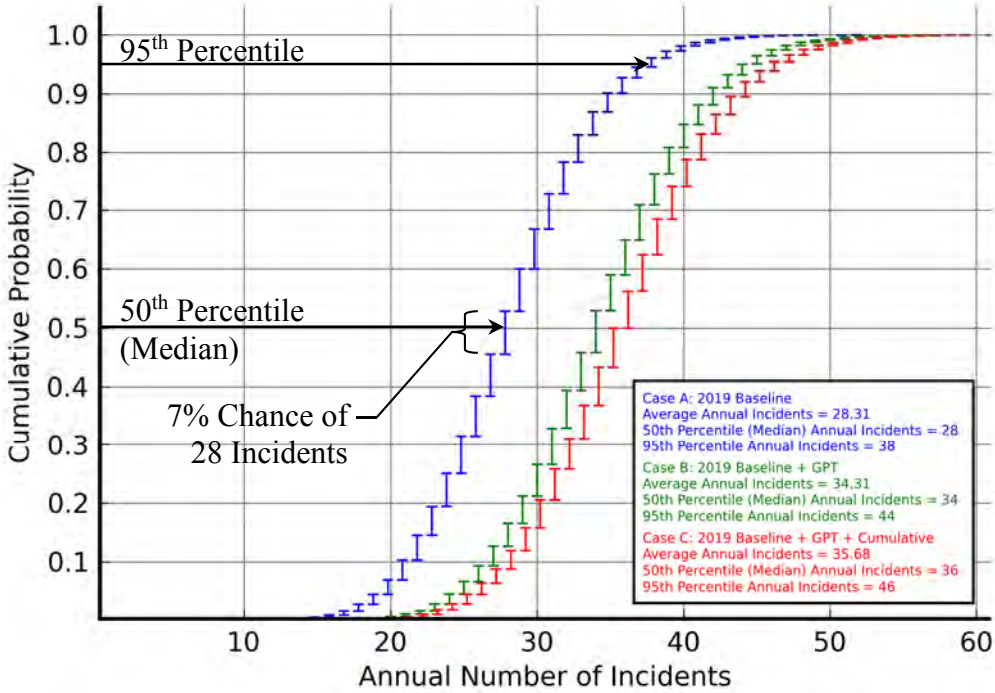

Figure 102 Cumulative distribution function of total annual number of incidents, for all vessel types, activity type, incident types, and subareas. Annual number of incidents for Cases A and C offset by ±0.2 for illustrational purposes only

Number of Incidents by Subarea

Table 87 shows the average annual number of incidents predicted by the contaminant outflow model for each subarea in 2019, summed across all vessel types, activity types, and incident types. Strait of Juan de Fuca East is predicted to have the highest average number of incidents. It also has the most traffic, Section 3.2.4. From Case B to Case C, Haro Strait and Boundary Pass is predicted to see the largest percentage increase. This is attributed to additional traffic calling at the Kinder Morgan terminal at Port Metro Vancouver.

Table 87 Average annual number of incidents by subarea, for all vessel, activity, and incident types[51]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	3.64	3.74	4.16	3%	14%
Strait of Juan de Fuca East	6.40	9.30	9.67	45%	51%
Haro Strait and Boundary Pass	0.78	0.78	0.87	0%	12%
Guemes Channel and Fidalgo Bay	5.95	6.20	6.20	4%	4%
Saddlebag	4.17	4.63	4.63	11%	11%
Rosario Strait	0.66	0.68	0.67	3%	2%
Cherry Point	6.69	8.98	9.48	34%	42%
All Subareas	28.31	34.31	35.68	21%	26%

Table 88 and Table 89 show the median and 95th percentile[52] annual number of incidents predicted by the contaminant outflow model for each subarea in 2019, summed across all vessel types, activity types, and incident types.

Table 88 Median annual number of incidents by subarea, for all vessel, activity, and incident types

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	3	4	4
Strait of Juan de Fuca East	6	9	10
Haro Strait and Boundary Pass	1	1	1
Guemes Channel and Fidalgo Bay	6	6	6
Saddlebag	4	4	4
Rosario Strait	0	0	0
Cherry Point	7	9	9
All Subareas	28	34	36

[51] Number of incidents and percent change are rounded to two decimal places. Percent change is calculated using four decimal places. The number of decimal places presented is not indicative of the accuracy of the model.

[52] Note that the sums of the median and 95th percentile annual number of incidents of each subarea do not equal the median and 95th percentile annual number of incidents across the entire study area. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each subarea will all occur in the same year, so the 95th percentile annual number of incidents across all subareas will intuitively be less than the sum of the 95th percentile annual number of incidents of each subarea.

Table 89 95th percentile annual number of incidents by subarea, for all vessel, activity, and incident types

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	7	7	8
Strait of Juan de Fuca East	11	15	15
Haro Strait and Boundary Pass	2	2	3
Guemes Channel and Fidalgo Bay	10	11	11
Saddlebag	8	8	9
Rosario Strait	2	2	2
Cherry Point	11	14	15
All Subareas	38	44	46

Figure 103 through Figure 109 show the cumulative distribution functions of predicted number incidents per subarea, summed across all vessel types, activity types, and incident types. Because the Poisson distribution was used to sample for the number of incidents in each scenario, the number of annual incidents is always calculated as an integer value.

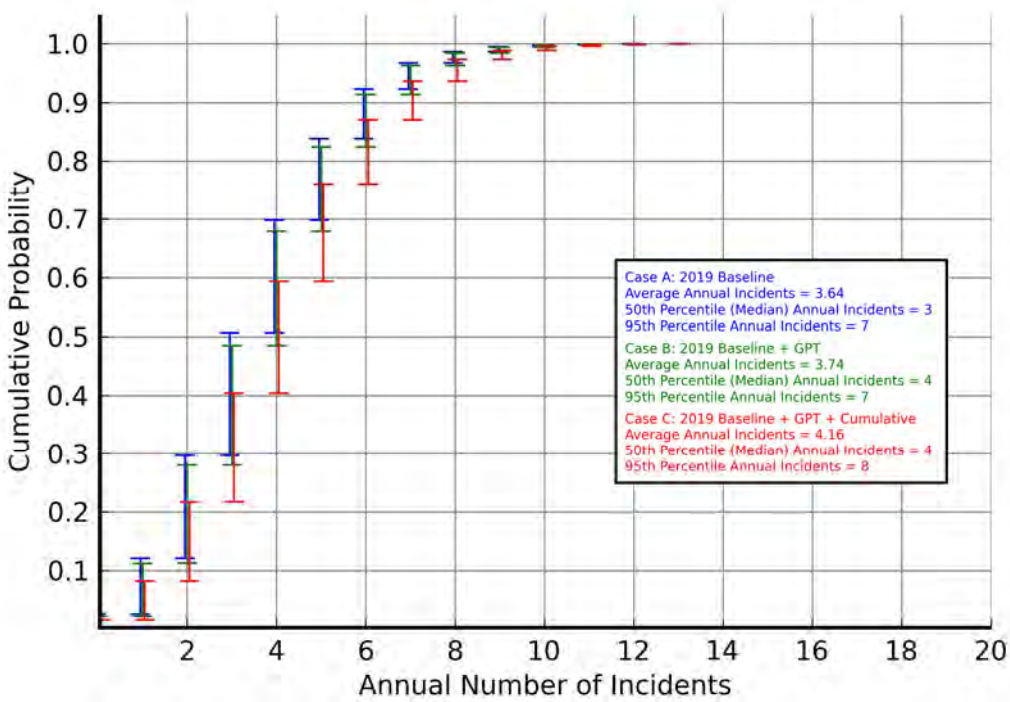

Figure 103 Cumulative distribution function of annual number of incidents in Strait of Juan de Fuca West, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

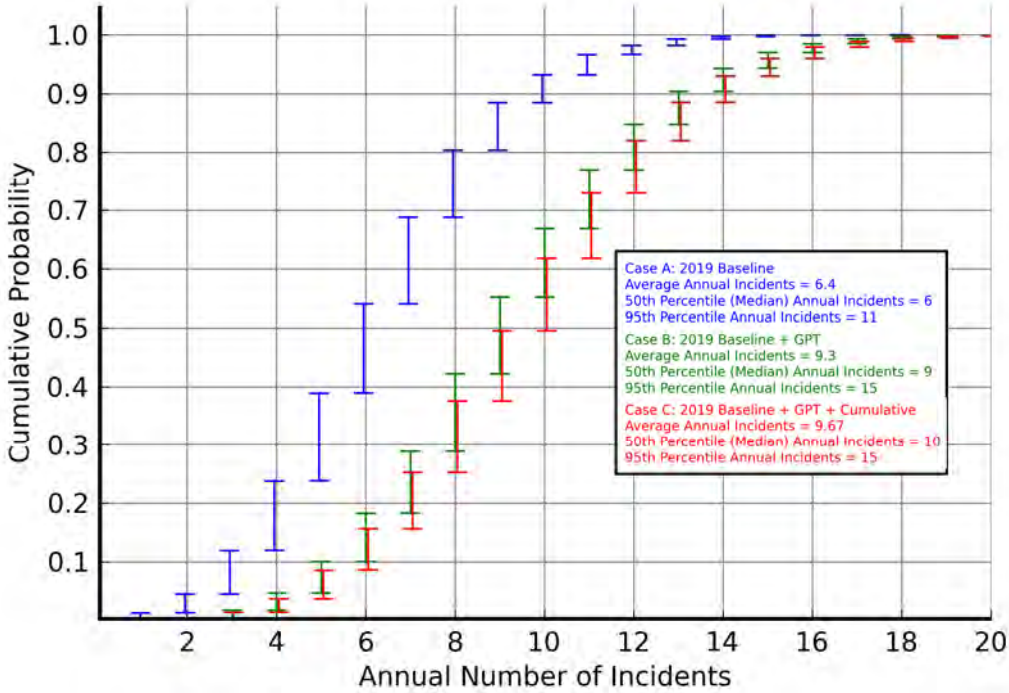

Figure 104 Cumulative distribution function of annual number of incidents in Strait of Juan de Fuca East, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

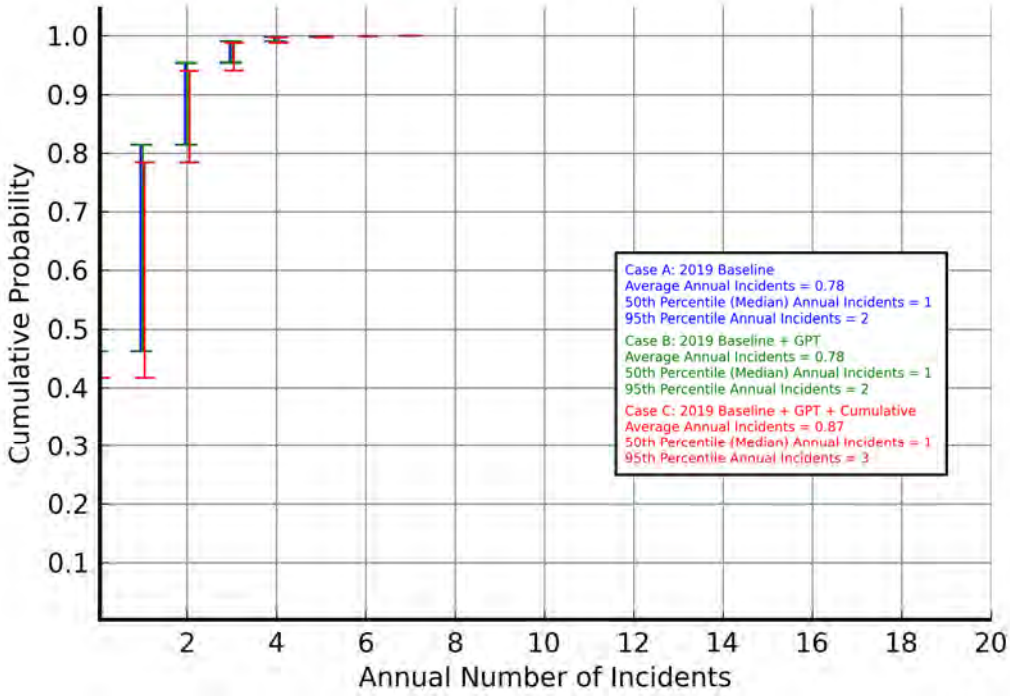

Figure 105 Cumulative distribution function of annual number of incidents in Haro Strait and Boundary Pass, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

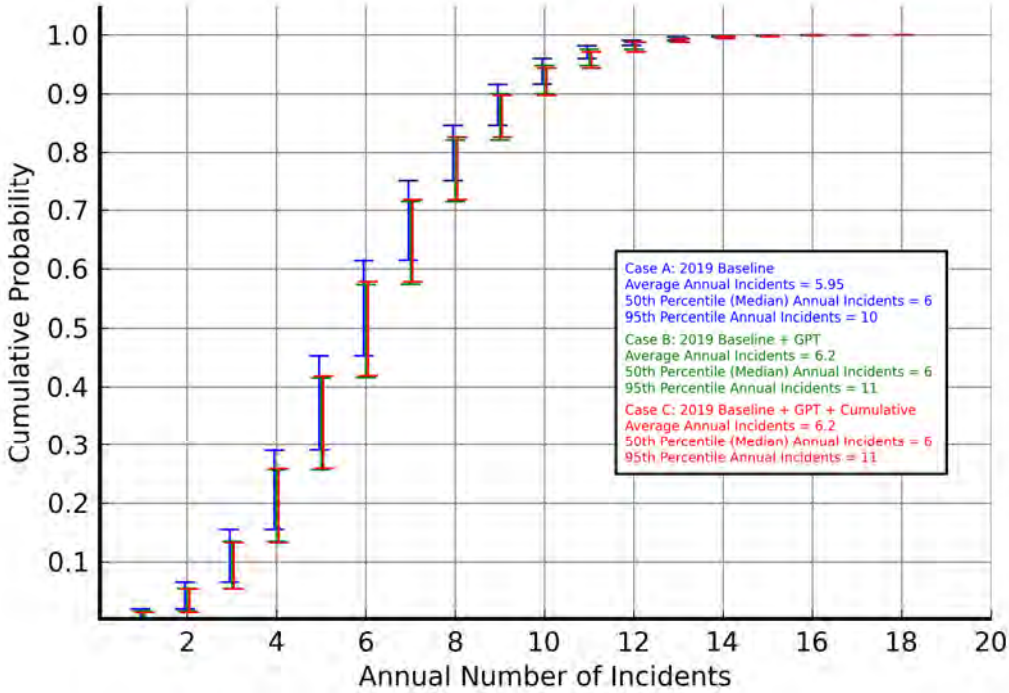

Figure 106 Cumulative distribution function of annual number of incidents in Guemes Channel and Fidalgo Bay, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

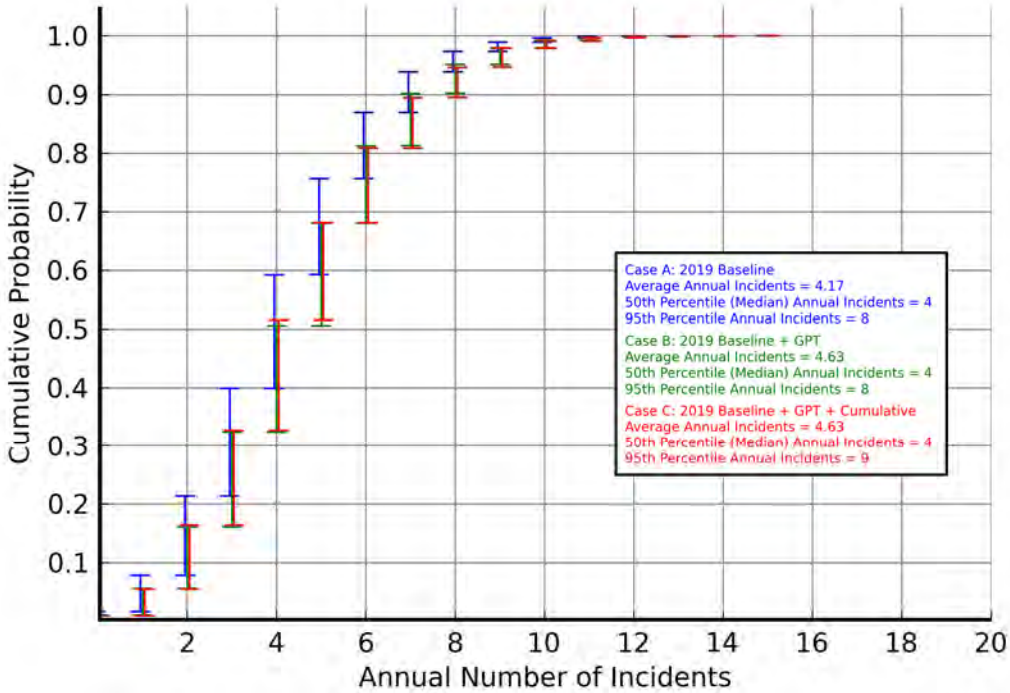

Figure 107 Cumulative distribution function of annual number of incidents in Saddlebag, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

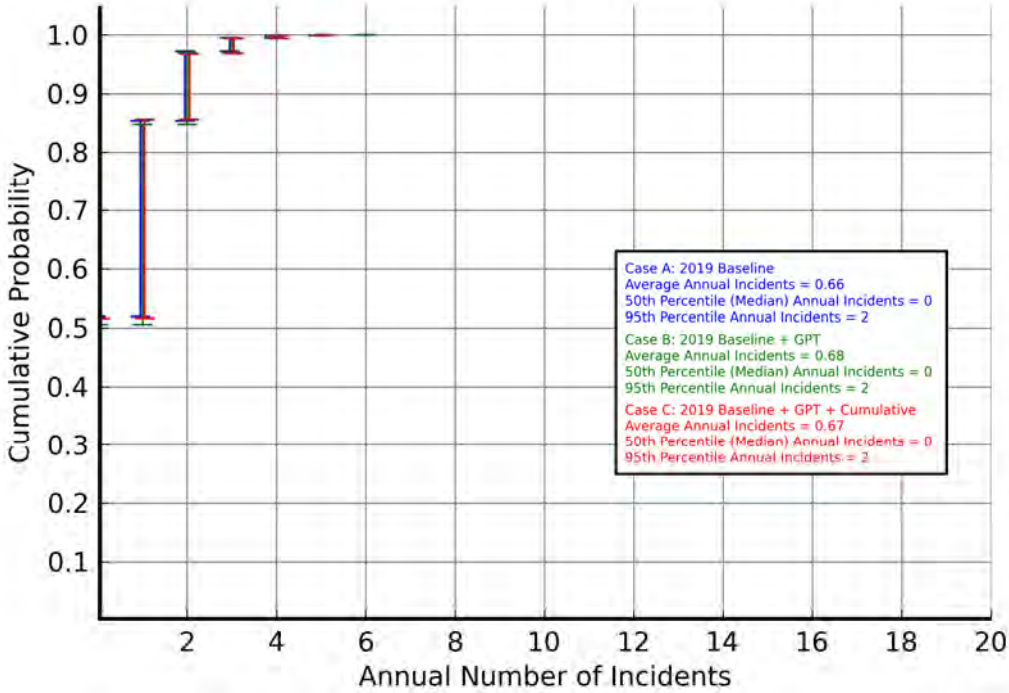

Figure 108 Cumulative distribution function of annual number of incidents in Rosario Strait, for all vessel, activity, and incident types. Annual number of incidents for Cases A and C offset by ±0.05 for visual purposes only

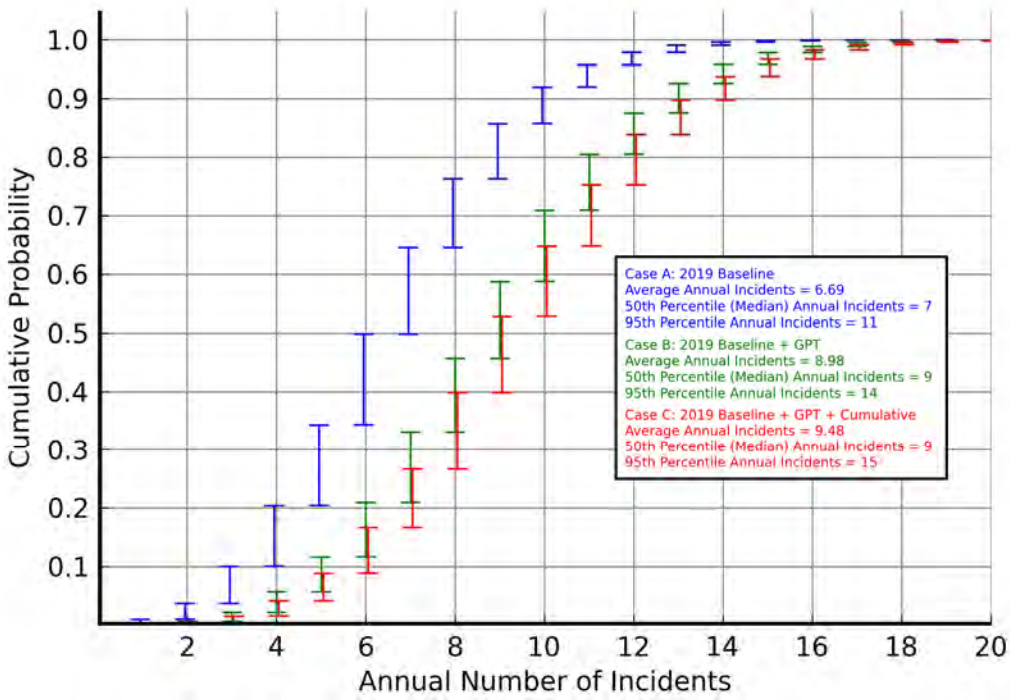

Figure 109 Cumulative distribution function of annual number of incidents in Cherry Point, for all vessel, activity, and incident types. Annual number of incidents for cases A and C offset by ±0.05 for visual purposes only

Number of Incidents by Incident Type

Table 90 shows the average annual number of incidents predicted by the contaminant outflow model for each incident type, summed across all vessel types, activity types, and subareas. Incident types with a higher incident rate are expected to have a greater number of incidents. From Section 3.3.7, Other Non-Impact has the highest incident rate of 0.001 incidents per vessel traffic day, averaged over all vessel types, activity types, and subareas. As expected, the incident type with a highest predicted number of incidents is Other Non-Impact.

Table 90 Average annual number of incidents by incident type, for all vessel types, activity types, and subareas[53]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Collision	0.80	1.33	1.38	65%	72%
Grounding	1.30	1.81	1.88	39%	45%
Allision	1.61	2.21	2.23	37%	39%
Transfer Error	1.70	1.78	1.78	5%	5%
Bunker Error	3.16	3.21	3.17	2%	0%
Other Non-Impact	19.74	23.98	25.24	22%	28%
All Incident Types	28.31	34.31	35.68	21%	26%

Table 91 and Table 92 show the median and 95th percentile[54] annual number of incidents predicted by the contaminant outflow model for each incident type, summed across all vessel types, activity types, and subareas.

[53] Number of incidents and percent change are rounded to two decimal places. Percent change is calculated using four decimal places. The number of decimal places presented is not indicative of the accuracy of the model.

[54] Note that the sums of the median and 95th percentile annual number of incidents of each incident type do not equal the median and 95th percentile annual number of incidents across all incident types. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each incident type will all occur in the same year, so the 95th percentile annual number of incidents across all incident types will intuitively be less than the sum of the 95th percentile annual number of incidents of each incident type.

Table 91 Median annual number of incidents by incident type, for all vessel types, activity types, and subareas

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Collision	1	1	1
Grounding	1	2	2
Allision	1	2	2
Transfer Error	2	2	2
Bunker Error	3	3	3
Other Non-Impact	20	24	25
All Incident Types	28	34	36

Table 92 95th percentile annual number of incidents by incident type, for all vessel types, activity types, and subareas

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Collision	2	3	4
Grounding	3	4	4
Allision	4	5	5
Transfer Error	4	4	4
Bunker Error	6	7	7
Other Non-Impact	27	32	34
All Incident Types	38	44	46

Number of Incidents by Incident Type and Subarea

Table 93 through Table 98 show the average annual number of spills (both oil and dry bulk spills) predicted by the contaminant outflow model for each incident type and subarea, summed across all vessel types and activity types. In these tables, the bottom row for All Subareas is the same result as presented for the incident type in Table 90.

Table 93 Average annual number of collision incidents by subarea, for all vessel types and activity types[55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.1696	0.1878	0.2115	11%	25%
Strait of Juan de Fuca East	0.2371	0.5826	0.5994	146%	153%
Haro Strait and Boundary Pass	0.0055	0.0055	0.0078	0%	42%
Guemes Channel and Fidalgo Bay	0.1326	0.1356	0.1356	2%	2%
Saddlebag	0.0700	0.1028	0.1057	47%	51%
Rosario Strait	0.0064	0.0074	0.0080	16%	25%
Cherry Point	0.1811	0.3035	0.3129	68%	73%
All Subareas	0.8022	1.3252	1.3809	65%	72%

Table 94 Average annual number of grounding incidents by subarea, for all vessel types and activity types[55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.3215	0.3314	0.3570	3%	11%
Strait of Juan de Fuca East	0.4079	0.7545	0.7837	85%	92%
Haro Strait and Boundary Pass	0.0058	0.0058	0.0061	0%	5%
Guemes Channel and Fidalgo Bay	0.1899	0.1907	0.1803	0%	-5%
Saddlebag	0.1363	0.1696	0.1625	24%	19%
Rosario Strait	0.0051	0.0057	0.0063	12%	24%
Cherry Point	0.2322	0.3532	0.3867	52%	67%
All Subareas	1.2986	1.8108	1.8825	39%	45%

[55] The number of decimal places presented is not indicative of the accuracy of the model.

Table 95 Average annual number of allision incidents by subarea, for all vessel types and activity types[55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.1398	0.1582	0.1673	13%	20%
Strait of Juan de Fuca East	0.2664	0.6099	0.6257	129%	135%
Haro Strait and Boundary Pass	0.1763	0.1763	0.1837	0%	4%
Guemes Channel and Fidalgo Bay	0.2550	0.2554	0.2513	0%	-1%
Saddlebag	0.2873	0.3233	0.3287	13%	14%
Rosario Strait	0.2837	0.2850	0.2795	0%	-1%
Cherry Point	0.2024	0.3979	0.3950	97%	95%
All Subareas	1.6107	2.2059	2.2311	37%	39%

Table 96 Average annual number of transfer error incidents by subarea, for all vessel types and activity types[55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0005	0.0005	0.0007	0%	40%
Strait of Juan de Fuca East	0.2985	0.3071	0.3035	3%	2%
Haro Strait and Boundary Pass	0.0000	0.0000	0.0000	-	-
Guemes Channel and Fidalgo Bay	0.5681	0.6249	0.6171	10%	9%
Saddlebag	0.0895	0.0895	0.0926	0%	3%
Rosario Strait	0.0000	0.0000	0.0000	-	-
Cherry Point	0.7422	0.7580	0.7619	2%	3%
All Subareas	1.6988	1.7800	1.7758	5%	5%

Most transfer errors were predicted by the contaminant outflow model from tankers, bulkers, and cargo vessels at-dock in subareas where they call at cargo terminals. For the purposes of this study, passenger vessels, fishing vessels, and tugs do not carry cargo. The BP Cherry Point refinery, Phillips 66 refinery at Ferndale, and proposed GPT are in the Cherry Point subarea. The Tesoro and Shell refineries in Anacortes are in the Guemes Channel subarea. These two subareas are predicted to have the most transfer errors. Other predicted transfer errors are attributed to tank barges transferring cargo fuel at dock or potentially lightering a tanker at an anchorage. Without any anchorages or terminals, no transfer errors are predicted in Haro Strait and Boundary Pass or in Rosario Strait.

Table 97 Average annual number of bunker error incidents by subarea, for all vessel types and activity types[55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0055	0.0055	0.0057	0%	4%
Strait of Juan de Fuca East	0.5016	0.5018	0.4897	0%	-2%
Haro Strait and Boundary Pass	0.0522	0.0522	0.0488	0%	-7%
Guemes Channel and Fidalgo Bay	1.1256	1.1740	1.1724	4%	4%
Saddlebag	0.7875	0.7875	0.7682	0%	-2%
Rosario Strait	0.0000	0.0000	0.0000	-	-
Cherry Point	0.6848	0.6848	0.6826	0%	0%
All Subareas	3.1573	3.2059	3.1674	2%	0%

Bunker error incident rates for the at-dock and the at-berth activity types were grouped over all subareas and combinations of vessel type, activity type, and subarea with no bunkering were zeroed, as described in Section 3.3.3.3. Bunker error incident rates for the underway and maneuvering activity types are zero. Tankers, bulkers, and cargo ships will not bunker in Haro Strait and Boundary Pass or in Rosario Strait. In turn, no tank barge will be delivering bunker and have the potential for a bunker error in either of those two subareas. The only vessel types which may potentially have a bunker error incident within Haro Strait and Boundary Pass, or in Rosario Strait, are the smaller vessels. [56] These potential bunker error incidents are attributed to tugs, passenger vessels, or fishing vessels refueling at dock. There is zero bunkering at the proposed GPT or at other docks in the Cherry Point Subarea for bulkers. The bulker at-dock bunker error IR is zero in the Cherry Point subarea. In remaining combinations of vessel types and subareas with potential bunker errors, a higher predicted number of bunker error incidents are attributed to the greater traffic in the subarea rather than to a higher incident rate in the subarea.

Historical bunkering volumes at locations within the North Puget Sound are presented in Section 2.5.2. This shows the greatest bunker volume at Port Angeles, in the Strait of Juan de Fuca East subarea.

[56] For the purposes of this study, the term "bunker" is used inclusive of fuel used by smaller boats, like tugs.

Table 98 Average annual number of non-impact error incidents by subarea, for all vessel types and activity types [55]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	3.0047	3.0587	3.4177	2%	14%
Strait of Juan de Fuca East	4.6916	6.5471	6.8706	40%	46%
Haro Strait and Boundary Pass	0.5393	0.5394	0.6254	0%	16%
Guemes Channel and Fidalgo Bay	3.6827	3.8229	3.8478	4%	4%
Saddlebag	2.8037	3.1530	3.1722	12%	13%
Rosario Strait	0.3652	0.3845	0.3724	5%	2%
Cherry Point	4.6513	6.4791	6.9378	39%	49%
All Subareas	19.7386	23.9847	25.2439	22%	28%

Other non-impact errors were the most frequent incident type in the forecast, as well as in the historical data. This incident type had the highest incident rate per vessel traffic day input to the model, over five times higher than the next highest incident rate (bunker errors), Table 71. Other non-impact errors represented 73% (313) of the 429 incidents in the historical dataset, Section 3.3.3.2. These incidents occurred in all subareas, as shown in Table 32 of Appendix G.

Total Number of Spills

Figure 110 shows the cumulative distribution function of total annual spills for each traffic volume case, summed across all vessel types, activity types, incident types, and subareas. The simulation results show that an average annual increase in the number of spills throughout the system of 26% is predicted with the addition of the proposed GPT (percentage difference between Case B average, 13.37 spills, and Case A average, 10.62 spills). The addition of cumulative traffic increases the average number of incidents by an additional 4% (percentage difference between Case C average, 13.93 spills, and Case B average, 13.37 spills). When compared to the Case A baseline, the average number of spills in Case C is an increase of 5% over Case B (= 13.93 / 10.62 - 13.37 / 10.62 = 131% - 126%) .

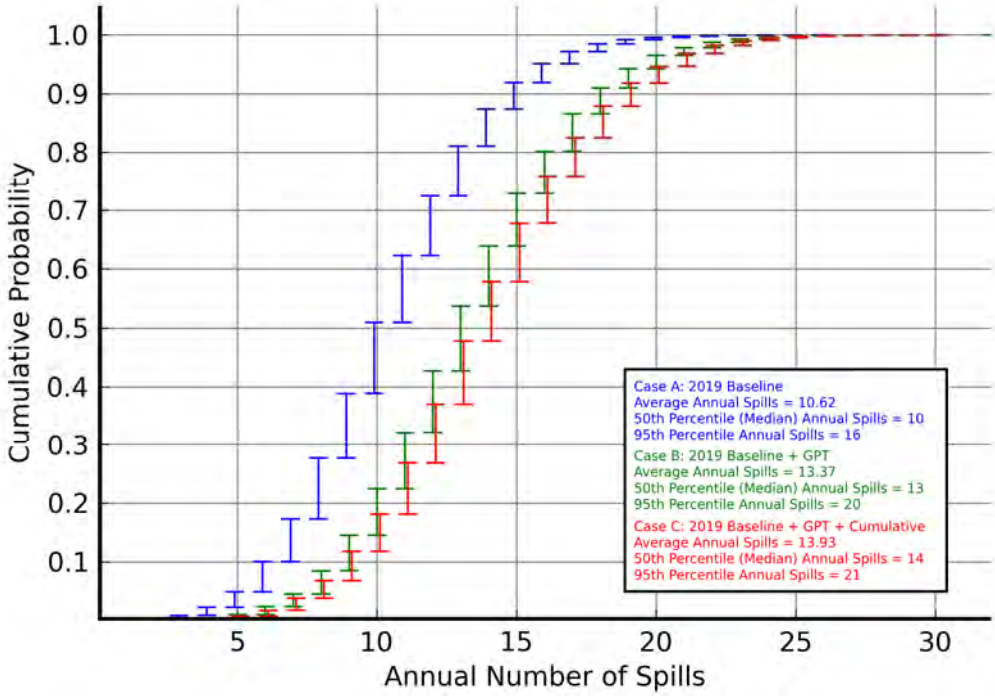

Figure 110 Cumulative distribution function of total annual number of spills for all subareas and vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.1 for visual purposes only

Number of Spills by Subarea

Table 99 shows the average annual number of spills (both oil and dry bulk spills) predicted by the contaminant outflow model for each subarea, summed across all vessel types, activity types, and incident types.

Table 99 Average annual number of spills by subarea, for all vessel, activity, and incident types[57]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change (B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.97	1.03	1.23	6%	27%
Strait of Juan de Fuca East	2.27	3.64	3.75	60%	65%
Haro Strait and Boundary Pass	0.17	0.17	0.20	0%	18%
Guemes Channel and Fidalgo Bay	2.70	2.84	2.84	5%	5%
Saddlebag	1.50	1.68	1.67	12%	11%
Rosario Strait	0.10	0.10	0.10	0%	0%
Cherry Point	2.92	3.91	4.14	34%	42%
All Subareas	10.62	13.37	13.93	26%	31%

[57] Number of spills and percent change are rounded to two decimal places. Percent change is calculated using four decimal places. The number of decimal places presented is not indicative of the accuracy of the model.

Table 100 and Table 101 show the median and 95th percentile[58] annual number of spills (both oil and dry bulk spills) predicted by the contaminant outflow model for each subarea, summed across all vessel types, activity types, and incident types.

Table 100 Median annual number of spills by subarea, for all vessel, activity, and incident types

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	1	1	1
Strait of Juan de Fuca East	2	3	4
Haro Strait and Boundary Pass	0	0	0
Guemes Channel and Fidalgo Bay	3	3	3
Saddlebag	1	1	1
Rosario Strait	0	0	0
Cherry Point	3	4	4
All Subareas	10	13	14

Table 101 95th percentile annual number of spills be subarea, for all vessel, activity, and incident types

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	3	3	3
Strait of Juan de Fuca East	5	7	7
Haro Strait and Boundary Pass	1	1	1
Guemes Channel and Fidalgo Bay	6	6	6
Saddlebag	4	4	4
Rosario Strait	1	1	1
Cherry Point	6	7	8
All Subareas	16	20	21

Figure 111 through Figure 117 show the cumulative distribution functions of predicted number spills per subarea, summed across all vessel types, activity types, and incident types. Because the Poisson distribution was used to sample for the number of incidents in each

[58] Note that the sums of the median and 95th percentile annual number of spills of each subarea do not equal the median and 95th percentile annual number of spills across the entire study area. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each subarea will all occur in the same year, so the 95th percentile annual number of spills across all subareas will intuitively be less than the sum of the 95th percentile annual number of spills of each subarea.

scenario, the number of annual incidents, and thus spills, is always calculated as an integer value.

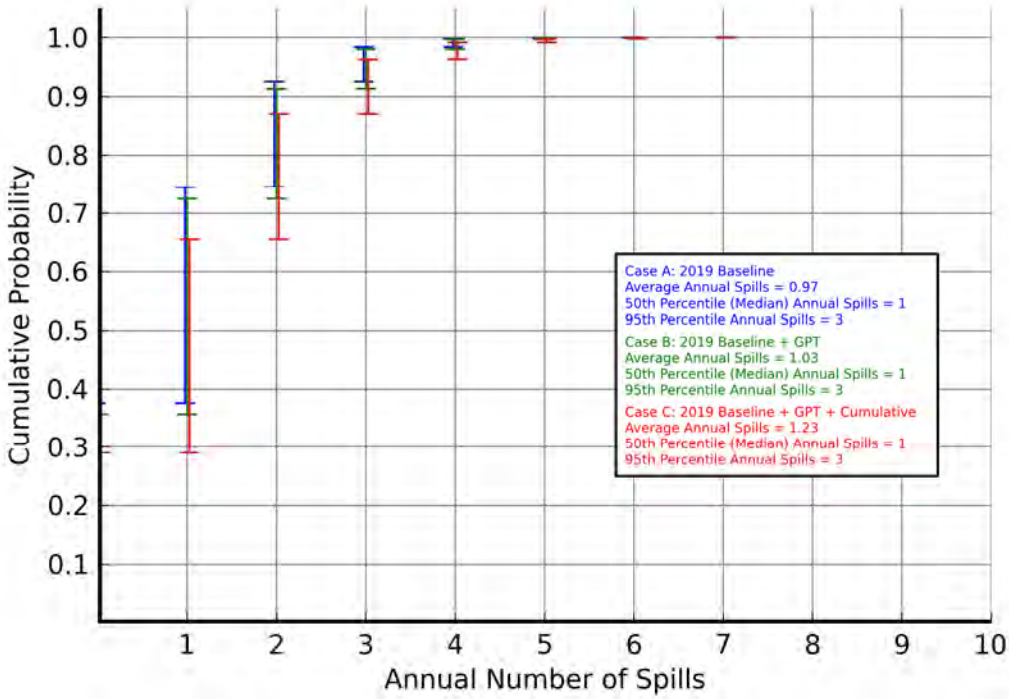

Figure 111 Cumulative distribution function of annual number of spills in Strait of Juan de Fuca West, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

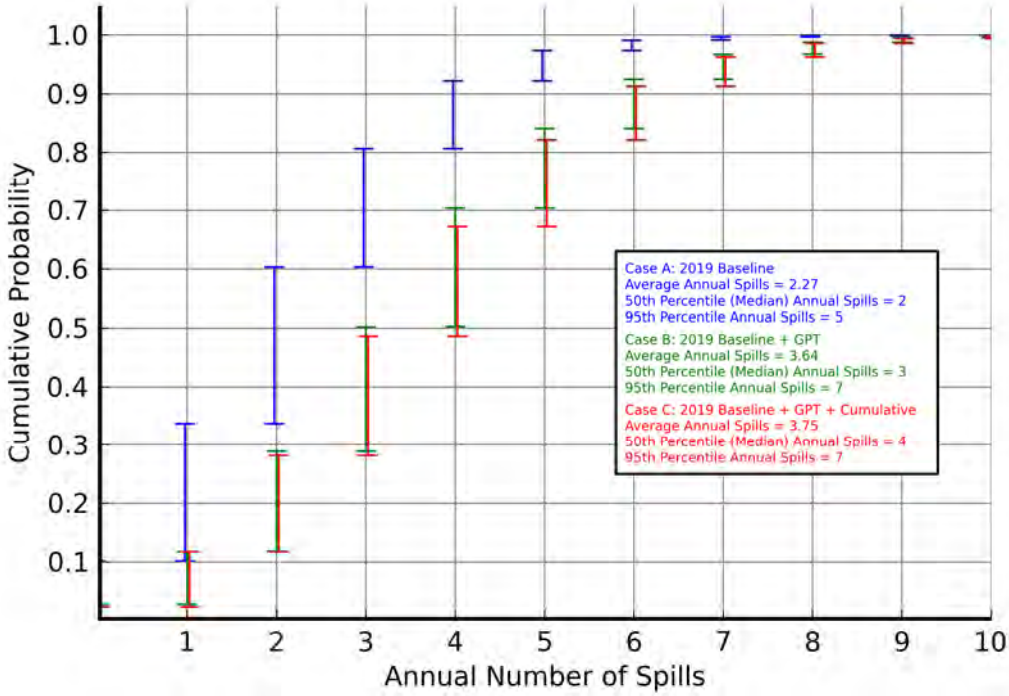

Figure 112 Cumulative distribution function of annual number of spills in Strait of Juan de Fuca East, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

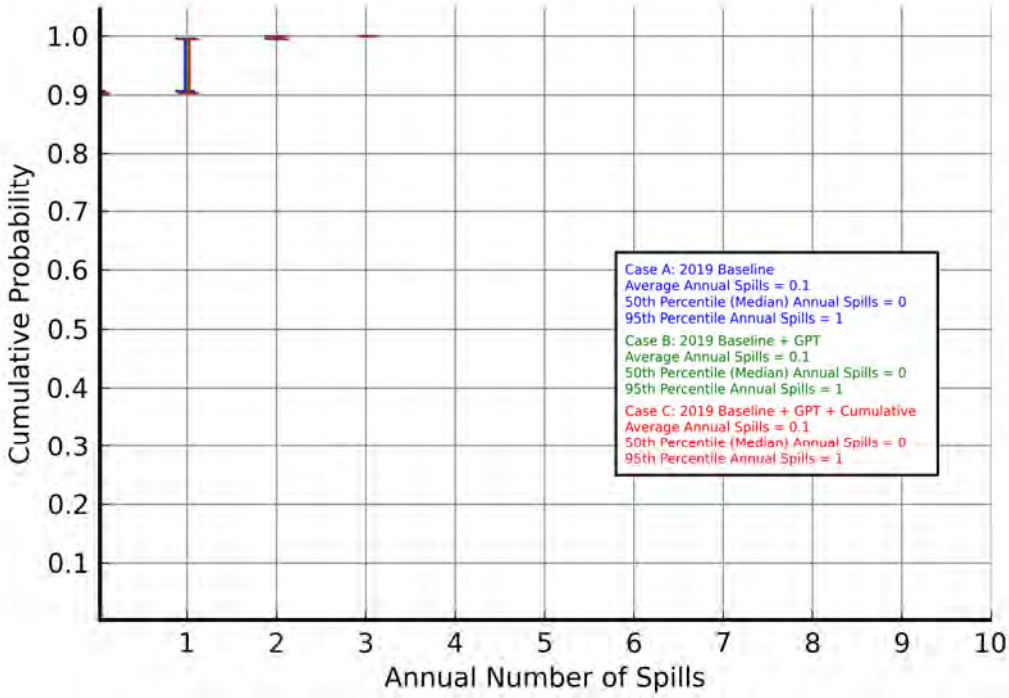

Figure 113 Cumulative distribution function of annual number of spills in Rosario Strait, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by± 0.025 for visual purposes only

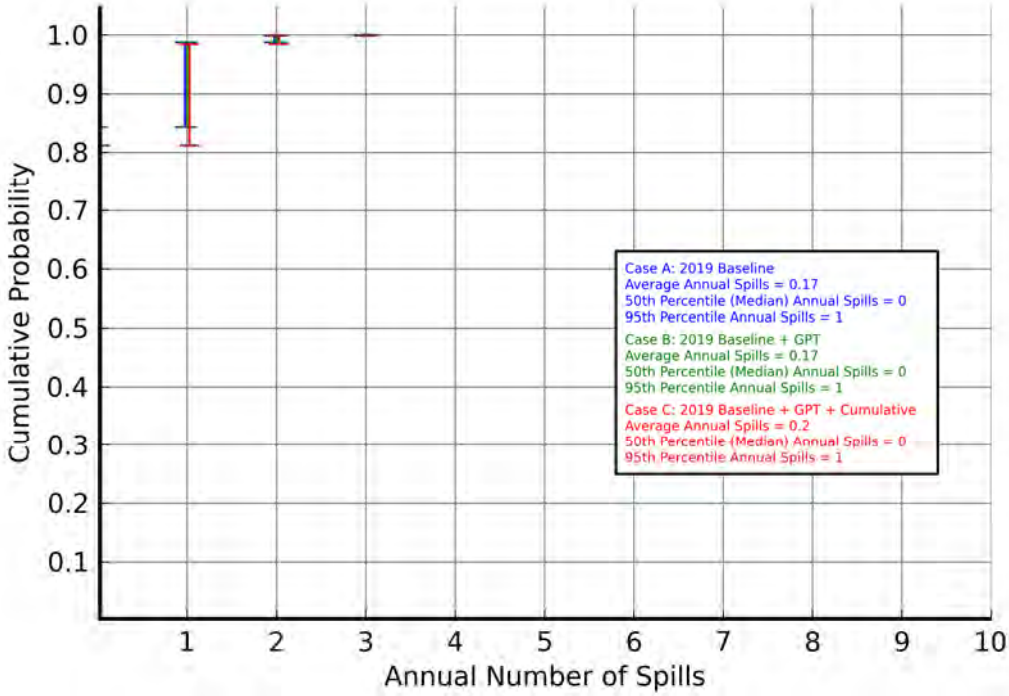

Figure 114 Cumulative distribution function of annual number of spills in Haro Strait and Boundary Pass, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

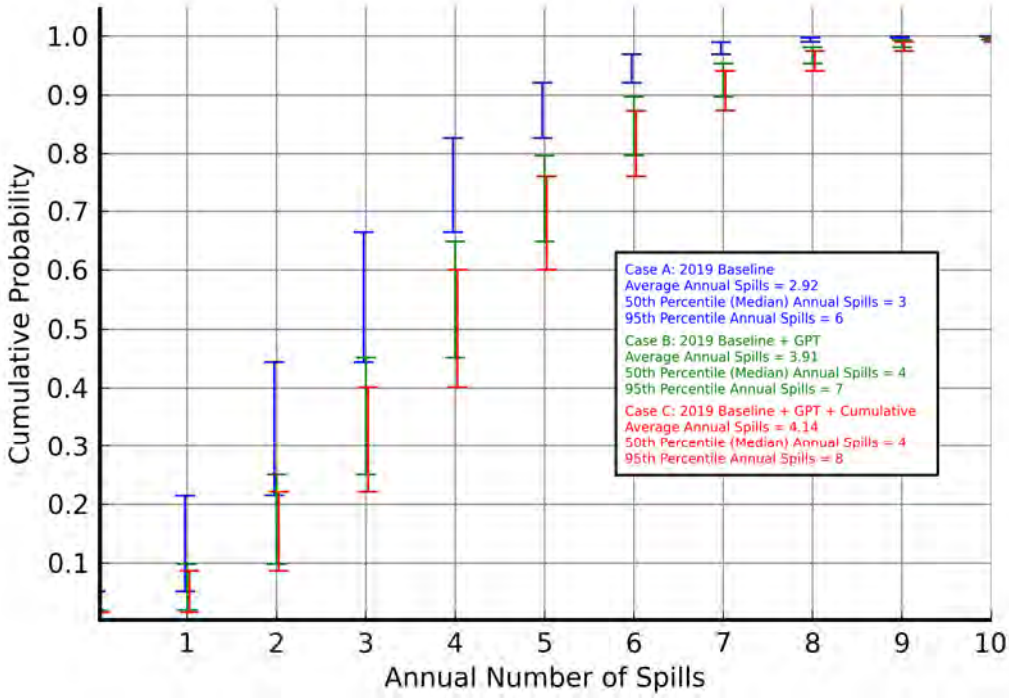

Figure 115 Cumulative distribution function of annual number of spills in Cherry Point, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

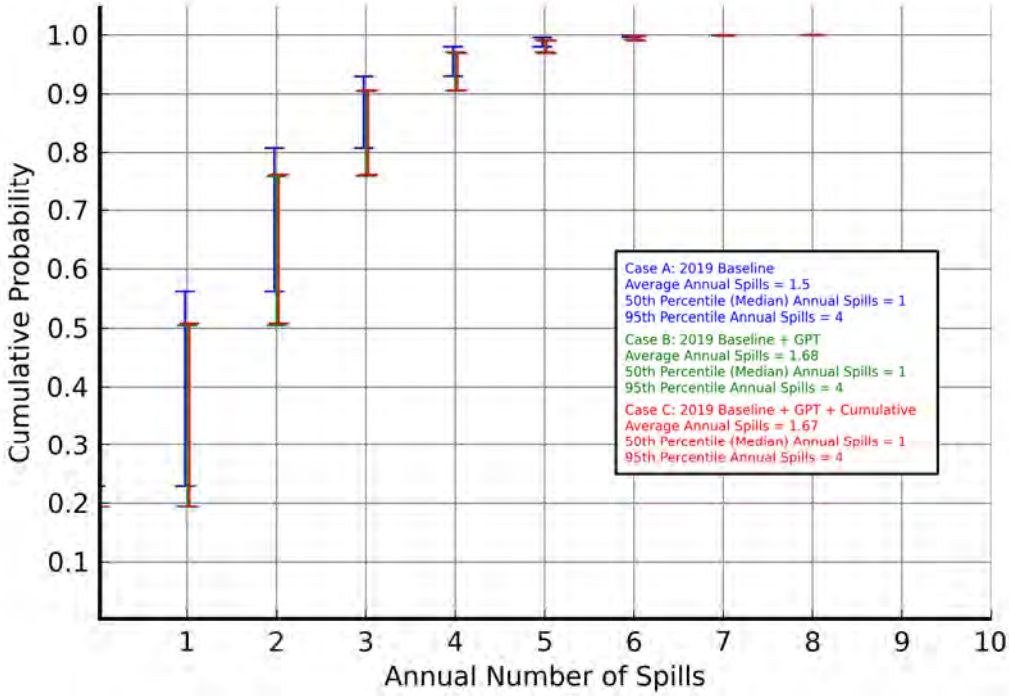

Figure 116 Cumulative distribution function of annual number of spills in Saddlebag, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

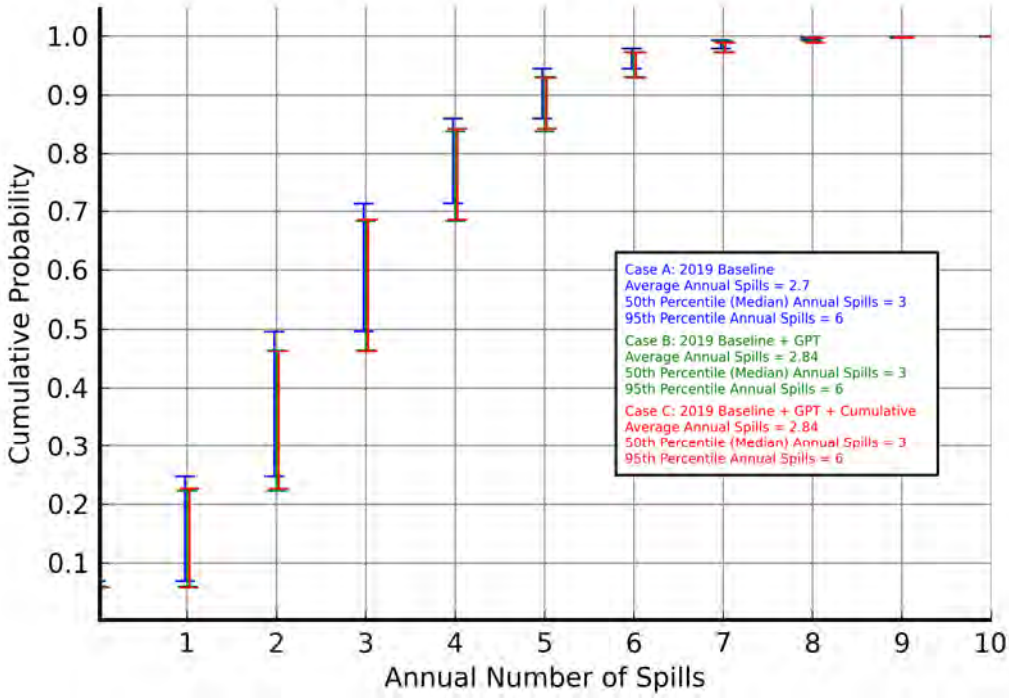

Figure 117 Cumulative distribution function of annual number of spills in Guemes Channel and Fidalgo Bay, for all vessel, activity, and incident types. Annual number of spills for Cases A and C offset by ±0.025 for visual purposes only

Number of Spills by Incident Type

Table 102 shows the average annual number of spills (both oil and dry bulk spills) predicted by the contaminant outflow model for each incident type, summed across all vessel types, activity types, and subareas. Incident types with a lower spill probability are expected to have a greater reduction from predicted number of incidents to predicted number of spills, as described in Section 3.4.3.4. For example, the spill probability from a collision is less than 20% (varying by vessel type, by whether it may be a cargo spill or bunker spill, and by hull or tank type). From an average of 0.80 collision incidents predicted in Case A (Table 90), 0.19 collision spills are predicted in Case A. The spill probability from a cargo transfer error is 92% (same across vessel types). From an average of 1.70 transfer error incidents predicted in Case A, there are 1.56 transfer error spills predicted in Case A. As expected, the incident type with a lower spill probability shows a greater reduction from predicted number of incidents to predicted number of spills.

Table 102 Average annual number of spills by incident type, for all vessel types, activity types, and subareas[59]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Collision	0.19	0.52	0.55	175%	188%
Grounding	0.13	0.22	0.23	76%	85%
Allision	0.23	0.56	0.56	147%	148%
Transfer Error	1.56	1.64	1.63	5%	5%
Bunker Error	2.91	2.95	2.92	2%	0%
Other Non-Impact	5.61	7.47	8.04	33%	43%
All Incident Types	10.62	13.37	13.93	26%	31%

Table 103 and Table 104 show the median and 95th percentile[60] annual number of spills (cargo oil, fuel oil, and dry bulk spills) predicted by the contaminant outflow model for each incident type, summed across all vessel types, activity types, and subareas.

[59] Number of spills and percent change are rounded to two decimal places. Percent change is calculated using four decimal places. The number of decimal places presented is not indicative of the accuracy of the model.
[60] Note that the sums of the median and 95th percentile annual number of spills of each incident type do not equal the median and 95th percentile annual number of spills across all incident types. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each incident type will all occur in the same year, so the 95th percentile annual number of spills across all incident types will intuitively be less than the sum of the 95th percentile annual number of spills of each incident type.

Table 103 Median annual number of spills by incident type, for all vessel types, activity types, and subareas

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Collision	0	0	0
Grounding	0	0	0
Allision	0	0	0
Transfer Error	1	1	1
Bunker Error	3	3	3
Other Non-Impact	5	7	8
All Incident Types	10	13	14

Table 104 95th percentile annual number of spills by incident type, for all vessel types, activity types, and subareas

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Collision	1	2	2
Grounding	1	1	1
Allision	1	2	2
Transfer Error	4	4	4
Bunker Error	6	6	6
Other Non-Impact	10	12	13
All Incident Types	16	20	21

Number of Spills by Incident Type and Subarea

Table 105 through Table 110 show the average annual number of spills (cargo oil, fuel oil, and dry bulk spills) predicted by the contaminant outflow model summed across all vessel types and activity types by subarea for each incident type: collision, grounding, allision, cargo transfer error, bunker error, and other non-impact. In these tables, the bottom row for All Subareas is the same result as presented for the incident type in Table 93.

Table 105 Average annual number of spills by subarea due to collisions, for all vessel types and activity types[61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0488	0.0617	0.0729	26%	49%
Strait of Juan de Fuca East	0.0800	0.3126	0.3176	291%	297%
Haro Strait and Boundary Pass	0.0015	0.0015	0.0018	0%	20%
Guemes Channel and Fidalgo Bay	0.0193	0.0198	0.0214	3%	11%
Saddlebag	0.0092	0.0294	0.0292	220%	217%
Rosario Strait	0.0002	0.0009	0.0016	350%	700%
Cherry Point	0.0308	0.0953	0.1015	209%	230%
All Subareas	0.1898	0.5211	0.5459	175%	188%

Table 106 Average annual number of spills by subarea due to groundings, for all vessel types and activity types[61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0296	0.0313	0.0361	6%	22%
Strait of Juan de Fuca East	0.0395	0.1083	0.1091	174%	176%
Haro Strait and Boundary Pass	0.0004	0.0004	0.0007	0%	75%
Guemes Channel and Fidalgo Bay	0.0187	0.0188	0.0184	1%	-2%
Saddlebag	0.0106	0.0167	0.0164	58%	55%
Rosario Strait	0.0002	0.0003	0.0007	50%	250%
Cherry Point	0.0272	0.0464	0.0516	71%	90%
All Subareas	0.1262	0.2222	0.2330	76%	85%

[61] The number of decimal places presented is not indicative of the accuracy of the model.

Table 107 Average annual number of spills by subarea due to allisions, for all vessel types and activity types [61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0457	0.0574	0.0580	26%	27%
Strait of Juan de Fuca East	0.0837	0.3172	0.3184	279%	280%
Haro Strait and Boundary Pass	0.0091	0.0091	0.0099	0%	9%
Guemes Channel and Fidalgo Bay	0.0233	0.0233	0.0269	0%	15%
Saddlebag	0.0172	0.0363	0.0373	111%	117%
Rosario Strait	0.0165	0.0168	0.0156	2%	-5%
Cherry Point	0.0316	0.1003	0.0968	217%	206%
All Subareas	0.2271	0.5603	0.5628	147%	148%

Table 108 Average annual number of spills by subarea due to transfer errors, for all vessel types and activity types [61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change	
				(B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0005	0.0005	0.0007	0%	40%
Strait of Juan de Fuca East	0.2768	0.2846	0.2795	3%	1%
Haro Strait and Boundary Pass	0.0000	0.0000	0.0000	-	-
Guemes Channel and Fidalgo Bay	0.5230	0.5747	0.5676	10%	9%
Saddlebag	0.0827	0.0827	0.0860	0%	4%
Rosario Strait	0.0000	0.0000	0.0000	-	-
Cherry Point	0.6799	0.6942	0.7000	2%	3%
All Subareas	1.5629	1.6367	1.6338	5%	5%

Table 109 Average annual number of spills by subarea due to bunker errors, for all vessel types and activity types [61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change (B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.0050	0.0050	0.0053	0%	6%
Strait of Juan de Fuca East	0.4621	0.4623	0.4516	0%	-2%
Haro Strait and Boundary Pass	0.0482	0.0482	0.0455	0%	-6%
Guemes Channel and Fidalgo Bay	1.0336	1.0784	1.0779	4%	4%
Saddlebag	0.7236	0.7236	0.7069	0%	-2%
Rosario Strait	0.0000	0.0000	0.0000	-	-
Cherry Point	0.6347	0.6347	0.6313	0%	-1%
All Subareas	2.9072	2.9522	2.9185	2%	0%

Table 110 Average annual number of spills by subarea due to other non-impact errors, for all vessel types and activity types [61]

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative	Incremental Percent Change (B - A)/A	(C - A)/A
Strait of Juan de Fuca West	0.8423	0.8720	1.0595	4%	26%
Strait of Juan de Fuca East	1.3270	2.1596	2.2690	63%	71%
Haro Strait and Boundary Pass	0.1107	0.1107	0.1466	0%	32%
Guemes Channel and Fidalgo Bay	1.0803	1.1246	1.1233	4%	4%
Saddlebag	0.6523	0.7864	0.7959	21%	22%
Rosario Strait	0.0801	0.0832	0.0840	4%	5%
Cherry Point	1.5156	2.3371	2.5568	54%	69%
All Subareas	5.6083	7.4736	8.0351	33%	43%

Total Annual Oil Outflow

Figure 118 shows the cumulative distribution function of total annual volume of oil outflow for the entire study area for each traffic volume case, summed across all vessel types, activity types, incident types, and subareas. Oil spills due to collisions, allisions, and groundings are predicted to occur infrequently, but result in large oil outflows when they do occur. Spills due to bunker error, transfer error, and other non-impact incidents are predicted to occur more frequently, but result in smaller oil outflows when they do occur. The simulation results show that in 2019, an increase in the median total annual oil outflow of 28% is predicted throughout the system with the addition of the proposed GPT (percentage difference between Case B median, 837 gallons, and Case A median, 656 gallons). The addition of cumulative traffic further increases the median total annual oil

outflow by another 19% (percentage difference between Case C median, 996 gallons, and Case B median, 837 gallons).

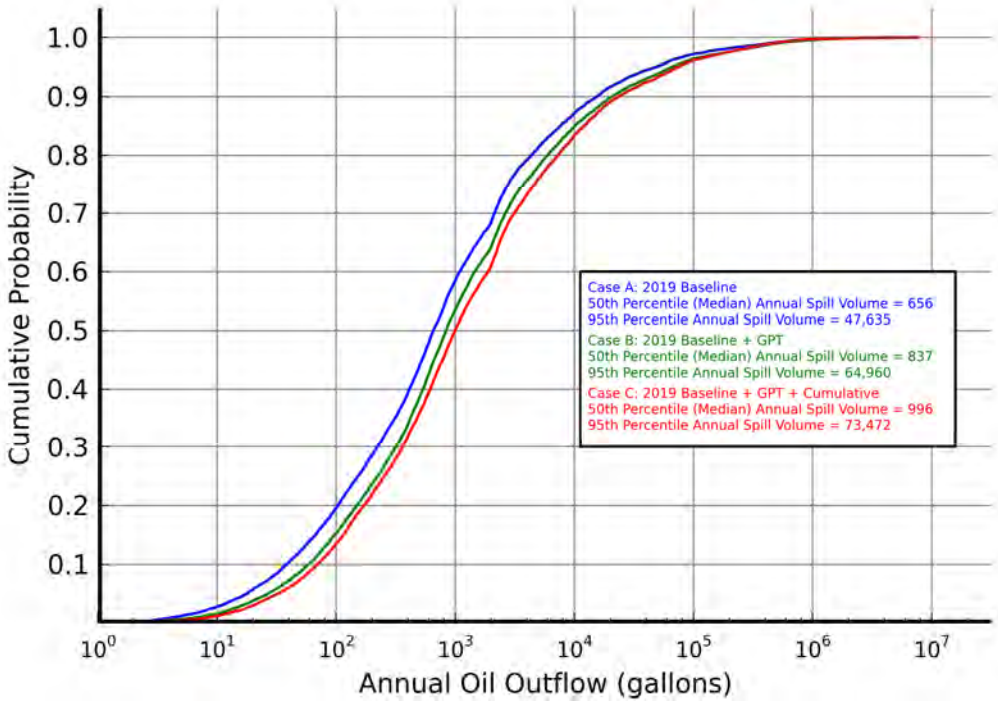

Figure 118 Predicted cumulative distribution function of total annual volume of oil outflow, for all subareas and all vessel, activity, and incident types

Total Annual Oil Outflow by Subarea

Table 111 and Table 112 show the median and 95th percentile[62] annual oil outflow predicted by the contaminant outflow model for each subarea, summed across all vessel types, activity types, and incident types.

[62] Note that the sums of the median and 95th percentile annual oil outflows of each subarea do not equal the median and 95th percentile annual oil outflows across the entire study area. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each subarea will all occur in the same year, so the 95th percentile annual oil outflow across all subareas will intuitively be less than the sum of the 95th percentile outflow of each subarea.

Table 111 Median annual oil outflow by subarea, for all vessel, activity, and incident types (gallons)

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	0	0	1
Strait of Juan de Fuca East	10	21	23
Haro Strait and Boundary Pass	0	0	0
Guemes Channel and Fidalgo Bay	14	17	17
Saddlebag	2	2	2
Rosario Strait	0	0	0
Cherry Point	22	36	48
All Subareas	656	837	996

Table 112 95th percentile annual oil outflow by subarea, for all vessel, activity, and incident types (gallons)

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	2,458	2,538	4,342
Strait of Juan de Fuca East	4,850	9,109	9,930
Haro Strait and Boundary Pass	8	8	18
Guemes Channel and Fidalgo Bay	2,183	2,245	2,240
Saddlebag	646	706	737
Rosario Strait	1	1	1
Cherry Point	5,058	6,716	8,751
All Subareas	47,635	64,960	73,472

Figure 119 through Figure 125 show the cumulative distribution functions of oil outflow per subarea, summed across all vessel types, activity types, and incident types.

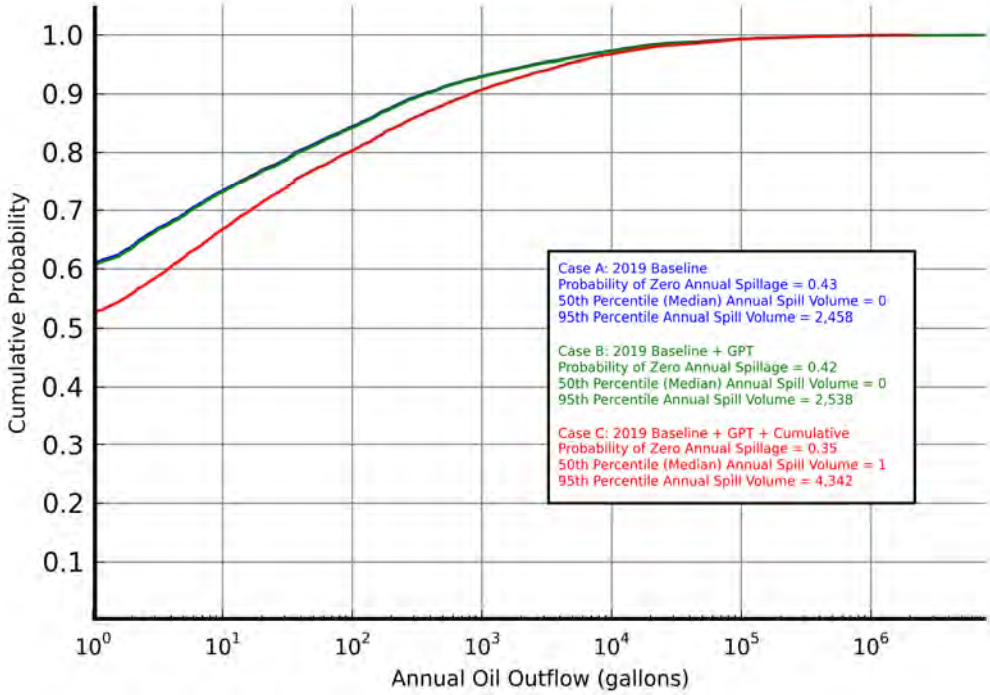

Figure 119 Predicted cumulative distribution function of total annual volume of oil outflow in Strait of Juan de Fuca West, for all vessel, activity, and incident types

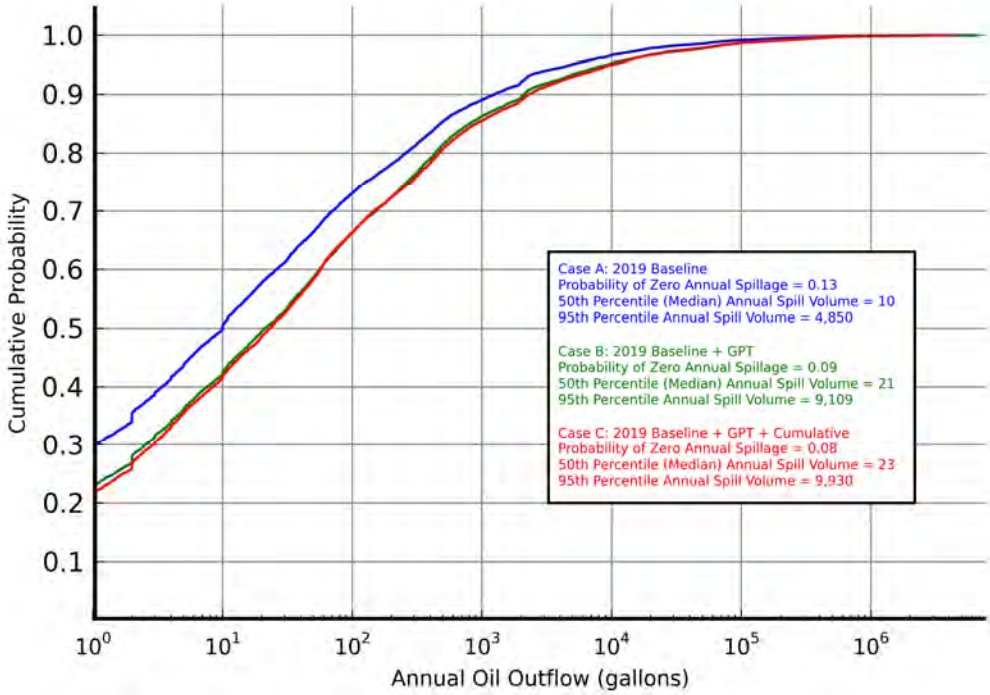

Figure 120 Predicted cumulative distribution function of total annual volume of oil outflow in Strait of Juan de Fuca East, for all vessel, activity, and incident types

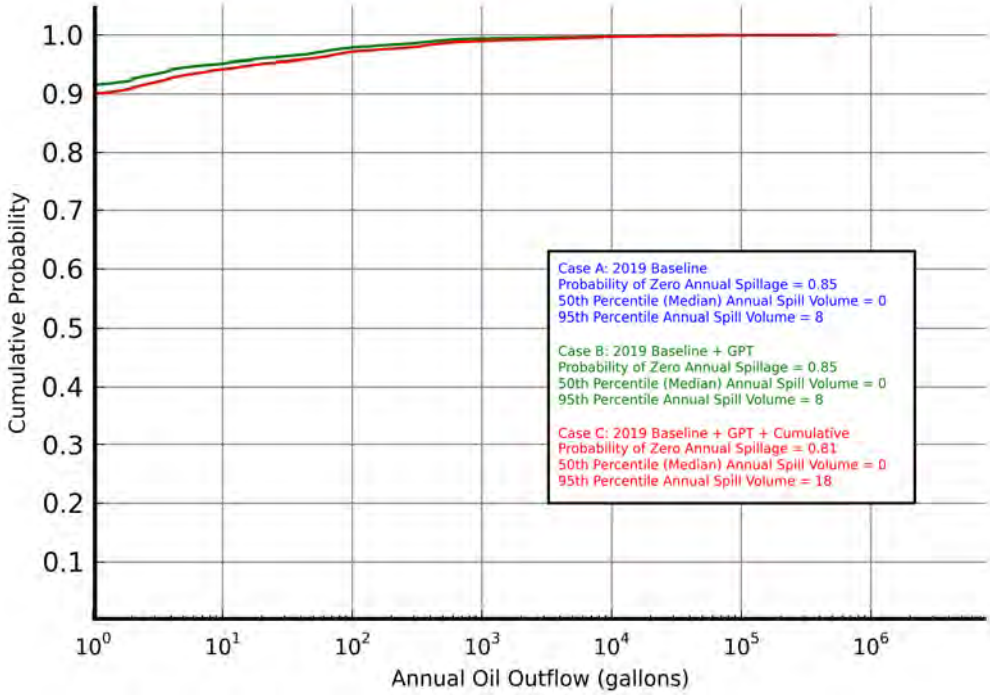

Figure 121 Predicted cumulative distribution function of total annual volume of oil outflow in Haro Strait and Boundary Pass, for all vessel, activity, and incident types

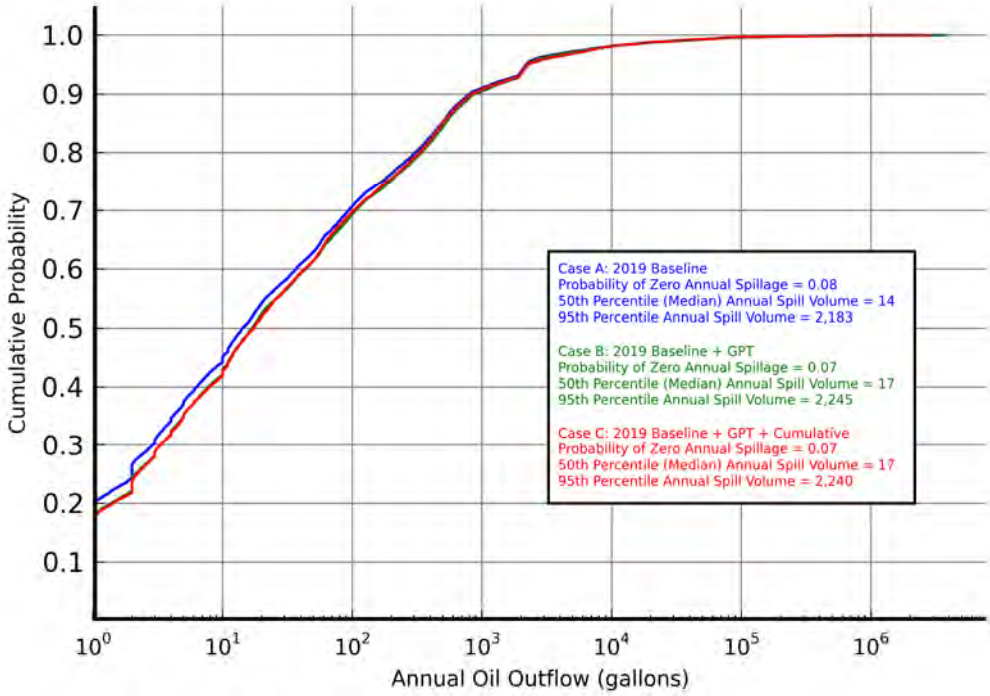

Figure 122 Predicted cumulative distribution function of total annual volume of oil outflow in Guemes Channel and Fidalgo Bay, for all vessel, activity, and incident types

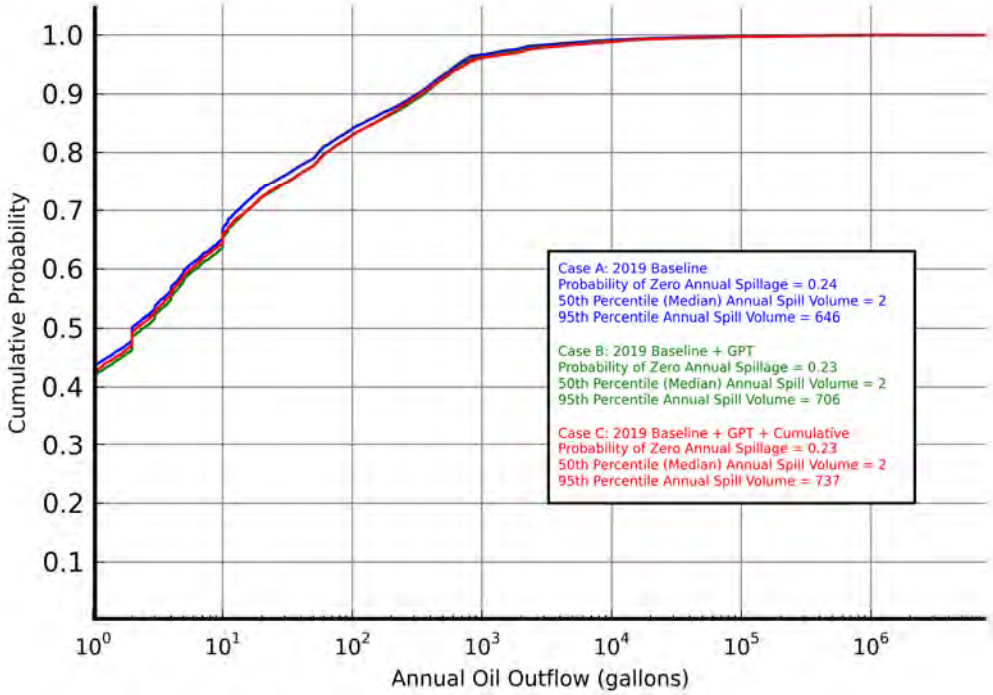

Figure 123 Predicted cumulative distribution function of total annual volume of oil outflow in Saddlebag, for all vessel, activity, and incident types

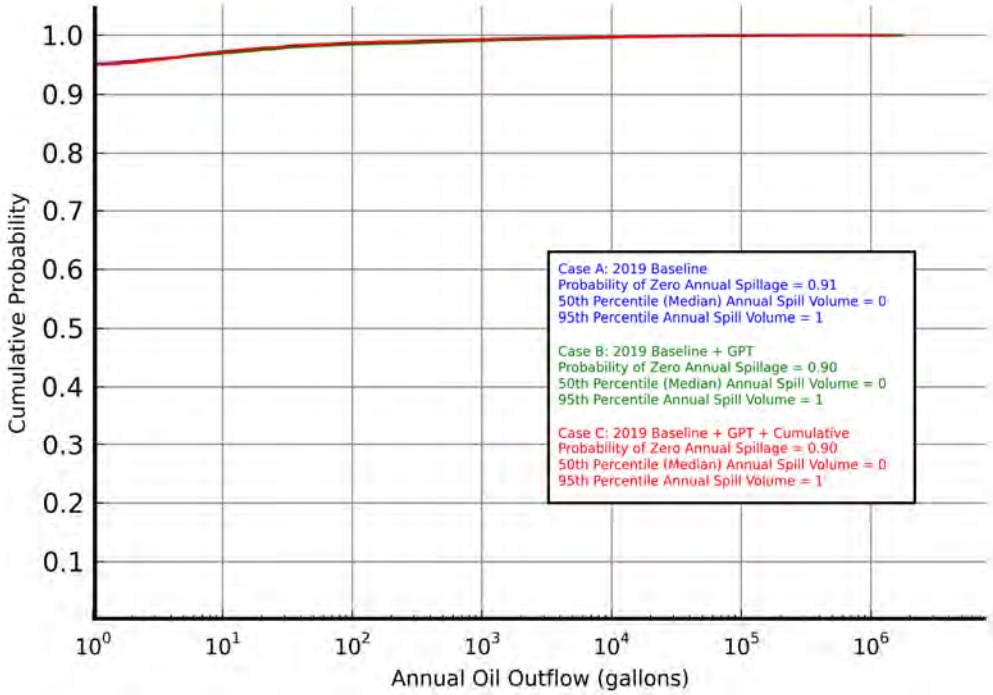

Figure 124 Predicted cumulative distribution function of total annual volume of oil outflow in Rosario Strait, for all vessel, activity, and incident types

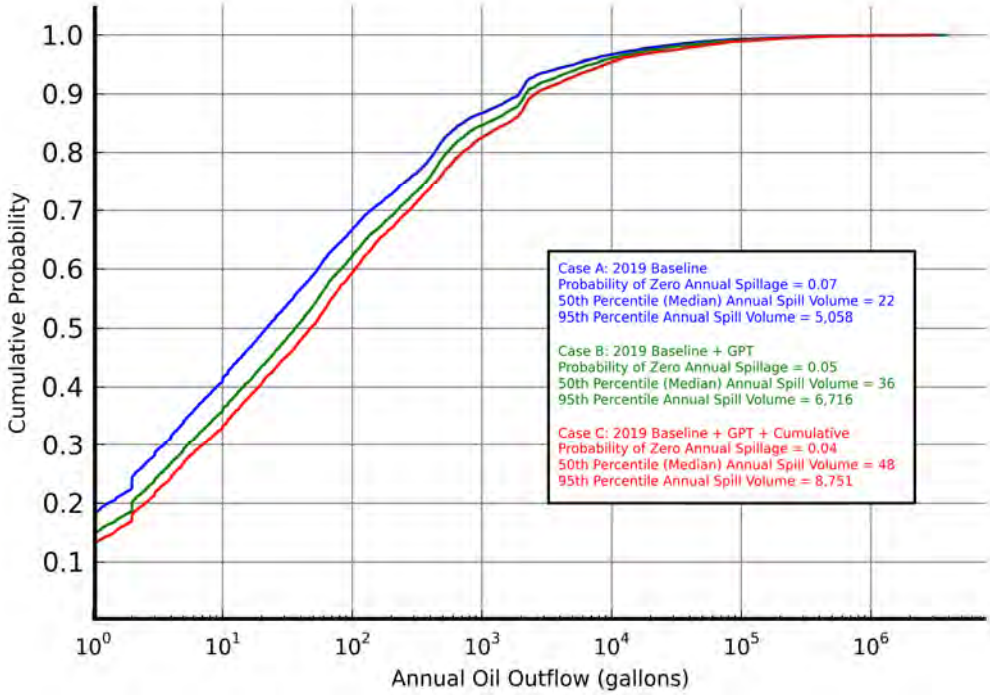

Figure 125 Predicted cumulative distribution function of total annual volume of oil outflow in Cherry Point, for all vessel, activity, and incident types

Total Annual Dry Bulk Outflow

Figure 126 shows the total annual reported[63] dry bulk outflow predicted by the contaminant outflow model for each vessel traffic case, summed across all vessel types, activity types, incident types, and subareas. Dry bulk spills due to collisions are predicted to occur infrequently, but result in large dry bulk outflows when they do occur. Other non-impact incidents are predicted to occur more frequently, but result in small dry bulk outflows when they do occur. Since no additional bulker traffic was modeled as part of cumulative traffic, Cases B and C are notionally identical. The only difference between Case B and Case C (noted in the predicted median and 95th percentile annual spill volumes) is due to uncertainty built into the Monte Carlo simulation, as discussed in Section 3.4.4.2. With the scarce data on dry bulk outflow, the Monte Carlo simulation predicts negligible median total annual reported bulk outflow due to baseline traffic, and an increase to 7,376 cubic feet with the addition of the proposed GPT.

[63] The contaminant outflow model relies on databases of reported spills. It is important to note that dry bulk spills are rarely reported.

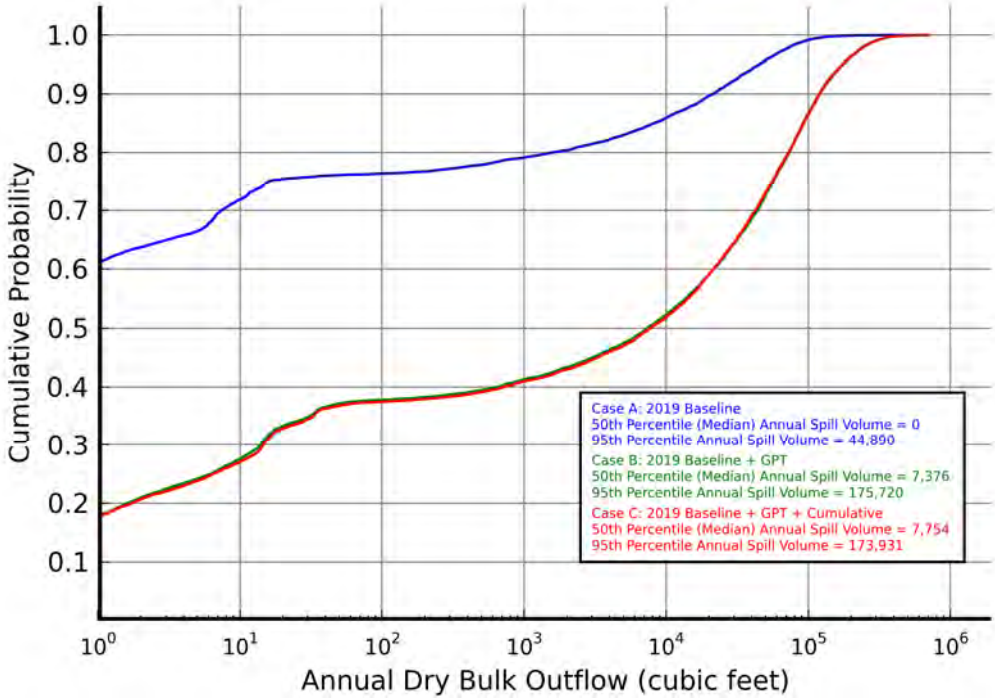

Figure 126 Predicted cumulative distribution function of total annual dry bulk outflow, for all subareas and all vessel, activity, and incident types

Total Annual Dry Bulk Outflow by Subarea

Table 113 and Table 114 show the median and 95th percentile[64] annual reported dry bulk outflow predicted by the contaminant outflow model for each subarea, summed across all vessel types, activity types, and incident types. Risk of bulk outflow due to transfer error is only at the terminal, in the Cherry Point subarea for GPT-calling bulkers. The increase from Case A to Case B in bulk outflow in other subareas is from the other-non impact errors and the collision incident types. Since there was no bulker traffic modeled as part of cumulative traffic, Cases B and C are notionally identical. The only difference between Case B and Case C is due to uncertainty built into the Monte Carlo Simulation, as discussed in Section 3.4.4.2.

[64] Note that the sums of the median and 95th percentile annual dry bulk outflows of each subarea do not equal the median and 95th percentile annual dry bulk outflows across the entire study area. This is a normal statistical phenomenon. An intuitive way to understand this phenomenon is to consider the 95th percentile. It is highly unlikely that the 95th percentile for each subarea will all occur in the same year, so the 95th percentile annual bulk outflow across all subareas will intuitively be less than the sum of the 95th percentile outflow of each subarea.

Table 113 Median annual dry bulk outflow by subarea, for all vessel, activity, and incident types (cubic feet)

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	0	0	0
Strait of Juan de Fuca East	0	17	17
Haro Strait and Boundary Pass	0	0	0
Guemes Channel and Fidalgo Bay	0	0	0
Saddlebag	0	0	0
Rosario Strait	0	0	0
Cherry Point	0	0	0
All Subareas	0	7,376	7,754

Table 114 95th percentile annual dry bulk outflow by subarea, for all vessel, activity, and incident types (cubic feet)

	Case A Baseline	Case B Baseline +GPT	Case C Baseline +GPT +Cumulative
Strait of Juan de Fuca West	6,192	14,227	15,324
Strait of Juan de Fuca East	20,356	136,575	135,794
Haro Strait and Boundary Pass	0	0	0
Guemes Channel and Fidalgo Bay	2	3	2
Saddlebag	0	34	35
Rosario Strait	0	0	0
Cherry Point	11	50,006	49,477
All Subareas	44,890	175,720	173,931

Figure 127 through Figure 133 show the cumulative distribution functions of reported annual bulk outflow per subarea, summed across all vessel types, activity types, and incident types, as predicted by the contaminant outflow model, summed across all vessel types, activity types, and incident types. Note that while the figures for Haro Strait (Figure 129) and Rosario Strait (Figure 132) show a probability of zero annual spillage of 1.00, there is in fact the possibility of dry bulk outflow in those subareas. The Monte Carlo simulation predicted spills in these subareas in less than 50 of the 10,0000 realizations, such that the probability rounded to 1.00. In Haro Strait and Boundary Pass, spills from non-GPT bulkers were predicted, but less than 0.5% of the time (and zero spills from GPT bulkers were predicted). In Rosario strait, spills were predicted for GPT bulkers, but less than 0.5% of the time (and zero spills from non-GPT bulkers were predicted).

Due to a lack of empirical data, another source of dry bulk outflow, dry cargo sweeping, was not captured by the contaminant outflow model. Dry cargo sweeping is discussed in Appendix E. Probability of zero annual spillage is the predicted probability that no dry

cargo spills are reported in a year. Note that all spill volumes are rounded to the nearest integer, such that it is possible for the probability of zero annual spillage to be less than 0.5 when the median spill volume is shown to be zero.

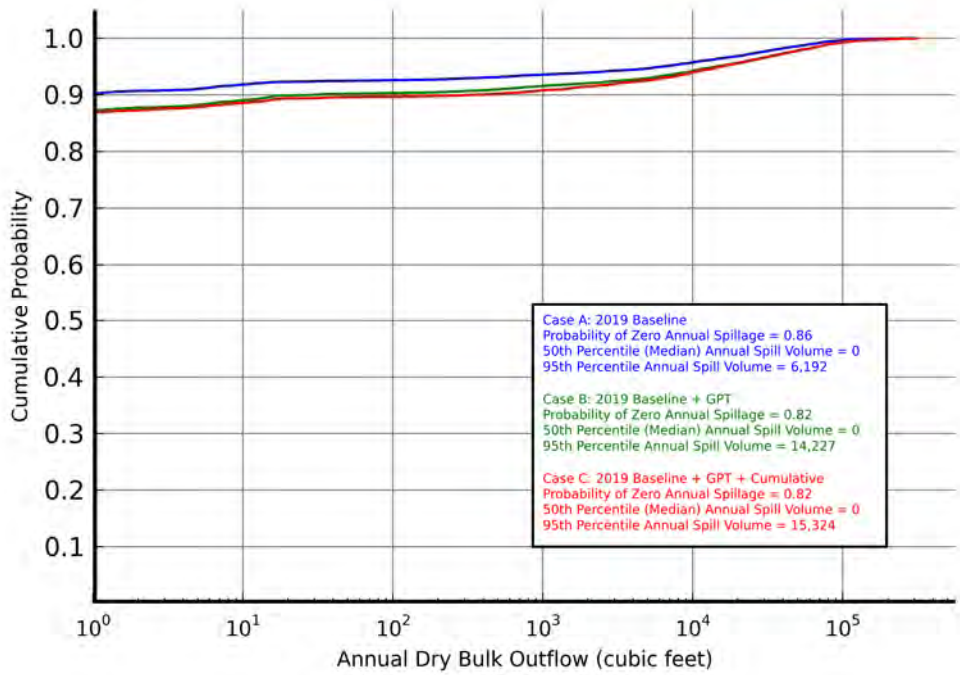

Figure 127 Predicted cumulative distribution function of total annual dry bulk outflow in Strait of Juan de Fuca West, for all vessel, activity, and incident types

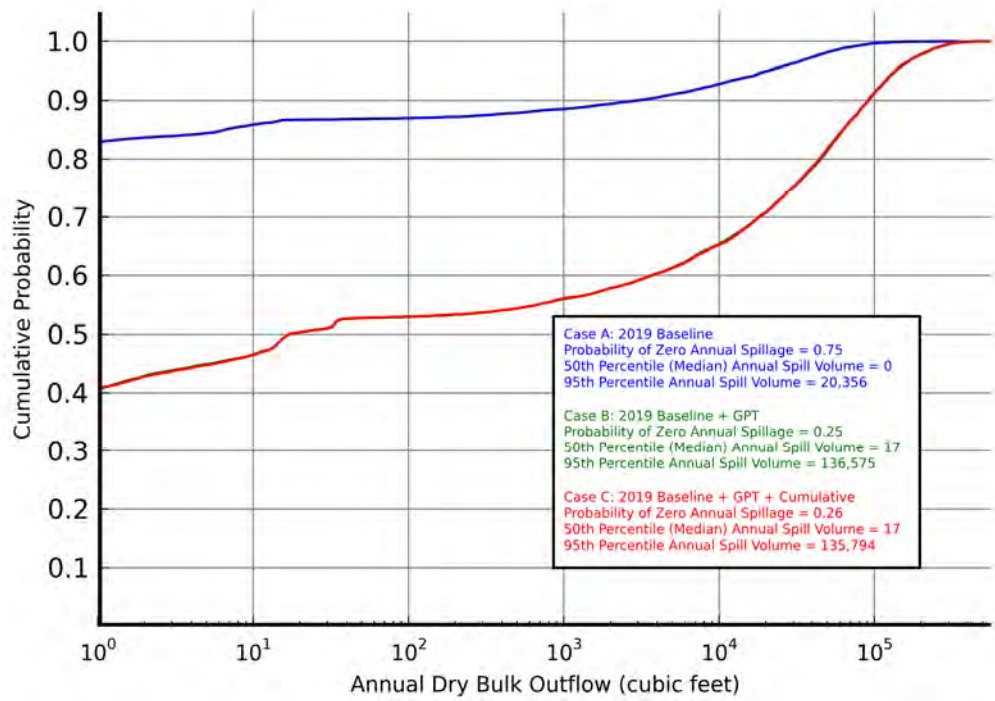

Figure 128 Predicted cumulative distribution function of total annual bulk outflow in Strait of Juan de Fuca East, for all vessel, activity, and incident types

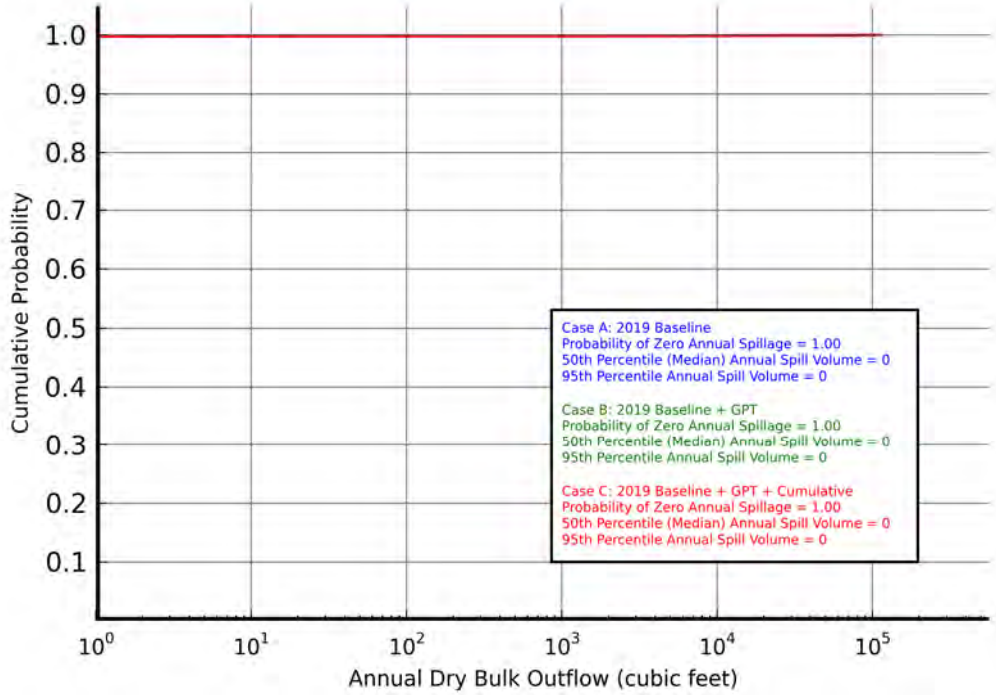

Figure 129 Predicted cumulative distribution function of total annual dry bulk outflow in Haro Strait and Boundary Pass, for all vessel, activity, and incident types

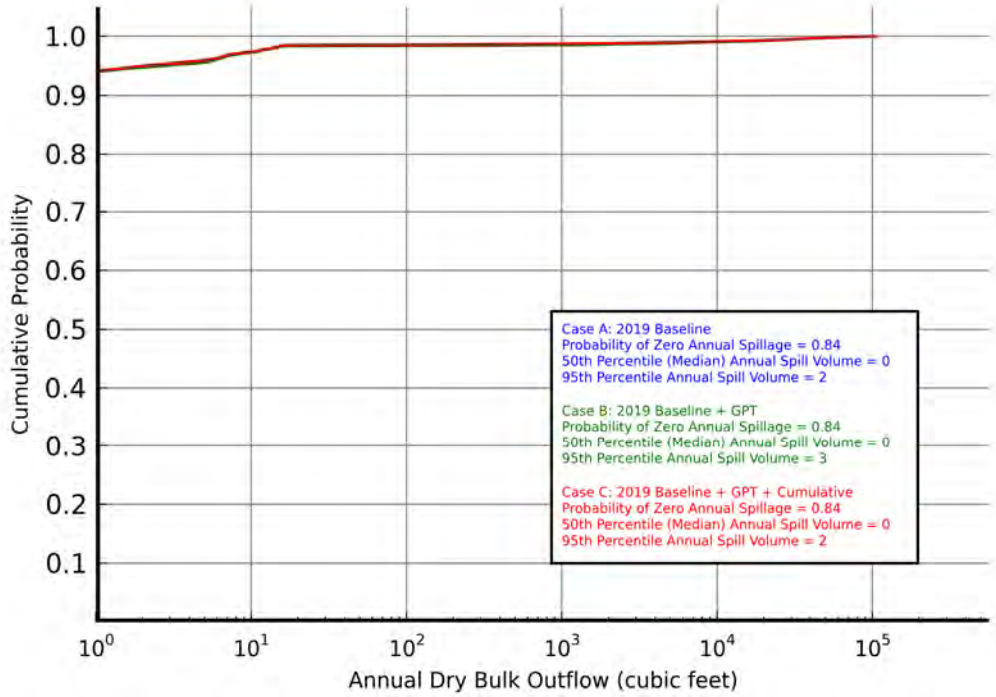

Figure 130 Predicted cumulative distribution function of total annual dry bulk outflow in Guemes Channel and Fidalgo Bay, for all vessel, activity, and incident types

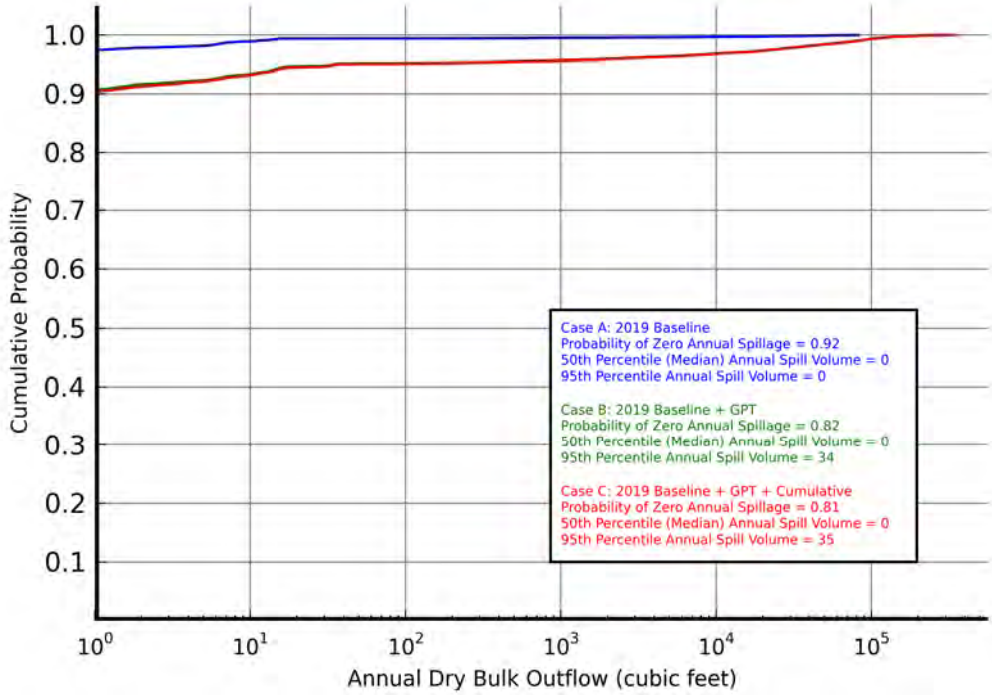

Figure 131 Predicted cumulative distribution function of total annual dry bulk outflow in Saddlebag, for all vessel, activity, and incident types

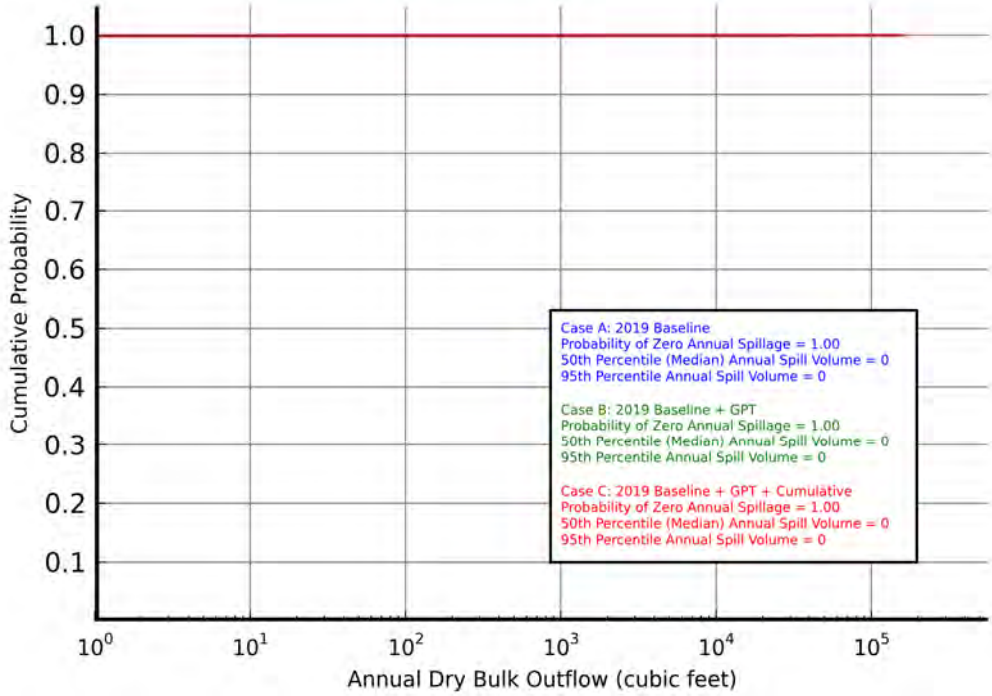

Figure 132 Predicted cumulative distribution function of total annual dry bulk outflow in Rosario Strait, for all vessel, activity, and incident types

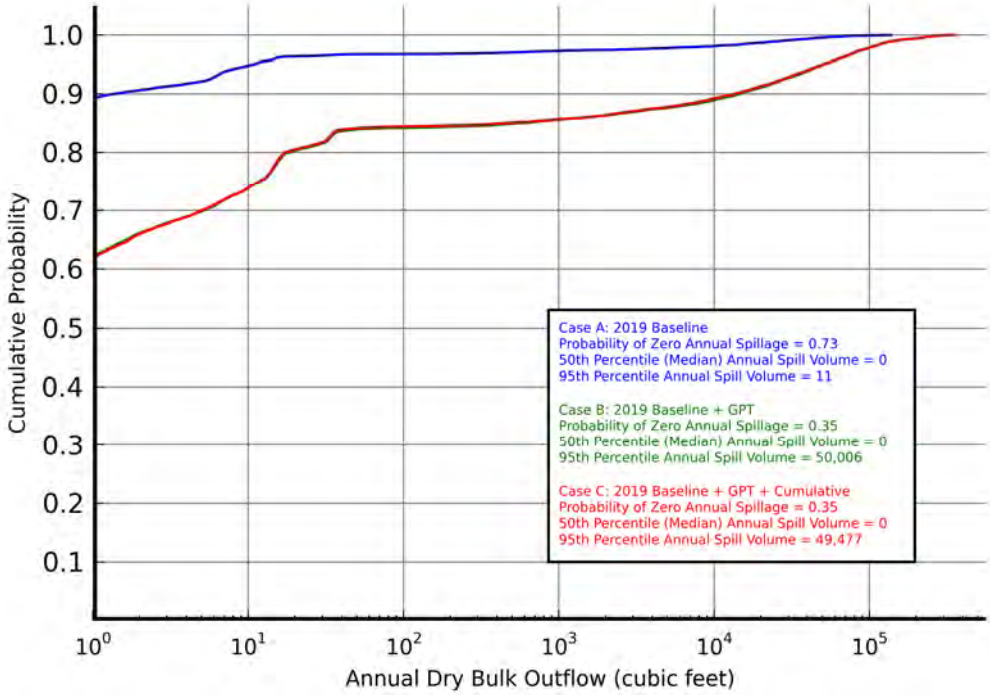

Figure 133 Predicted cumulative distribution function of total annual dry bulk outflow in Cherry Point, for all vessel, activity, and incident types

3.4.4.4 Potential Size of Contaminant Release from a GPT-Calling Vessel

GPT-Calling Vessel Oil Spill Size

When a spill does occur, the size of the spill depends on the capacity of the vessel and the percentage of the vessel capacity that is spilled. The addition of the proposed GPT will introduce new Panamax and Capesize bulk carriers into the system, as well as increased use of tugboats and tank barges, as described in Section 3.4.3.3. The distribution of bunker oil spill sizes predicted from GPT-calling bulk carriers, GPT support tugs, and GPT support tank barges are shown in Figure 134, Figure 135, and Figure 136, respectively.

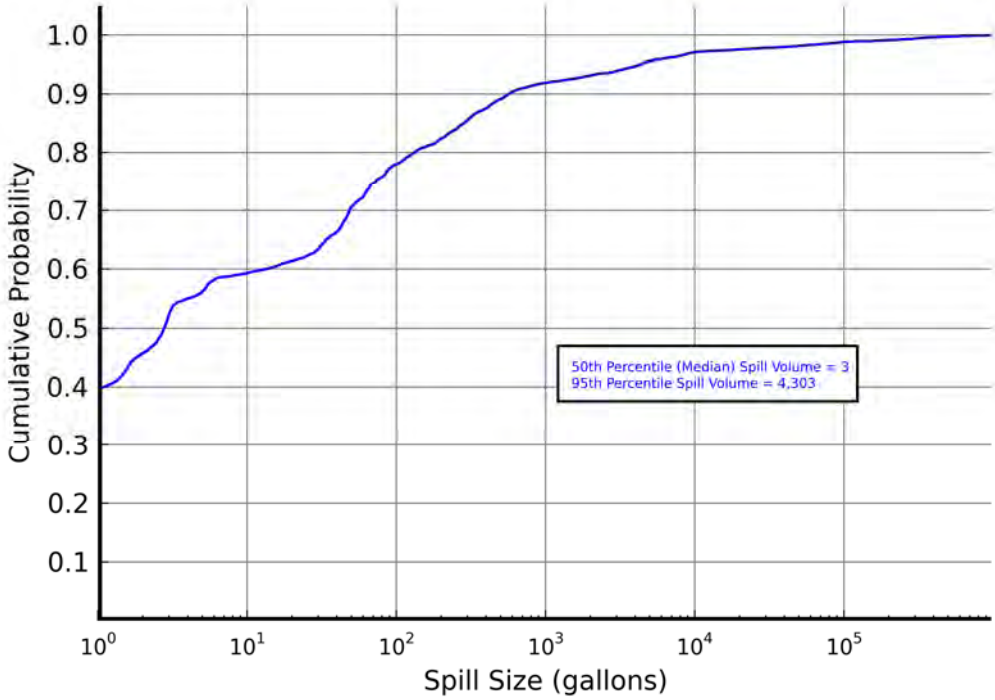

Figure 134 Predicted oil spill size cumulative distribution function of GPT-calling bulkers, for all subareas, activity types, and incident types

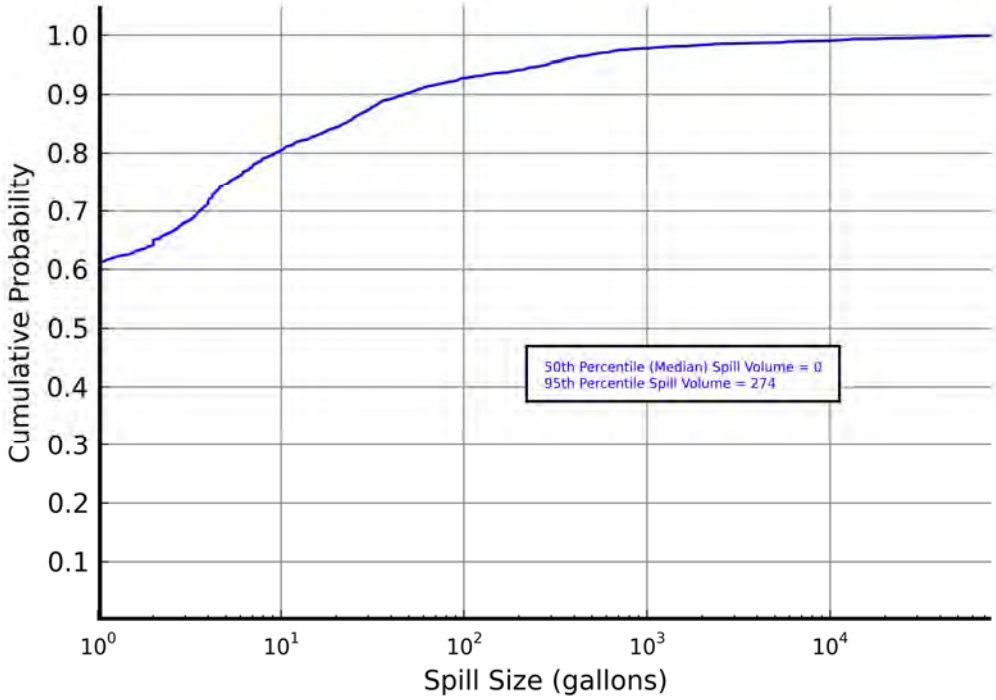

Figure 135 Predicted oil spill size cumulative distribution function of GPT assist tugs and tugs supporting tank barges during GPT-calling vessel bunkering operations, for all subareas, activity types, and incident types

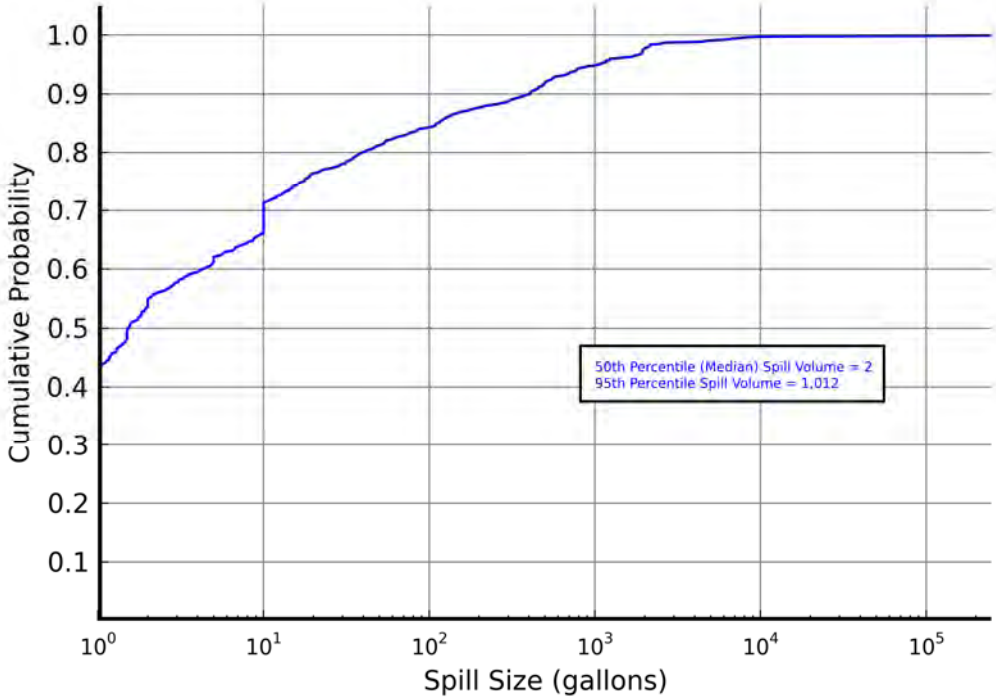

Figure 136 Predicted oil spill size cumulative distribution function of tank barges during GPT-calling vessel bunkering operations, for all subareas, activity types, and incident types

GPT-Calling Vessel Dry Bulk Spill Size

The distribution of predicted dry bulk spill sizes of GPT-calling bulk carriers is shown in Figure 137.

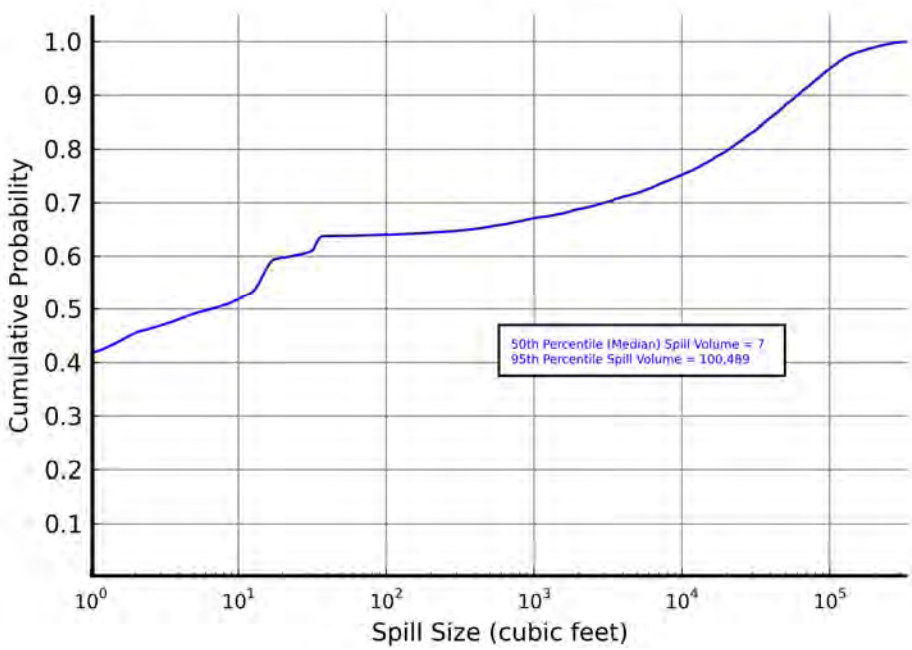

Figure 137 Cumulative distribution function of predicted GPT-calling bulker dry bulk spill size, for all subareas, activity types, and incident types

3.4.5 Summary of Results

Total annual oil and dry bulk outflow in the study area is predicted to increase with the addition of the proposed GPT. The increased numbers of predicted spills result from the increased bulk carrier, tugboat, and tank barge traffic in the system. The magnitude of the increase in potential total annual oil and bulk outflow is predicted to be proportional to the quantity and size of the vessel traffic introduced into the system by the proposed GPT, which are Panamax and Capesize bulk carriers, assist tugboats, tank barge-towing tugboats, and tank barges. The outflow contaminant model predicts a 26% increase in the average total annual number of spills throughout the study area due to the addition of the proposed GPT, with increases in each subarea ranging from 0 to 60%. Cumulative traffic is predicted to increase average total annual number of spills by an additional 4%. The outflow contaminant model predicts a 28% increase in median total annual oil outflow throughout the study area, with an additional 19% increase predicted due to cumulative traffic. The outflow contaminant model predicts an increase in median reported total annual bulk outflow from zero to 7,376 cubic feet. There are no bulk carriers in cumulative traffic, so cumulative traffic is not predicted to be the cause for any additional dry bulk outflow.

The geographic location where the most spills from GPT-calling vessels are predicted to occur is the Strait of Juan de Fuca East (3.64 – 2.27 = 1.37 GPT-calling vessel spills, on average in 2019), followed by Cherry Point (3.91 – 2.91 = 0.99 GPT-calling vessel spills, on average in 2019). Subareas with less GPT-related traffic show a smaller increase in number of incidents, spills, and outflow volume.

The outflow model predicts that the incident types with the greatest increase in risk in terms of number of spills due to the proposed GPT project are “other non-impact” incidents and impact incidents (collisions, groundings, and allisions). The incident type with the greatest predicted percentile increase in average annual number of spills is collision. A 175% increase is predicted, which corresponds to an increase in the annual average of 0.33 spills due to collision. The incident type with the greatest predicted magnitude increase in average annual number of spills is other non-impact (an increase of 1.86 incidents (33%) per year is predicted).

Section 4 Select Vessel Traffic Impacts to the Lummi Nation

4.1 Introduction

This section of the VTARAS focuses on select impacts of the proposed GPT upon the Lummi Nation's fishing and cultural resources. This section addresses:

- GPT vessel traffic impact on Lummi cultural sites;
- The impact of GPT vessel traffic on Lummi fishing in their usual and accustomed fishing areas; and,
- The risk of collision between GPT vessel traffic and Lummi fishing vessels.

It is beyond the scope of this study to address all potential effects of the proposed GPT upon the Lummi Nations fishing and cultural resources.

This section blends both qualitative and quantitative analysis to inform the reader and to develop the conclusions.

Section 4.3 of this report addresses GPT vessel traffic wakes upon a representative Lummi cultural site. The energy of GPT vessel traffic wake hitting shore is compared against the historical energy of weather induced waves hitting the shoreline.

Section 4.4 describes the impact of GPT vessel traffic upon the usual and accustomed fishing areas. The analysis includes the amount of time and the areas where fishing will be interrupted by GPT vessel traffic. This analysis also estimates the changes in Lummi fishing gear loss as a result of the increased GPT vessel traffic.

Section 4.5 assesses the risk of collisions between Lummi fishing vessels and the incremental GPT vessel traffic.

The Lummi Nation Usual and Accustomed grounds and stations (U&A) at least partially overlap all but one of the subareas analyzed in this study. As an example, the Cherry Point subarea is entirely within the Lummi Nation U&A, but only portions of the Strait of Juan de Fuca East subarea are within the Lummi U&A. The Strait of Juan de Fuca West subarea is entirely outside of the Lummi U&A. The increase in vessel traffic associated with the proposed GPT project will vary by subarea, with the largest increase being 33% in the Cherry Point subarea. This study does not try to address the question of compatibility of GPT vessel traffic and Lummi fishing activities. It does attempt to address the anticipated impact of GPT vessels upon Lummi usual and accustomed fishing areas and cultural resources. In addition to the quantitative analysis presented in this section, it is understood that increases in ballast water discharge and the number and volume of contaminant spills also affect the Lummi Nation's fishing and cultural resources.

Lummi fishers currently spend approximately one-third of their time in the Cherry Point subarea during various fishing activities. In 2013 the Washington State Department of Fish and Wildlife (WDFW) estimated that 6,996,112 cubic meters of ballast water were released into Puget Sound by all marine vessels. Because nearly all of the vessels currently calling on the two existing petroleum oil refineries and the aluminum smelter in the Cherry Point subarea

import either crude oil or raw materials for aluminum smelting, very little of the estimated ballast water discharges for all of Puget Sound currently occurs in the Cherry Point subarea. The ballast water discharges related to GPT calling vessels are projected to be 13,900,000 cubic meters (or nearly 3.7 billion gallons) per year that the terminal operates at full capacity, 487 vessel calls. This volume projected for 2019 will nearly triple the total 2013 ballast water discharges in all of Puget Sound. Nearly all ballast water discharges from GPT calling vessels will be within the Cherry Point subarea.

Historically, untreated ballast water discharges have been implicated as a vector for introducing non-indigenous and possibly invasive species. To meet the 2013 Coast Guard regulations (Reference 129), bulk carriers calling at the proposed GPT will require refitting with ballast water treatment systems at their first dry-docking after 1 January 2016. Assuming a five-year dry docking schedule, this fleet would complete its refitting by 31 December 2020.

In the interim period, regulations require all vessels without a ballast water treatment system to perform open-ocean ballast water exchange if the vessel captain determines that the exchange can be safely performed.

Ballast water treatment systems technology and implementation is developing rapidly and current data supporting its efficacy is limited. As the ballast water treatment industry matures, more data will become available supporting the best approach for ballast water treatment. Additional studies, beyond the scope of the VTARAS, should be undertaken to assess the impact of ballast water discharges on fishing activities.

In general, the conclusions of Section 4 are as follows:

- The total annual energy arriving at the shoreline from passing GPT vessel traffic wakes is equal to approximately one quarter of the total annual energy from weather.
- GPT vessel traffic will restrict certain areas, at certain times, from Lummi fishing. The site of the proposed GPT wharf will be permanently excluded from Lummi fishing. Fishing disruption in the Cherry Point subarea increases by 76% with GPT compared to the baseline disruption without the terminal.
- The probability of a collision between GPT vessel traffic and Lummi fishing traffic is very low. The terminal was found to add 0.01 potential collisions in 2019, with respect to a conservatively-predicted baseline collision rate. This increase amounts to a 16.7% increase over the baseline traffic without GPT.

4.2 Assembly of Questions for Lummi Fishers

4.2.1 Introduction

The Lummi Fisheries and Natural Resources Commission (LFNRC), an 11-member natural resources policy setting body elected by Lummi fishers, was given a questionnaire on 13 November 2012. A follow-up meeting was held in the Lummi offices on 12 December, which was attended by the members of the LFNRC, the Lummi Harvest Manager, and several other Lummi Fishers. This follow-up meeting provided both answers to and clarification on related questions that enabled the Lummi to complete the questionnaire. On 4 January 2013, representatives from the LFNRC notified Glosten that all responses to the questionnaire were finalized.

The purpose of the questionnaire, and the follow up meeting with Lummi representatives, was to obtain the following information from the Lummi Nation:

- An evaluation of GPT-calling vessels' impact on the Lummi fishing fleet, including gear loss, associated Homeland Security exclusion zones, and interference with fishing.
- An assessment of the increased vessel traffic impact on Lummi treaty rights to fish throughout the Lummi Nation's Usual and Accustomed grounds and stations.
- Statistical measurement of the impact from the area that the Lummi are temporarily excluded from fishing, multiplied by the expected duration of the temporary exclusion.
- An assessment of the increased vessel use of anchorages and its impact on Lummi treaty rights to fish using the same statistical measure: exclusionary area multiplied by duration.

4.2.2 Summary of Questionnaire Findings

While the Lummi did not respond to every survey question, the Lummi did supply additional unrequested information that ultimately proved pertinent to the study.

The questionnaire responses support the following main findings:

- Lummi fishers harvested over 5 million pounds of finfish and shellfish in each of the years studied (2009-2011), and obtained these harvests from a number of fishery sites excluding the Strait of Juan de Fuca West, with the majority of the harvest slated for commercial use.
- Lummi fishing gear varies by the type of harvest.
- The majority (95%) of Lummi fishing vessels are less than 30 feet in length and are launched, retrieved and trailered at Gooseberry Point. The majority of Lummi fishers harvest salmon. Although the Lummi do not track vessel participation in individual fisheries, the greatest number of fishing trips are made during the months of August, September, and October.
- Lummi fisheries are managed in terms of access days and times. Schedules may be set either in preseason or days ahead of time via conference call or in-person meeting.

The full questionnaire, including response summaries, is provided in Appendix F.

4.3 Traffic Impact on Cultural Resources

4.3.1 Introduction

The contracting parties agreed that an appropriate method to assess the impacts of increased vessel traffic on traditional cultural properties and underwater archaeology was to evaluate the impact of the wake waves of GPT-bound vessels on the shoreline at locations where historic fishing sites exist (Figure 138).

Virtually all anticipated vessel traffic to the proposed GPT will be comprised of bulk transport vessels (bulkers) and berthing/mooring assist tugboats (tugs). Tug and tank barges supporting bunkering of GPT-bound vessels are not expected to transit past Lummi Island. Assist tugs

are expected to transit to the proposed terminal from a homeport in the Saddlebag subarea. A Capesize bulker, a Panamax bulker, and a tugboat were analyzed.

This analysis compared three wave parameters: height, energy density, and energy flux. Wave energy is comprised of both potential energy and kinetic energy. Potential energy is stored in the wave height. Kinetic energy comes from the wave propagation. Energy flux is the average rate of transfer of energy per unit width (width being measured perpendicular to the direction of wave propagation).

This analysis found that tugboat wakes have a larger wave height and more energy flux than bulker wakes. The tugboat speed used in calculations is a transit speed of 14 knots. The transit speed will produce a higher wake than speeds for loitering, maneuvering, or ship-assisting, which are much lower speeds. Therefore, the transit speed gives conservative estimates of vessel wake. Nevertheless, tugboat wakes are considerably smaller than an annual maximum storm wave as follows:

- Height: 13% of an annual maximum storm wave.
- Energy Density: 2% of an annual maximum storm wave.
- Energy Flux: 1% of an annual maximum storm wave.

This difference in magnitude between vessel wakes and annual storm waves is maintained when aggregated over an entire year. The total wave energy from a year of waves and storms and the total wake wave energy from GPT-bound vessels were estimated. It was found that the total annual wave energy from GPT-calling vessels is 24% as much as the total annual energy from wind-generated waves. Total energy seen at the shoreline would increase by 24% with the additional vessel traffic attributable to the proposed GPT operating at full capacity in 2019.

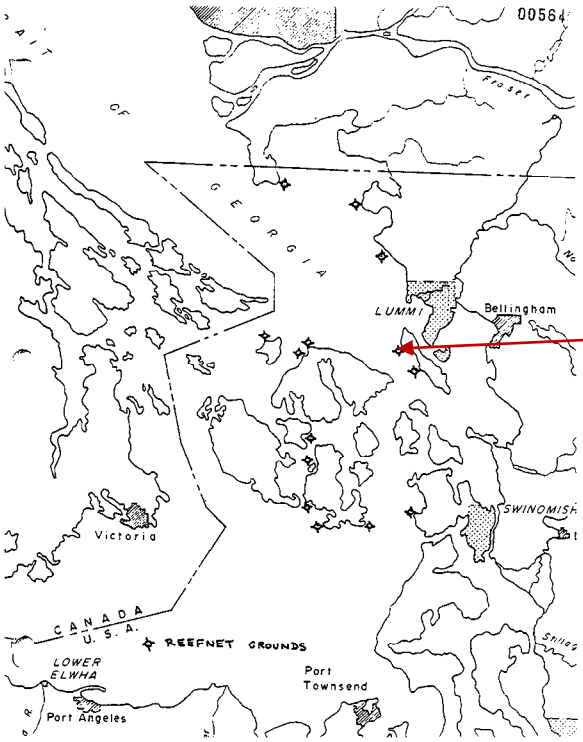

Figure 138 Historic reef net sites marked with 'X,' Reference 72

The analysis is detailed in the six subsections that follow. Section 4.3.2 details the method used to quantify and analyze impact on the Lummi Nation cultural sites. Section 4.3.3 provides background on key principles of the impact analysis method; wake energy. Predicted wake energy due to vessels (Section 4.3.4) and wind (Section 4.3.5) are presented, and these predictions are accumulated over time in Section 4.3.6. Finally, the effect of pier location is discussed in Section 4.3.7.

4.3.2 Method of Impact Analysis

A map of shoreline locations of interest was provided to the GPT VTARAS Work Group by the Lummi Nation (see Figure 138). The shoreline locations were then identified on a chart. With the understanding that the locations of Lummi Nation cultural sites are sensitive information and that the map does not represent all of the cultural sites, Glosten focused their wake analysis on Village Point on the western shoreline of Lummi Island. Village Point was chosen because it is the site nearest to traffic lanes that will be used by GPT-bound deep draft ships and GPT-bound assist and docking tugs. Consequently, it will also have the highest incidence of vessel wake wave height and wake energy.

The impact of increased vessel traffic on the shoreline and cultural properties was measured by comparing two quantities:

1. The arriving wake wave energy of increased vessel traffic (Section 4.3.4).
2. The wave energy at background levels without GPT-bound traffic (Section 4.3.5).

The background wave energy levels chosen for comparison were those produced by an average summer maximum storm and an average annual maximum storm. It was assumed that storm events characterize the energy levels to which the shoreline and cultural properties are exposed without the GPT-bound traffic. In addition, the total annual energy from GPT-calling vessel wake was compared with total annual wave energy from wind driven waves (Section 4.3.6).

There are other locations identified as sites of cultural properties and underwater artifacts that are not exposed to significant wave and storm energy; however, these locations are also not exposed to GPT-bound vessel wakes.

4.3.3 Physical Principles of Wake Energy

Vessel wakes are commonly recognized as the set of waves that trail a moving vessel. Vessel wakes are actually comprised of a set of transverse waves propagating in the same direction as the vessel, and a set of diverging waves propagating at an acute angle to the sailing line (Figure 139). The height of the transverse waves diminishes faster than that of the diverging waves, as the distance from the sailing line increases. Therefore, waves reaching the shoreline are expected to be comprised primarily of diverging waves. The maximum height of these diverging waves is estimated based on *An Empirical Model for Ship-Generated Waves* (Reference 68). The wave pattern remains steady in a vessel-fixed frame of reference. Therefore, wave period and length can be estimated from the vessel speed and the angle the direction of wave propagation makes with the sailing line. Here, the theoretically predicted wave direction is 35°16' (see θ in the middle of Figure 139), though this is theoretically correct only at the cusp locus line.

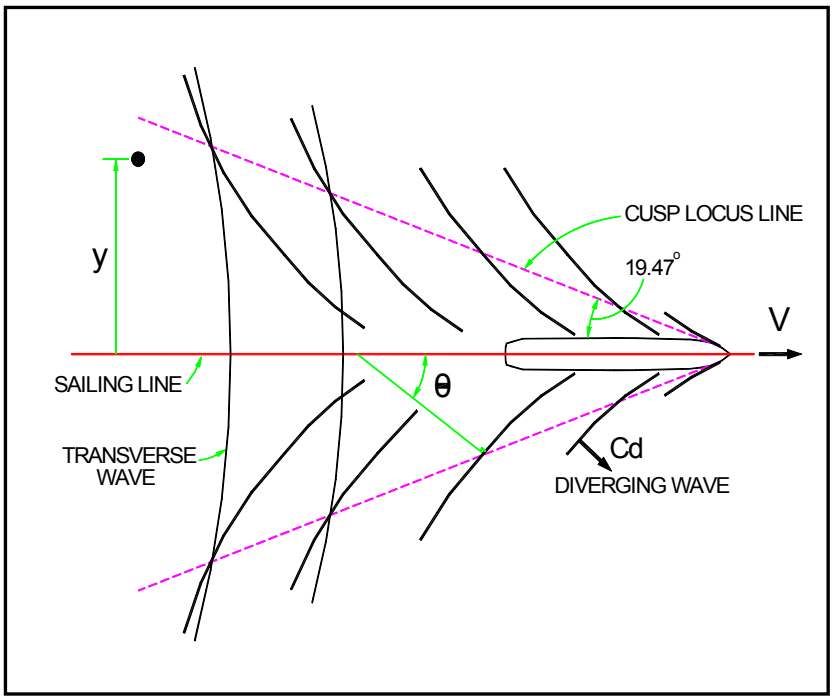

Figure 139 Pattern of wave crests generated by a moving vessel, Reference 68

Once the wave parameters are estimated, the average energy density $\overline{E}$ is given by:

$$\overline{E} = \frac{\rho g H^2}{8} \qquad 4\text{-}1$$

The energy flux, P, is obtained by multiplying the average energy density by the group velocity, c_G:

$$P = \overline{E} c_G \qquad 4\text{-}2$$

The group velocity can be determined as follows:

$$c_G = \frac{1}{2}\left[1 + \frac{2kd}{\sinh(2kd)}\right]c \qquad 4\text{-}3$$

Here, ρ is density of water, g is gravitational acceleration, H is wave height, k is wave number, d is water depth and c is wave celerity (e.g., wave speed) (Reference 89).

4.3.4 Vessel-Generated Wake Energy

The impact of vessel wakes on traditional cultural properties was evaluated by analyzing the wakes from a Capesize bulker, a Panamax bulker, and a tugboat in terms of height, period, energy density, and energy flux. The sailing line was at least one-quarter nautical mile from the shoreline at this location. A southbound vessel would be further from shore. Since the

vessel wake energy decreases with distance, using the shorter distance is a conservative prediction for greater energy. The speed of the bulker was assumed to be 12 knots, and that of the tugboat to be 14 knots, which is a relatively high tugboat speed, but also is a conservative estimate for this wake energy analysis. The water depth was assumed to be 180 feet. Table 115 shows the particulars of the representative vessels used in wake wash calculations. The dead weight tonnage (DWT) in the table is an estimate obtained by scaling based on length from actual bulkers: *M/V San Juan Prospector* (length 835 feet, DWT 69,156 LT) for Panamax and *M/V E. R. Bayern* (length 958 feet, DWT 177,188 LT) for Capesize. The entrance length in the third column is defined as the length from the bow to the start of the parallel middle body. The Panamax bulker dimensions used here are upper bound dimensions for Panamax class.

Table 115 Particulars of vessels used in estimating wake wash

Type	Length, ft	Entrance length, ft	Beam, ft	Draft, ft	Block coefficient	Displ. LT	DWT, LT	Speed, kt
Panamax bulker	950	95	106	39.5	0.836	95,048	78,676	12
Capesize bulker	919	92	148	56	0.827	180,045	169,965	12
Tug boat	139	45	46	12.5	0.600	1,371	-	14

Based on both previous assumptions and parameters given in Table 115, the height, period, energy density, and energy flux of wakes generated by a Capesize bulker, a Panamax bulker, and a tugboat, at a distance of one-quarter nautical mile from the sailing line, are shown in Table 116. Comparisons with similar results for wind-generated waves are shown in the next section.

Table 116 Wave energy from vessel-generated wakes

Source	Height ft	Period sec	Energy Density ($\bar{E}$) ft-lb/ft^2	Energy Flux ($\bar{P}$) ft-lb/ft-sec
Panamax bulker, 12 knots	0.07	3.2	0.04	0.29
Capesize bulker, 12 knots	0.11	3.2	0.10	0.79
Tugboat, 14 knots	1.1	3.8	9	86

4.3.5 Wind-Generated Wave Energy

In order to estimate the severity of wind-generated wave conditions at Lummi Island, a wave hindcast was performed using *Coastal Engineering Design and Analysis System* software (Reference 35). The average of summer maximum and the average of annual maximum wave conditions were hindcast by applying the corresponding wind speeds for Cherry Point taken from Table 117. The seasonal maximums in Table 117 are summarized from National Data Buoy Center historical records for the years 2008-2011 (Reference 57). In the hindcast, they were assumed to blow in the direction of the longest fetch, i.e. from the northwest.

Table 117 Seasonal maximum wind speed (2 minute average in knots) for Cherry Point by year

Season\Year	2008	2009	2010	2011	Average
Spring	-	34	43	36	38
Summer	-	23	29	23	**25**
Fall	38	45	40	40	41
Winter	37	32	42	34	36
Annual Maximum	38	45	43	40	**41**

The calculated wave height, period, energy density, and energy flux corresponding to the average of summer maximum and the average of annual maximum wave conditions are shown in Case A and Case B, respectively, of Table 118. Results for vessel wakes are shown for comparison in the last three rows.

Table 118 Comparison of wave energy from wind-generated waves in summer (Case A), annual (Case B), and from vessel wake by a Panamax bulker (Case C), Capesize bulker (Case D) and by a tugboat (Case E)

Case	Source	Height ft	Period sec	Energy Density ($\bar{E}$) ft-lb/ft^2	Energy Flux (F) ft-lb/ft-sec
A	Wind-generated waves, average summer maximum	4.7*	5.8**	179	2,659
B	Wind-generated waves, average annual maximum	8.2*	7.4**	537	10,215
C	Panamax bulker, 12 knots	0.07	3.2	0.04	0.29
D	Capesize bulker, 12 knots	0.11	3.2	0.10	0.79
E	Tugboat, 14 knots	1.1 (22% of A, 13% of B)	3.8	9 (5% of A, 2% of B)	86 (3% of A, 1% of B)

*Root-mean-square wave height
**Modal period

Table 118 illustrates that the wake created by a Panamax bulker (Case C) is less than that created by a Capesize bulker (Case D) which in turn is small relative to that created by a tugboat. The tugboat wake (Case E) could be 22% of a summer maximum storm wave in terms of height. However, the tugboat wake has only 5% of the energy density $\bar{E}$ of a summer maximum storm wave, and 3% of the energy flux F of a summer maximum storm wave. The tugboat wake has 13% of the height of an annual maximum storm wave. It has 2% of the energy density $\bar{E}$ of an annual maximum storm wave, and only 1% of the energy flux F of an annual maximum storm wave.

Criteria are not well established for vessel wake height, energy density, and energy flux that will minimize adverse effect on shoreline morphology and damage to nearshore underwater properties. Nonetheless, this analysis shows that the wake wash energy from GPT-calling bulkers and tugboats is a small percentage of the annual maximum storm wave energy arriving at Lummi Island via wind-generated waves.

4.3.6 Total Annual Energy Over One (1) Year

In Sections 4.3.4 and 4.3.5, wake generated by a passing GPT-calling vessel was compared with waves generated in a windstorm, in terms of wave height, energy density, and energy flux. In this section, the total annual energy from all GPT-calling vessels is estimated, and compared with the total annual energy from all wind-generated waves.

The total annual energy over one year from GPT vessel traffic $\overline{E}_{\text{year,vessel}}$ is estimated by multiplying the energy flux due to vessel wake P_{vessel} by the duration of shoreline exposure T to such wakes:

$$\overline{E}_{\text{year,vessel}} = P_{\text{vessel}} T \qquad 4\text{-}4$$

Table 4-6 of Reference 114 indicates that when the proposed GPT is fully operational, 487 vessels are expected to call every year. Considering both inbound and outbound transits, this translates to 974 bulker transits per year. Two tugs will also transit past Lummi Island en route to assisting each bulker call at the terminal. This translates to 1948 tug transits per year. The length of time that Village Point is exposed to wakes is the exposure duration. Energy arriving at the shoreline is found by the multiplying of number of transits, exposure duration per transit (assumed to be one hour), and energy flux P_{vessel}. This energy calculation is done separately for the tugs and the bulkers, and then the total annual energy is the sum from the two vessel types. Total annual energy arriving at the shoreline is $\overline{E}_{\text{year,vessel}}$ 6.1×10^{8} ft-lbs per foot of shoreline. This is to be compared with the total annual energy from wind-generated waves $\overline{E}_{\text{year,waves}}$. In the absence of wave measurements, an estimate of this is derived from the wind measurements at Cherry Point (Reference 57). Table 119 shows the joint probability of wind speed and direction at Cherry Point developed from wind records for the years 2009 through 2012. Wind speeds are 2-minute averages and the measurement elevation was interpreted to be 27 feet above mean sea level. The number of hours in a year that each of these combinations prevails can be calculated by multiplying the probability by the total number of hours in a year.

Table 119 Joint probability of wind speed and direction at Cherry Point

Wind Direction /Speed	North	North-east	East	South-east	South	South-West	West	North-west
0 - 5 knots	3.07%	3.46%	3.98%	9.46%	6.96%	2.37%	2.54%	3.21%
5 - 10 knots	1.37%	4.46%	3.24%	9.71%	8.22%	1.71%	1.78%	3.66%
10 - 15 knots	0.16%	4.16%	1.91%	4.80%	4.75%	1.88%	0.56%	1.35%
15 - 20 knots	0.01%	1.55%	0.65%	1.91%	1.81%	1.25%	0.36%	0.43%
20 - 25 knots	-	0.30%	0.15%	0.65%	0.60%	0.43%	0.18%	0.17%
25 - 30 knots	-	0.06%	0.01%	0.16%	0.23%	0.09%	0.03%	0.03%
30 - 35 knots	-	-	-	0.03%	0.08%	0.01%	-	-
35 - 40 knots	-	-	-	0.01%	0.03%	-	-	-
40 - 45 knots	-	-	-	0.01%	0.01%	-	-	-
45 - 50 knots	-	-	-	-	-	-	-	-

For each combination of wind speed and wind direction in Table 119, wave conditions were hindcast using *Coastal Engineering Design and Analysis System* software (Reference 35 and Reference 39). The hindcast is for Village Point, and this assumed that wind speed and direction measured at Cherry Point applies to Village Point. The resulting root-mean-square wave height, H_{rms}, and modal period, T_p, combinations are shown in Table 120. The modal period is the period corresponding to the peak of the wave energy spectrum. In other words, T_p is the wave period with the most wave energy. Since Village Point is located on the western shore of Lummi Island, winds from the east and northeast will not generate any waves that can reach that point. Therefore, the columns in Table 120 corresponding to winds from the east and northeast do not contain any sea state.

Table 120 Hindcast sea states for various wind speed/direction combinations at Village Point

Wind Direction/Speed	North	North-east	East	South-east	South	South-West	West	North-west
0 – 5 knots	H_{rms}=0.2ft T_p=1.4s	-	-	H_{rms}=0.4ft T_p=2.1s	H_{rms}=0.4ft T_p=2.1s	H_{rms}=0.3ft T_p=1.4s	H_{rms}=0.3ft T_p=1.7s	H_{rms}=0.4ft T_p=2.1s
5 – 10 knots	H_{rms}=0.6ft T_p=2.7s	-	-	H_{rms}=0.9ft T_p=2.5s	H_{rms}=0.9ft T_p=2.6s	H_{rms}=0.7ft T_p=2.3s	H_{rms}=0.9ft T_p=3.2s	H_{rms}=1.3ft T_p=3.9s
10 - 15 knots	H_{rms}=1.2ft T_p=3.8s	-	-	H_{rms}=1.3ft T_p=3.1s	H_{rms}=1.4ft T_p=3.0s	H_{rms}=1.1ft T_p=2.8s	H_{rms}=1.7ft T_p=3.7s	H_{rms}=2.5ft T_p=5.5s
15 - 20 knots	H_{rms}=1.9ft T_p=4.8s	-	-	H_{rms}=1.9ft T_p=3.5s	H_{rms}=1.9ft T_p=3.6s	H_{rms}=1.6ft T_p=3.3s	H_{rms}=2.8ft T_p=5.8s	H_{rms}=3.6ft T_p=5.0s
20 - 25 knots	H_{rms}=2.8ft T_p=5.7s	-	-	H_{rms}=2.3ft T_p=3.8s	H_{rms}=2.4ft T_p=3.9s	H_{rms}=2.0ft T_p=3.6s	H_{rms}=3.7ft T_p=5.2s	H_{rms}=4.7ft T_p=5.8s
25 - 30 knots	H_{rms}=3.6ft T_p=5.2s	-	-	H_{rms}=2.9ft T_p=4.3s	H_{rms}=3.0ft T_p=4.3s	H_{rms}=2.4ft T_p=3.9s	H_{rms}=4.5ft T_p=5.7s	H_{rms}=5.7ft T_p=6.3s
30 - 35 knots	H_{rms}=4.3ft T_p=5.4s	-	-	H_{rms}=3.4ft T_p=4.5s	H_{rms}=3.5ft T_p=4.6s	H_{rms}=2.9ft T_p=4.2s	H_{rms}=5.4ft T_p=6.2s	H_{rms}=6.7ft T_p=6.6s
35 - 40 knots	H_{rms}=5.0ft T_p=6.0s	-	-	H_{rms}=4.0ft T_p=4.8s	H_{rms}=4.1ft T_p=4.9s	H_{rms}=3.4ft T_p=4.5s	H_{rms}=6.3ft T_p=6.6s	H_{rms}=7.8ft T_p=7.3s
40 - 45 knots	H_{rms}=5.7ft T_p=6.3s	-	-	H_{rms}=4.6ft T_p=5.2s	H_{rms}=4.7ft T_p=5.3s	H_{rms}=3.9ft T_p=4.9s	H_{rms}=7.2ft T_p=7.0s	H_{rms}=8.9ft T_p=7.7s
45 - 50 knots	H_{rms}=6.4ft T_p=6.7s	-	-	H_{rms}=5.1ft T_p=5.4s	H_{rms}=5.3ft T_p=5.4s	H_{rms}=4.3ft T_p=5.1s	H_{rms}=8.0ft T_p=7.3s	H_{rms}=10.1 ft T_p=8.1s

The energy flux in a sea state can be calculated by substituting the root-mean-square height and modal period into Equation 4-2. A sea state is assumed to prevail for the same amount of time as the wind speed and direction combination that generates it. Therefore, the amount of time a sea state prevails is calculated by multiplying the probability from the corresponding cell of Table 119 by the total number of seconds in a year. The total annual energy arriving at the shoreline can then be estimated by multiplying the energy flux for each sea state in Table 120 by the amount of time that sea state prevails, and summing up the products from all the cells in Table 120. This procedure yields a total annual energy $\overline{E}_{\text{year,waves}}$ of 2.6×10^9 ft-lbs per foot of shoreline. This was performed and compared with the total annual energy from vessel wake $\overline{E}_{\text{year,vessel}}$, which was calculated to be 6.1×10^8 ft-lbs. Thus, the total annual energy

from GPT-calling vessels $\overline{E}_{\text{year,vessel}}$ is 24% (= 6.1×10^8 / 2.6×10^9) as much as the total annual energy from wind-generated waves $\overline{E}_{\text{year,waves}}$.

4.3.7 Effect of Pier Location

The alternative alignment for the wharf is an alignment discussed by the state agencies. It has been included in the study for assessment purposes only. PIT does not propose this alignment as part of the Gateway Pacific Project. Pier location does not meaningfully affect the analysis of this section. The two alternative pier locations are close to each other and differ mainly in their alignments by about 20 degrees (Figure 140). The vessel route to either alternative will be identical except for the final approach and berthing. The final approach and berthing involve slow speed maneuvering which does not produce significant wake. In view of the above, no measurable difference is expected in the potential impact to cultural properties due to wave energy differences by choosing one alternative over the other.

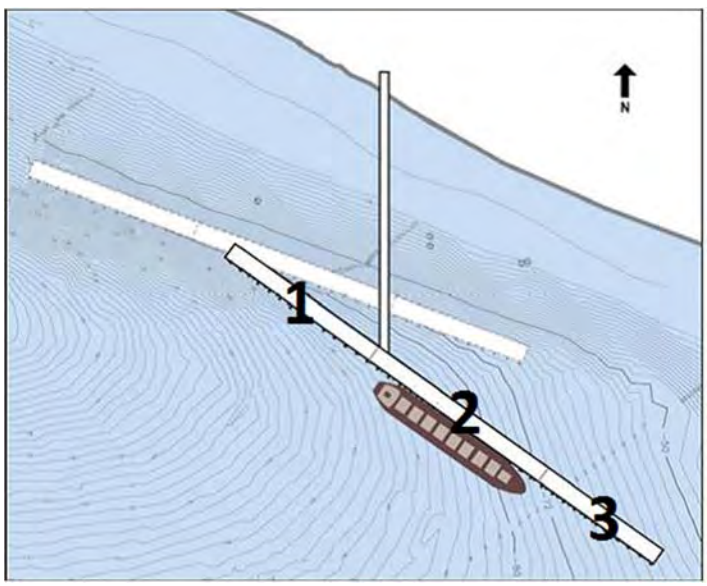

Figure 140 Second wharf alignment; Berths 1-3 labeled

4.4 Traffic Impact on Tribal Fishing

4.4.1 Introduction

This section addresses the current fishing practices of the Lummi Nation, and the potential impacts of the proposed GPT on those fishing practices. The analysis estimates where and when the Lummis currently fish and assesses how GPT-related vessels could disrupt this fishing. Two forecast cases were considered: Case A is the baseline 2019 traffic level, and Case B adds to Case A: GPT-calling bulkers, assist tugs, and tugs and tank barges which support GPT bunkering. The difference between Case A and Case B is the impact of the proposed GPT. For the purpose of this analysis the study team focused on only these two cases in order to highlight the impact of GPT-calling traffic on Lummi fishers.

In measuring the disruption of Lummi fishing time due to GPT-related vessels, the study team took into account both time and area. The goal was to measure the time and area that Lummis

fish (referred to as water-day-areas), measure the time and area that passing vessels disrupt this fishing activity (referred to as vessel-day-areas), and compare the magnitude of the disruption with and without GPT-calling vessels. The analysis predicts that GPT would increase the Lummi fishing disruption by 76% in Cherry Point and 19% in Saddlebag, compared to baseline vessel traffic in 2019. Although the analysis shows that Juan de Fuca East will see the greatest relative increase in disruption, this increase is largely due to the time and area occupied by GPT vessels at anchor and associated bunkering activity at Port Angeles. As Port Angeles is outside of the Lummi U&A, the disruption to Lummi fishers in the Juan de Fuca East subarea will be less than computed for the entire subarea.

A secondary aspect of disruption is the loss of Lummi fishing gear due to GPT vessel traffic. The study team relied on information provided by the Lummi Natural Resources Department to estimate potential gear loss resulting from GPT-related vessel traffic.[48] Questionnaire responses (Section 4.2) suggested that for every 5% increase in vessel traffic, Lummi fishermen would expect to lose an additional two (2) to three (3) Dungeness crab pots or traps. If gear loss changes proportionately with traffic changes, the study team estimates that in Case A, fishers will expect to lose an additional four pots in Haro Strait-Boundary Pass or less than three additional pots in Juan de Fuca East. However, in Guemes Channel Fidalgo Bay, Saddlebag, Rosario Strait or Cherry Point—where rail projects are expected to lower the volume of vessel transits—fishers may actually see a decrease in gear loss.

In Case B, vessel traffic estimates in all subareas increase, in turn generating increases in gear loss estimates. With the addition of GPT, gear loss per Lummi fisher is expected to increase by thirteen pots or less in Juan de Fuca East, one pot in Guemes Channel Fidalgo Bay, nine pots in Rosario Strait, and nearly fifteen pots in Cherry Point. For example, it is estimated that a fisherman who would lose 45 pots in the Cherry Point subarea in Case A (without GPT) would lose 60 pots (33% more) in Case B (with-GPT). In contrast, a fisherman with pots in Haro Strait-Boundary Pass would expect to lose about the same number with or without GPT (reflecting a near 0% difference) as vessel traffic day increases are small in this subarea.

Section 4.4.2 reviews the fishing practices of the Lummi Nation. Section 4.4.3 describes the calculation of water-day areas of Lummi Fishing, the forecasted disruption by non-GPT vessels, and the forecasted disruption by GPT-related vessels. Section 4.4.4 compares the impact of the Case A forecasted disruption to the Case B forecasted disruption. Section 4.4.5 describes the potential gear loss that could result from GPT-related vessels.

4.4.2 The Lummi Fishers

The Lummis are the original Native American inhabitants of Washington's northernmost coast and Southern British Columbia. The Lummi people collectively form the Lummi Nation, which is a self-governing nation within the United States, and the third largest tribe in Washington State (Reference 71).

Traditionally a fishing people, the Lummis pride themselves on their seafood harvesting traditions and continue to successfully operate within the Puget Sound fisheries, targeting a wide range of species including Sockeye, Pink, Chinook, Coho, Chum, Steelhead, Crab,

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[48] While beyond the scope of this study, going forward, the study team recommends that additional data be gathered regarding the location, timing, and magnitude of gear loss by type.

Shrimp, Halibut, Clams, Oysters, Sea Cucumber, Sea Urchin, and Geoduck. While the Lummis also fish for subsistence and ceremonial use, 90% of their fisheries are commercial (Appendix F).

The salmon fishery, which combined makes up the largest share of the Lummi's harvest, comprises five species: Sockeye, Pink, Chinook, Coho, and Chum (Appendix F). The Lummis process those fisheries using three gear types – drift gillnet, set gill net, and seine. In 2013 the Lummis fished a reef net for subsistence and ceremonial purposes, and plan to do the same during 2014 (Appendix F).

Lummis fish in portions of all of the subareas of the study area except for Juan de Fuca West. Table 121, requested from the Lummis by the study team, provides an estimate of the percentage of time spent in each area during fishing trips for each species. It is noted that some fishers may choose to fish exclusively within a particular subarea, perhaps at a location designated for elders or specific practices (hand pulled versus mechanically pulled nets) while other fishers may choose to fish throughout the U&A. The two areas that see the most fishing activity are Saddlebag and Cherry Point. Combined, the salmon fisheries make up the largest of the Lummis' harvests by volume, and the bulk of that fishing (approximately 55%) takes place in those areas. The Dungeness crab fishery, the Lummi's second most significant fishery by harvest volume, is heavily concentrated in the Cherry Point subarea.

According to the Lummi Natural Resources Department, Lummi will be expanding its geoduck fishery in 2014 to the Alden Bank geoduck tract also located in the Cherry Point subarea. Current plans are for up to fifteen vessels to be anchored there conducting commercial diving operations. In addition, Point Roberts, also in the Cherry Point subarea, is scheduled to be surveyed for geoduck clams in 2014.

4.4.3 Methodology

In measuring the disruption of fishing time due to GPT-related vessels, the study team had to take into account both time and area. The goal was to measure the time and area that Lummis fish (referred to as water-day-areas), measure the time and area that passing vessels disrupt this fishing activity (referred to as vessel-day-areas), and compare the magnitude of the disruption with and without GPT-calling vessels. This disruption is a relative measure, expressed as the percentage of time and area that non-Lummi vessels occupy relative to water-day-areas.[49]

4.4.3.1 Calculate Water-Day-Areas of Lummi Fishing

The first step in this analysis was to understand where the Lummis are fishing, and how often they are fishing. Unlike larger fishing vessels, Lummi fishing boats are not tracked by AIS. Few records exist which can tell us details about Lummi transits. Consequently, the study team relied on information provided by the Lummi Tribe to conduct the analysis.

Strait of Juan de Fuca West and the San Juan Islands were excluded from the analysis. According to the Lummi Natural Resources Department, the Lummis currently fish in some portion of all the study subareas with the exception of Juan de Fuca West (Table 121). The San Juan Islands are not within the project study area, but the Lummis do fish there. The

[49] Units of measurement for both water-day-areas and vessel-day-areas are vessel-day square nautical miles. Vessel day estimates for non-Lummi vessels are measured in fractions of days.

remainder of time spent fishing for each fish type in the below table can be assumed spent in the San Juan Islands.

Table 121 Percent of Lummi fishing time spent in study area, by subarea (Appendix F)

Fishery	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddle-bag	Guemes Channel	Cherry Point	Total
Salmon	0%	10%	10%	10%	35%	5%	20%	90%
Halibut	0%	23%	23%	10%	2%	2%	20%	80%
Dungeness Crab	0%	0%	10%	10%	10%	5%	55%	90%
Clams & Oysters (no vessel time)	0%	0%	0%	0%	46%	4%	46%	96%
Geoduck	0%	50%	0%	20%	30%	0%	0%	100%
Sea Urchins and Sea Cucumbers	0%	10%	10%	10%	5%	10%	10%	55%
Shrimp	0%	23%	25%	10%	5%	2%	15%	80%

Source: Lummi Natural Resources Department 2014.

To gain information on the location of the Lummi fishing fleet, landing data are reported by the Lummi Tribe using Lummi Tribe fish ticket data for each species by year (Table 122). These data capture the total number of trips with a landing and were used as a proxy for the total number of trips taken for each species from 2006 through 2011.

Table 122 Lummi fish tickets by species and year (trips)

Fishery	2006	2007	2008	2009	2010	2011
Salmon	4,091	4,931	5,101	4,110	5,634	6,418
Halibut	294	297	188	120	281	216
Dungeness Crab	3,649	3,984	4,493	5,059	4,330	4,353
Clams & Oysters (no vessel time)	5,059	4,366	3,699	2,302	3,715	3,078
Geoduck	9	0	25	20	12	22
Sea Urchins & Sea Cucumbers	250	200	247	465	660	754
Shrimp	72	62	49	52	90	72

Source: Lummi Natural Resources Department 2014.

Using the total number of trips (Table 122) and the percent of Lummi fishing time spent in each area (Table 121), the study team calculated the average number of fishing trips by area (Table 123).

Table 123 Annual average Lummi fishing trips by area, 2006-2011

Fishery	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddle-bag	Guemes Channel	Cherry Point	San Juan Islands
Salmon	433	433	433	1514	216	865	433
Halibut	46	46	20	4	4	40	40
Dungeness Crab	0	370	370	370	185	2032	370
Clams & Oysters (no vessel time)	0	0	0	1460	127	1460	127
Geoduck	6	0	3	4	0	0	0
Sea Urchins & Sea Cucumbers	37	37	37	18	37	37	166
Shrimp	13	14	6	3	1	9	11

Source: Northern Economics, Inc. 2013

To convert the number of trips taken in each subarea to water-days, the study team multiplied the number of fishing trips in each subarea (Table 123) by fishing trip duration estimates per species provided by the Lummi Tribe (Table 124).

Table 124 Number of hours per trip (landing)

Fishery	Length (hours)	Average (hours)	Water-Days
Salmon	6-12	9	0.38
Halibut	8-14	11	0.46
Dungeness Crab	6-10	8	0.33
Clams & Oysters	These trips do not use vessels	N/A	N/A
Geoduck	6	6	0.25
Sea Urchins & Sea Cucumbers	6-12	9	0.38
Shrimp	6-10	8	0.33

Source: Lummi Natural Resources Department 2014.

The total number of water-days and average time spent in each subarea are presented in Table 125. The majority of fishing effort was allocated to the Cherry Point and Saddlebag subareas.

Table 125 Water-days by subarea and species

Fishery	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddlebag	Guemes Channel	Cherry Point
Salmon	162	162	162	568	81	324
Halibut	21	21	9	2	2	18
Dungeness Crab	0	123	123	123	62	677
Clams & Oysters (no vessel time)	0	0	0	0	0	0
Geoduck	2	0	1	1	0	0

Fishery	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddlebag	Guemes Channel	Cherry Point
Sea Urchins & Sea Cucumbers	14	14	14	7	14	14
Shrimp	4	5	2	1	0	3
Total	203.0	325.0	310.9	701.6	158.7	1036.9
Percent of Time in Subarea	7%	10%	10%	23%	5%	33%

Source: Northern Economics, Inc. 2013

While Table 125 presents effort by subarea and species, it does not accurately portray total fishing days as multiple trips could take place in a single day (refer to Table 123). To account for this, the study team asked the Lummis to estimate the number of days each year that at least one landing occurred. The Lummi Natural Resources Department supplied the study team with the information summarized in Table 126.

Over the past six years, an average of 312 days were fished each year (assuming that there was at least one landing for every day fished). This equates to approximately 26 days fished each month.[50]

Table 126 Number of days that a Lummi FV landing occurred by year and month, 2006-2011

Month	2006	2007	2008	2009	2010	2011	Six year Average
Jan	21	26	24	29	21	28	25
Feb	23	27	19	27	28	25	25
Mar	28	31	21	27	30	28	28
Apr	29	17	28	26	16	28	24
May	14	2	27	23	28	27	20
Jun	29	28	26	28	28	30	28
Jul	19	24	26	24	26	29	25
Aug	30	30	26	29	28	31	29
Sep	29	29	29	30	30	30	30
Oct	31	31	31	30	31	31	31
Nov	24	27	28	24	28	30	27
Dec	26	22	20	23	22	16	22
Average	303	294	305	320	316	333	312

Note: data are numbers of days in which at least one Lummi fishing vessel is on the grounds; in most cases there are many vessels on the grounds on any given day.
Source: Lummi Natural Resources Department, 2013

[50] Number of days in which at least one Lummi fishing vessel is on the grounds; in most cases there are many vessels on the grounds on any given day.

The six-year average annual number of days that a landing occurred (312) was allocated over subareas based on the proportion of time spent fishing in each subarea (Table 125). The results of this allocation are shown below in Table 127.

As dictated by the scope, the study team had to take into account both time and area in measuring the disruption of fishing time due to GPT-related vessels. The goal was to measure the time and area that Lummis fish (referred to as water-day-areas), measure the time and area that passing vessels disrupt this fishing activity (referred to as vessel-day-areas), and compare the magnitude of the disruption with and without GPT-calling vessels. The days shown in Table 127 were multiplied by the total square nautical miles represented by each subarea to yield an estimate of water-day-areas (the total time and area where Lummis fish). While the total area for the subarea Strait of Juan de Fuca East was used in this calculation, it is understood that the Lummi U&A does not encompass this entire area.

Table 127 Lummi annual water-day areas

Subarea	Total Area (nm^2)	Average Days Boats are on the Water (2006-2011)	Water-Day-Areas (nm^2)
Strait of Juan de Fuca West	445	0	0
Strait of Juan de Fuca East	471	20	9,594
Haro Strait-Boundary Pass	64	33	2,086
Rosario Strait	57	31	1,786
Saddlebag	104	70	7,294
Guemes Channel	28	16	450
Cherry Point	231	104	24,047

Source: Northern Economics, Inc. 2014

According to the Lummi Natural Resources Department (Appendix F),

> *"The number of fishers (and vessels) participating (in the fisheries) in any given year depends on the abundance of salmon, halibut, crab and shrimp in that year as well as the abundance of these species during immediately preceding years. The abundance of these species in previous years contributes to the ability of fishers to have the financial means to pay the overhead costs associated with being a commercial fisher. The number of participants in 2011 is probably similar to the number in 2012."*

Given this variability, the study team used the 5-year average number of landing days to calculate water-day-areas, and held this constant for 2019.[51]

4.4.3.2 Calculate the Forecasted Disruption of Traffic by Case

In Tables 15 and 17 of Appendix A (by Northern Economics, Inc.) the historical and current patterns of traffic in North Puget Sound were examined and used to forecast vessel activity in the study area. The study team modeled two future traffic scenarios: Case A is the baseline

[51] The most recent five years of data were assumed to be a stronger indicator of the immediate future, so the entire 1995-2010 dataset was not used in this analysis by NEI.

2019 traffic level, and Case B adds to Case A GPT-calling bulkers, assist tugs, and tugs and tank barges which support GPT bunkering. The difference between Case A and Case B is the impact of the proposed GPT. For the purpose of this analysis, the study team focused on only these two cases in order to highlight the impact of GPT-calling traffic on Lummi fishers.

Results from vessel traffic modeling (Appendix A) provided the study team with an estimate of time spent by activity for vessels in each study subarea (Table 128 through Table 131). In 2019 with the proposed GPT operating at full capacity, the expected 487 deep draft vessels, the required assist tugs, and bunkering vessels will increase vessel traffic in the Lummi's usual and accustomed fishing areas. The increase will vary by subarea, with the largest increase being 33% in vessel traffic in the Cherry Point subarea.

Table 128 Case A, transit and at-dock vessel days by subarea, 2019

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tanker	257	279	29	225	9	48	338	1,185
Tank Barge	84	122	28	227	42	60	406	969
Bulker	1,042	567	265	166	88	7	418	2,555
General Cargo	131	80	30	9	0	1	30	281
Container	486	268	90	1	206	2	82	1,136
Tugs	385	828	123	667	296	389	1,165	3,852
Fishing Vessels	177	75	0	1,263	1,715	3	0	3,233
Passenger Vessels	116	990	307	867	431	31	336	3,078
Total	2,679	3,210	873	3,425	2,786	541	2,776	16,290

Table 129 Case A, at-anchor vessel days by subarea, 2019

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	0	358	0	242	243	0	9	852
Tank Barge	0	161	0	140	53	0	0	355
Bulker	0	96	0	11	2	0	6	115
General Cargo	0	10	0	2	0	0	0	12
Container	0	6	0	0	0	0	0	6
Tugs	1	230	3	204	133	5	0	578
Fishing Vessels	0	0	0	0	0	0	0	0
Passenger Vessels	0	0	0	0	0	0	0	0
Total	1	861	3	599	432	5	15	1,917

Table 130 Case B, transit and at-dock vessel days by subarea, 2019

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Tanker	257	279	29	225	9	48	338	1,185
Tank Barge	84	145	28	289	42	67	406	1,061
Bulker	1,354	797	278	175	102	83	1,099	3,887
General Cargo	131	80	30	9	0	1	30	281
Container	486	268	90	1	206	2	82	1,136
Tugs	385	891	123	737	397	422	1,402	4,358
Fishing Vessels	177	75	0	1,263	1,715	3	0	3,233
Passenger Vessels	116	990	307	867	431	31	336	3,078
Total	2,991	3,526	886	3,565	2,901	656	3,695	18,219

Table 131 Case B, at-anchor vessel days by subarea, 2019

Vessel Type	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point	Total
Tanker	0	358	0	242	243	0	9	852
Tank Barge	0	221	0	140	53	0	0	415
Bulker	0	765	0	11	89	0	6	871
General Cargo	0	10	0	2	0	0	0	12
Container	0	6	0	0	0	0	0	6
Tugs	1	290	3	204	133	5	0	638
Fishing Vessels	0	0	0	0	0	0	0	0
Passenger Vessels	0	0	0	0	0	0	0	0
Total	1	1,650	3	599	519	5	15	2,793

In order to gauge the magnitude of proposed GPT's impact on Lummi fishing, the study team used the time calculated above (in vessel traffic days) and combined it with the area that the vessel traffic in each of the three project cases will occupy (nautical miles). This metric, referred to as the disruption, is a measurement of day-area (vessel traffic days and square nautical miles).

The vessel types included in the vessel traffic study vary widely in size. The study team assigned average lengths and widths (breadths) to each vessel type to gauge the amount of surface area that each vessel occupies as it travels through the study area (Table 132). Sources

of vessel dimensions used to determine averages included the MX data (Section 3.2.3.1) and incident database (Section 3.3.3.2). In addition, it is estimated that all vessels at anchor will take up an anchorage space 600 yards in radius (or 0.28 nm^2).[52] This 0.28 nm^2 would increase the "Displaced Area" (final column of Table 132) for all vessels at anchor.

Table 132 Non-GPT calling vessels, by size

Vessel Type	Average Length (ft)	Average Breadth (ft)	Homeland Security Zone (ft)	Displaced Area Displaced (ft^2)	Displaced Area (nm^2)
Tanker	711	111	300	931,822	0.025
Tank Barge	288	69	300	593,556	0.016
Bulker	599	93	-	55,688	0.002
General Cargo	646	100	-	64,677	0.002
Container	858	114	-	97,711	0.003
Tug	97	34	-	3,298	0.000
Fishing Vessel	142	71	-	10,082	0.000
Passenger Vessel	311	62	300	603,082	0.016

Note: Displaced area for Tanker, Tank Barge, and Passenger Vessel is calculated as (length + 2×buffer) × (breadth + 2×buffer), where the buffer length is the Homeland Security Zone (column 3) (Reference 75)

The study team multiplied vessel days (Table 128 through Table 131) with vessel size (Table 132) and anchorage space size (0.28 nm^2) to generate an estimate of the area that each vessel type will disrupt as it anchors or travels through the study area. The results of this calculation are summarized in Table 133 and Table 134.

Table 133 Case A estimated disruption in vessel day nm^2, 2019

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
Total Lummi Fishing Vessel Days-Area	N/A	9,594	2,086	1,786	7,294	450	24,047
Case A Transit and At-Dock Disruption (Days-Area)	N/A	27	7	24	9	3	22
Case A At-Anchor Disruption (Days-Area)	N/A	241	1	168	121	2	4
Facility Disruption		0	0	0	0	0	0
Total Case A Disruption	N/A	268	8	192	130	4	26
Total Case A Disruption as Percent of Total Lummi Fishing Vessel Days-Area (%)	N/A	2.79	0.37	10.74	1.78	0.95	0.11

[52] This is the size of the majority of individual anchorage spaces within the study area.

Table 134 Case B estimated disruption in vessel day nm^2, 2019

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
Total Lummi Fishing Vessel Days-Area	N/A	9,594	2,086	1,786	7,294	450	24,047
Case B Transit and At-Dock Disruption (Days-Area)	N/A	28	7	25	9	3	23
Case B At-Anchor Disruption (Days-Area)	N/A	462	1	168	145	2	4
Facility Disruption		0	0	0	0	0	19
Total Case B Disruption	N/A	490	8	193	155	4	45
Total Case B Disruption as Percent of Total Lummi Fishing Vessel Days-Area (%)	N/A	5.10	0.38	10.80	2.12	1.00	0.19

In addition to the GPT-related vessel traffic, the study team took into account the disruption that the wharf and overwater portion of the access trestle itself will generate. The proposed terminal will include a deep-draft wharf with access trestle (Figure 141). The study team estimates that these elements, combined with a 400-foot security buffer zone, will occupy approximately 1.88 million square feet (or 0.051 nm^2) of space,[53] 365 days a year (18.59 in days-area).

[53] An alternate pier location or orientation would change the footprint square footage relatively very little, if at all.

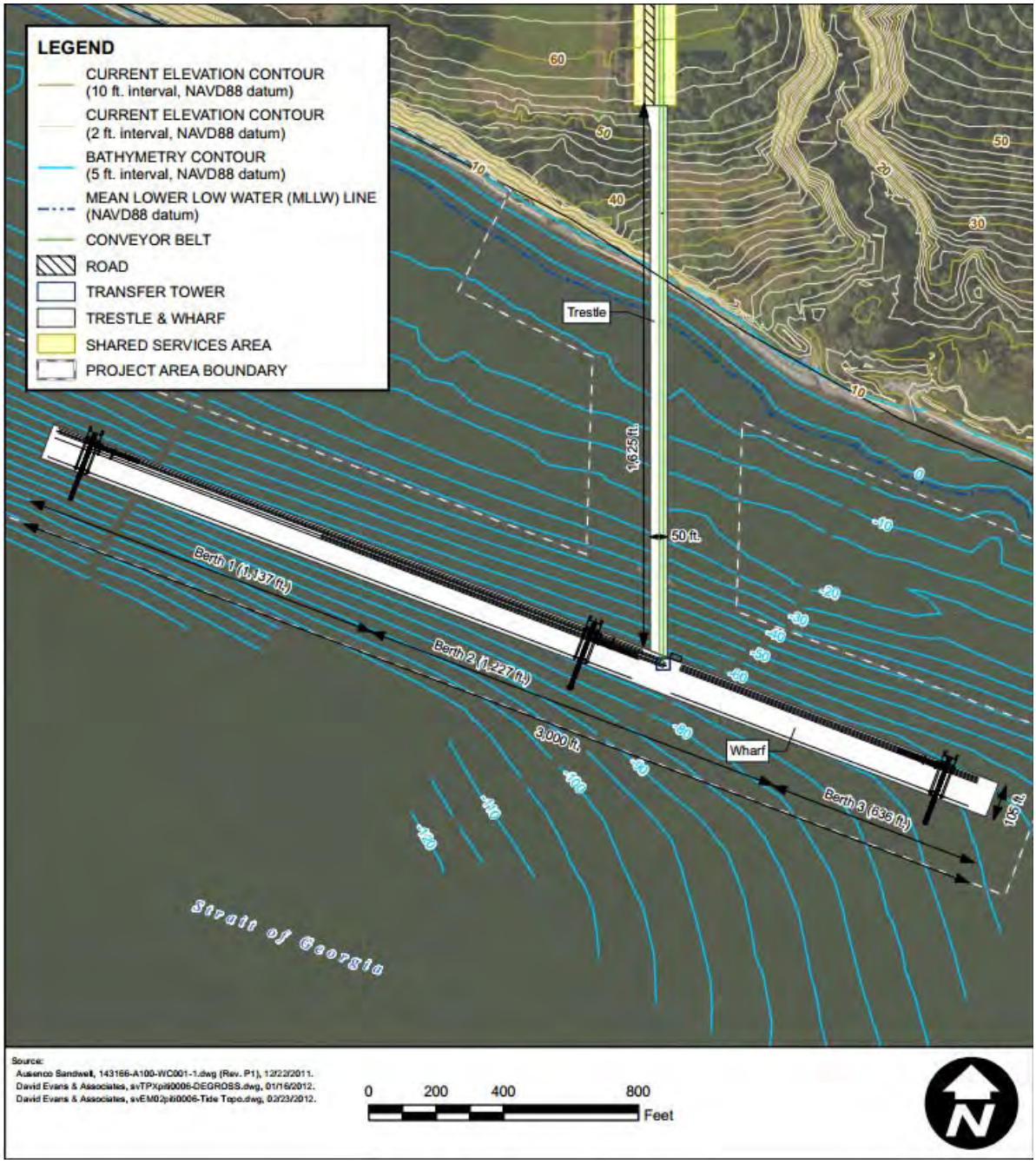

Figure 141 Proposed GPT facility, Reference 114

4.4.4 Results

At full build-out, the proposed GPT is expected to accommodate 487 vessels per year. For each bulker call at GPT, there will be two assist tugs providing maneuvering and docking support. In addition, some GPT-bulkers are also expected to bunker within the study area; tug and tank barge moves required to support this bunkering are considered GPT-related traffic. The difference between Case B disruption and Case A disruption is the total GPT-related disruption (Table 135).

Table 135 GPT- related disruption in vessel day nm^2, 2019

Activity	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point
Total Fishing Vessel Days-Area	N/A	9,594	2,086	1,786	7,294	450	24,047
In Transit and At-Dock Disruption (Days-Area; Case B – Case A)	N/A	0.7	0.0	1.0	0.0	0.2	1.0
At-Anchor Disruption (Days-Area; Case B – Case A)	N/A	220.9	0.0	0.0	24.4	0.0	0.0
Facility Disruption (Days-Area; Case B – Case A)		0.0	0.0	0.0	0.0	0.0	18.6
Total GPT-Related Disruption (Days-Area; Case B – Case A)	N/A	221.6	0.0	1.0	24.5	0.2	19.6
GPT-Related Disruption as Percent of Total Lummi Fishing Vessel Days-Area (%)	N/A	2.31	0.00	0.06	0.34	0.05	0.08
GPT-Related Disruption as Percent of Total Case A Disruption (%) (Case B - Case A) / Case A	N/A	82.65	0.24	0.53	18.79	5.33	76.43

GPT-related vessels are expected to increase vessel traffic days in all study subareas; yet, the disruption calculation is driven by time at-anchor. The largest vessel day nm^2 disruption is expected at-anchor in Juan de Fuca East (462 vessel day nm^2), followed by at-anchor in Saddlebag (145 vessel day nm^2). GPT bulkers are expected to anchor in Port Angeles while undergoing bunker operations; thus the large Juan de Fuca East increase is attributed to tugs and tank barges, as well as bulkers. The Lummi U&A includes portions of the Juan de Fuca East subarea but does not extend to Port Angeles. Consequently, the disruption to Lummi Fishers for this subarea will be less than forecast by this analysis. Increases in Saddlebag are due to forecasted anchoring by GPT bulkers. The steady state queueing analysis predicted approximately two GPT-calling bulkers queuing at anchor at any given time (Section 2.4.5.3). The facility disruption in Cherry Point is attributable to the physical area that the proposed GPT facility will occupy (Figure 142).

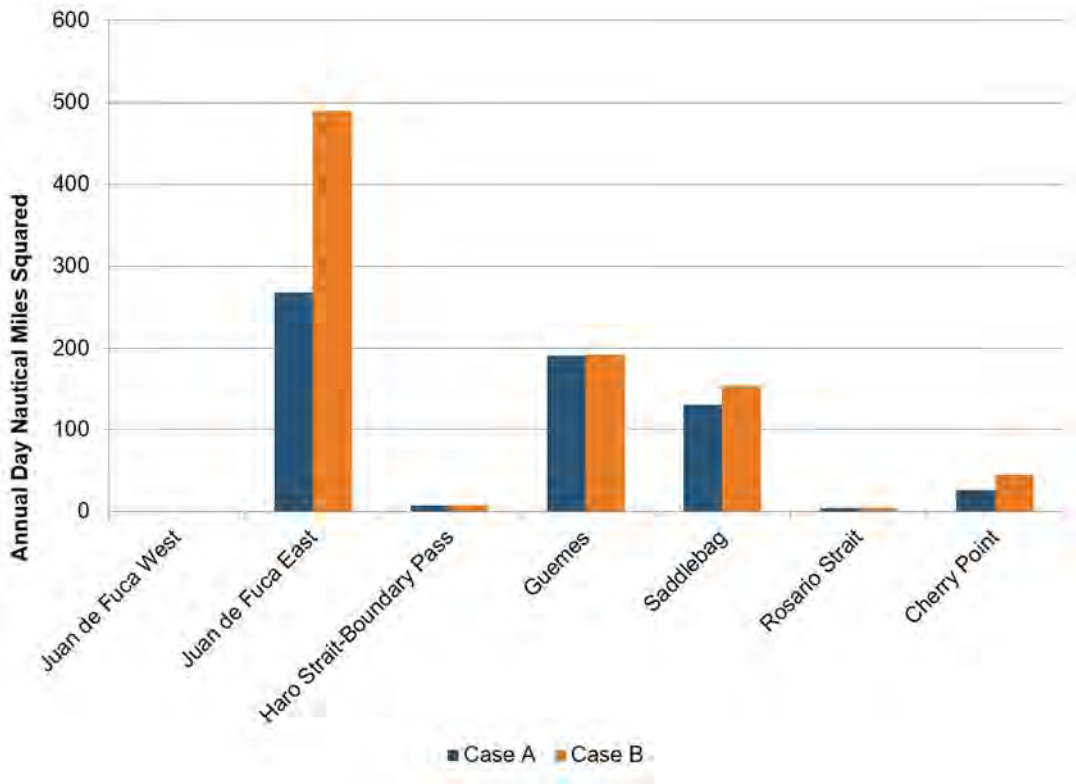

Figure 142 Lummi fishing disruption in vessel day nm^2 by case and study area, 2019

While days-area is an adequate metric for measuring the disruption generated by GPT-vessels, it provides little context with which to grasp its meaning. Vessel-day square-nautical miles is an uncommon unit of measure, making it difficult to grasp the implications of the case results. As such, the value of this analysis is perhaps the comparison of vessel days-area rather than the significance of the metric itself.

Table 136 compares the measured disruption in Cases A and B. By comparing days-areas we see that the proposed GPT would increase the Lummi fishing disruption by 76% in Cherry Point and 19% in Saddlebag. Juan de Fuca East will see the greatest relative increase, as the time and area occupied by anchoring GPT vessels will increase time spent in this subarea by 83 percent. But, as noted above, the Lummi U&A does not include Port Angeles so the Lummi Fishing disruption attributed to the proposed GPT Project will be less than computed for this subarea.

Table 136 Case comparison, 2019

2019	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
Total Fishing Vessel Days-Area	0	9,594	2,086	1,786	7,294	450	24,047
Total Case A Disruption	n/a	268	8	192	130	4	26
Normalized Case A Disruption (Disruption/Total Fishing Vessel Days-Area, %)	0.0	2.8	0.4	10.7	1.8	0.9	0.1
Total Case B Disruption	n/a	490	8	193	155	4	45
Normalized Case B Disruption (%)	0.0	5.1	0.4	10.8	2.1	1.0	0.2
Difference in Disruption (Case B minus Case A)	0	222	0	1	24	0	20
Normalized Disruption Increase (%)	0.0	82.7	0.2	0.5	18.8	5.3	76.4

The disruption captured by Table 136 captures only a portion of the total GPT-related disruption. The disruption in fishing is more than just the surface area of the vessel and any associated exclusion zone passing through the fishing grounds. Fishing opportunities are for a limited duration over a specific harvest management area. Finfish are in transit and if a net cannot be set or has to be retrieved due to a vessel passing through the area, the opportunity to catch the fish that are also passing through may be lost. If the noise or other physical disruption associated transiting vessel disturbs the fish, they may react in a manner that precludes the fisher from being successful. Similarly, if a transiting vessel dislodges or otherwise impacts a buoy that marks the location of a crab pot, a shrimp pot, or a long-line, the fishing opportunity is eliminated even if the vessel passage does not coincide with a Lummi fishing vessel being in the area. That is, the Lummi fishing vessel may only be out for 8 to 12 hours per day but the gear is fishing essentially the entire time. The next section analyzes potential gear loss due to GPT.

4.4.5 Potential Gear Loss

The Lummi fishermen currently fish with several types of gear including drift nets, set nets, seiners, minimal reef nets, set lines and pots. Pots are used primarily for crab and shrimp harvests, while set lines are used for halibut. As shown in Table 137, drift gillnets, set gillnets, and seiners are used for harvesting salmon.

Table 137 Lummi harvest data by gear type, 2011 (Appendix F)

	Percent of Total Harvest		
Fishery	**Drift Gillnet**	**Set Gillnet**	**Seine**
Chinook	13%	18%	2%
Chum	16%	12%	5%
Coho	28%	68%	1%
Pink	3%	2%	66%
Sockeye	39%	-	26%
Total	**100**%	**100**%	**100**%

The study team relied on information provided by the Lummi Natural Resources Department to estimate potential gear loss resulting from GPT-related vessel traffic. While gear loss has been a persistent problem for the Lummi fishermen, little to no data quantifying the extent of gear loss have been captured. The Lummi response to the study team's questions regarding gear loss is shown below:

> *"In 2008, a gear loss forum was held with Lummi fishers and industry representatives. As part of this forum, the LFNRC was asked to estimate the number of crab pots that were lost each year. Based on anecdotal information it was estimated that Lummi crab fishers lost an average of 40-50 pots per fisher per year. No estimates were determined for other types of gear loss (e.g., gill nets) due to vessel traffic,"* (Appendix F).

The Lummi response went on to note that gear loss is more common in certain areas, mainly the tug and tanker holding areas in Saddlebag and Cherry Point, and shipping lanes throughout the Lummi's usual and accustomed fishing area, including Cherry Point, Haro Strait, Rosario Strait, Guemes Channel, and the Strait of Juan de Fuca East (Appendix F).

The study team relied on the 2008 pot loss estimate to gauge how gear loss may be affected by GPT-related traffic in the future. The analysis operates under the assumption that gear loss will change proportionally with changes in vessel traffic. So, for every 5% increase in total vessel traffic, Lummi fishermen would expect to lose an additional 5% in gear on top of the average reported loss from 2008 of 45 pots. An additional 5% in gear loss amounts to two (2) to three (3) more pots lost per fisher.

According to the historical data available summarized in Section 3.2 and Appendix A, there were a total of 18,700 vessel traffic days within the study area in 2008, for all vessel types and activity types. The majority of these occurred in the Guemes Channel and the Strait of Juan de Fuca East subareas (Figure 143).

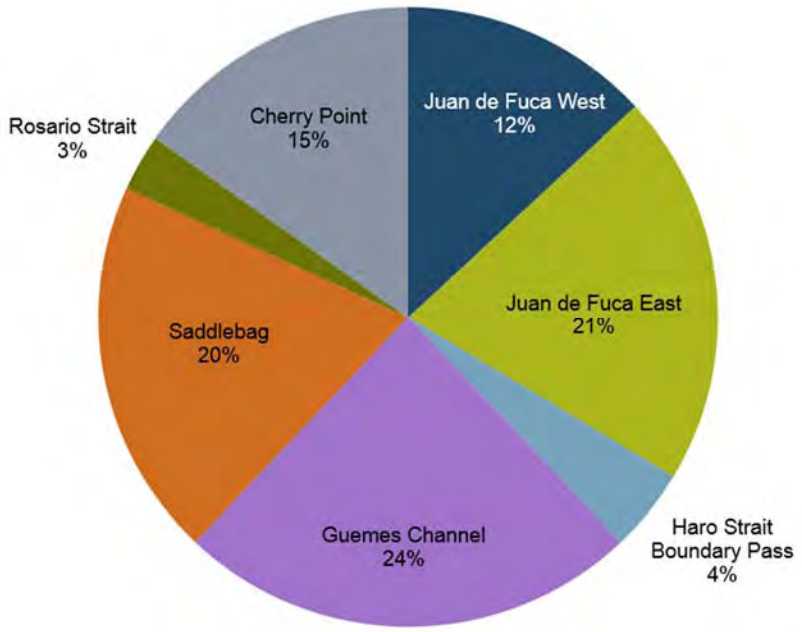

Figure 143 Vessel traffic days for all vessel types and activity types by subarea, 2008

4.4.5.1 2019 Gear Loss Impacts

Given the available information from a 2008 Lummi Nation gear loss forum, 2008 traffic levels were explored. Table 138 compares 2008 traffic volumes to those modeled in Case A. Between 2008 and 2019 (Case A), total forecasted vessel traffic days are expected to decrease by 470 days or approximately 2.5%. However, at the subarea level, results vary greatly. Vessel transits through the Strait of Juan de Fuca West, Strait of Juan de Fuca East, and Haro Strait-Boundary Pass are expected to increase, but are offset by a reduction in volumes to Guemes Channel, Saddlebag, Rosario Strait and Cherry Point. The reduction in these four areas is due to forecasted reductions in tanker volumes to North Puget Sound as vessel traffic is replaced with rail-delivered crude.

Table 138 Vessel traffic day comparison, 2008 and Case A

Vessel Days	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle -bag	Rosario Strait	Cherry Point	Total
2008	2,452	3,841	812	4,504	3,705	556	2,838	18,709
Case A Vessel Traffic Days	2,692	4,079	877	4,025	3,218	550	2,796	18,237
Vessel Traffic Day Difference (Case A vs. 2008)	240	238	64	-479	-487	-6	-42	-471
Vessel Traffic Day Difference (%)	9.81	6.20	7.94	-10.64	-13.15	-1.01	-1.48	-2.52

Impacts on Lummi gear loss would vary depending on which subarea the fisher is fishing in; we would expect gear loss by the Lummi fishermen to increase in Juan de Juan de Fuca East and Haro Strait. Gear loss in all other subareas is expected to decrease.

Table 139 compares 2008 vessel traffic to forecasted vessel traffic in Case B (2019 with GPT-related vessel traffic). In Case B, total vessel traffic days for all vessel types and activity types are expected to increase by 2,334 or 12% between 2008 and 2019. The largest increases by subarea are in the Strait of Juan de Fuca East subarea, where GPT-calling bulkers vessels may likely go to anchor and to bunker, and in the Cherry Point subarea, where they will be at dock.

Table 139 Vessel traffic day comparison, 2008 and Case B

Vessel Days	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2008	2,452	3,841	812	4,504	3,705	556	2,838	18,709
Case B Vessel Traffic Days	3,004	5,184	889	4,165	3,420	666	3,715	21,043
Vessel Traffic Day Difference (Case B vs. 2008)	552	1,343	77	-339	-285	110	876	2,334
Vessel Traffic Day Difference (%)	22.53	34.96	9.44	-7.54	-7.68	19.77	30.88	12.48

Figure 144 compares vessel traffic days in 2008 to Case A and Case B. In both of the 2019 cases, the greatest disruption is expected in Juan de Fuca East. This increase is largely due to the time and area occupied by GPT vessels at anchor at Port Angeles. As Port Angeles is outside of the Lummi U&A, the disruption to Lummi fishers in the Juan de Fuca East subarea will be less than computed for the entire subarea. Not surprisingly, the second greatest relative disruption due to GPT will take place in the Cherry Point subarea.

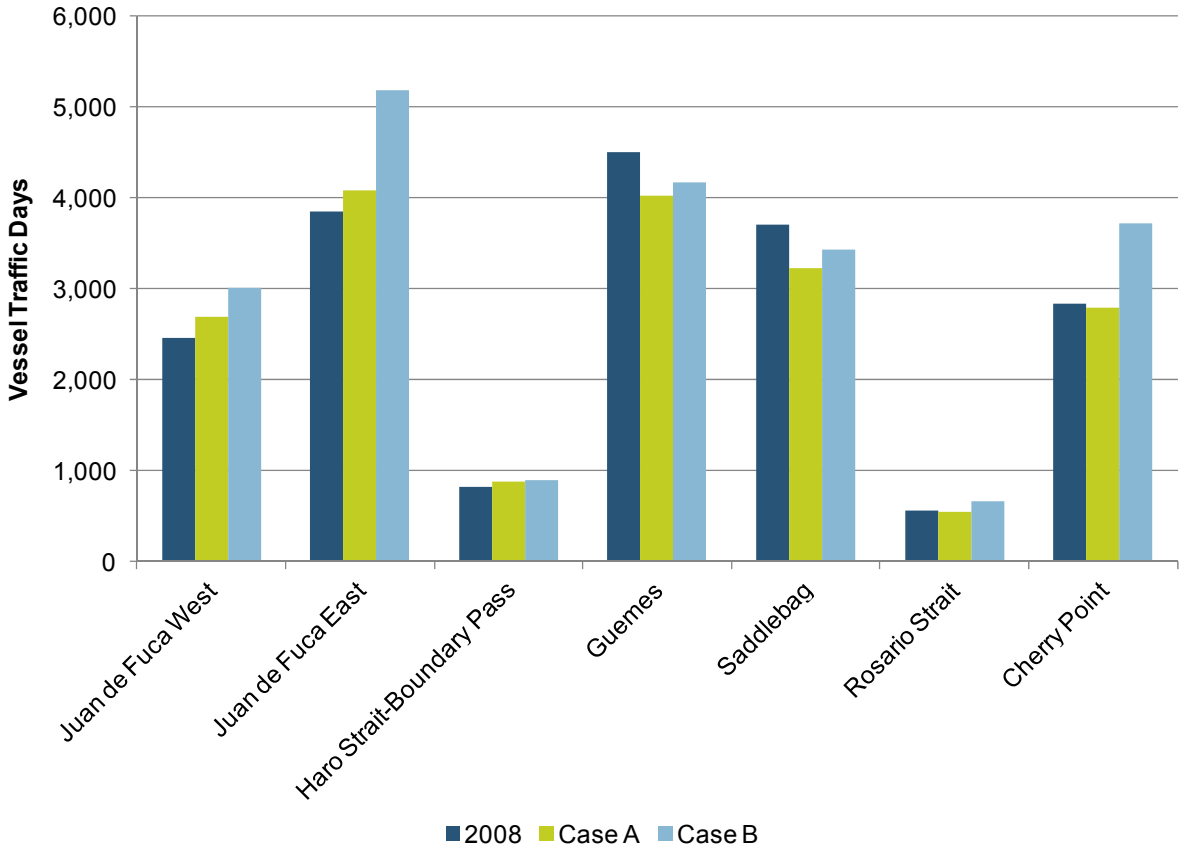

Figure 144 Vessel traffic day comparison (2019) by subarea

To estimate the impact that the 2019 vessel traffic changes will have on Lummi gear loss, the team proportioned per-fisher gear loss to traffic changes (Table 140).[54] In 2008 it was estimated that each Lummi fisher loses between 40 and 50 pots each year (45 average). If gear loss changes proportionately with traffic changes, in 2019 Case A, fishers will expect to lose an additional four (3.6) pots in Haro Strait-Boundary Pass and up to three (2.8) pots Juan de Fuca East. However, in Guemes Channel, Saddlebag, Rosario Strait and Cherry Point—where rail projects are expected to lower the volume of vessel transits—fishers may actually see a decrease in gear loss.

Gear loss is only predicted in subareas where the Lummi fish; this excludes Juan de Fuca West. As noted above, the Lummi U&A includes only a portion of the Striat of Juan de Fuca East subarea, so the gear loss is expected to be less than computed for this subarea.

[54] Impacts to gear such as long-lines and marker buoys are not included in this analysis and historical loss volumes were unavailable.

Table 140 Case A and Case B comparison, 2019

Vessel Days	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
CASE A Vessel Day Difference	N/A	238	64	-479	-487	-6	-42
Difference as a Percentage of 2008 Vessel Days (%)	N/A	6.2	7.9	-10.6	-13.1	-1.0	-1.5
Additional pots lost in Case A for every 45 pots lost	N/A	2.8	3.6	-4.8	-5.9	-0.5	-0.7
CASE B Vessel Day Difference	N/A	1,343	77	-339	-285	110	876
Difference as a Percentage of 2008 Vessel Days (%)	N/A	34.96	9.44	-7.54	-7.68	19.77	30.88
Additional pots lost in Case B for every 45 pots lost	N/A	15.7	4.2	-3.4	-3.5	8.9	13.9

In Case B, vessel traffic estimates in all subareas increase, generating increases in gear loss estimates. To estimate the impact to gear loss with the addition of the proposed GPT, projected gear loss in Case A was subtracted from projected gear loss in Case B. Gear loss per Lummi fisher is expected to increase by thirteen (12.9) or less pots in Juan de Fuca East, nine (9.4) pots in Rosario Strait, or nearly fifteen (14.6) pots in Cherry Point (Table 141).

For example, we estimate that a fisherman who would lose 45 pots in the Cherry Point subarea without GPT (Case A) and would lose 60 (33% more) with GPT (Case B). In contrast, a fisherman with pots in Haro Strait-Boundary Pass instead would expect to lose about the same number with or without GPT (reflecting a near 0% difference) as vessel traffic day increases are small.

Table 141 Case A and Case B estimated gear loss, 2019

Vessel Days	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddle-bag	Rosario Strait	Cherry Point
Additional pots lost in Case A for every 45 pots lost	N/A	2.8	3.6	-4.8	-5.9	-0.5	-0.7
Additional pots lost in Case B for every 45 pots lost	N/A	15.7	4.2	-3.4	-3.5	8.9	13.9
Difference (Case B - Case A)	N/A	12.9	0.7	1.4	2.5	9.4	14.6

Given the limited data available, the study team has no historical record of how gear loss relates to vessel traffic days by subarea. As previously noted, this analysis operates under the assumption that gear loss will change proportionally with changes in vessel traffic. While this assumption offers an estimate of the GPT-related impact, it does little to highlight ways in which gear loss can be mitigated (other than to reduce total vessel traffic days). In addition, the study team acknowledges that the various gear types and methods used by the Lummi mean that the surface area disruption measured in this analysis does not capture GPT-related disruption in its entirety. Going forward, the study team recommends that additional data be gathered regarding the location, timing, and magnitude of gear loss by type.

4.5 Risk of Collision with Lummi Fishing Vessels

4.5.1 Introduction

This section details the quantitative approach used to estimate the potential change in collision risk between GPT-calling vessels and Lummi fishing vessels when the proposed GPT project is in operation. A collision occurs when two vessels are in the same place at the same time. There were no relevant collisions in the 16-year data baseline. There are no collision data, therefore, from which to determine a collision incident rate. Available traffic data are annual and mapped to project-specific subareas or subarea groups. Even though the historical and accident database indicates that no collisions in 16 years occurred between GPT-calling vessel types and tribal fishing vessels (Section 4.5.2), in order to model the change in collision risk, the conservative assumption was made that one collision incident occurred in the year before or the year after the data set. Thus, to calculate the baseline collision rate (BCR), it was assumed that there was one collision in 17 years.

To perform the quantitative evaluation of the risks posed by GPT traffic on Lummi fishing vessels, a BCR of 0.1192 collisions per 10,000 vessel traffic days was calculated based on a conservative assumption that one (1) collision occurs every 17 years. This conservative assumption resulted in 0.0588 collisions for the baseline average year of 4,934 traffic days (4,659 from VTS vessels; 275 from Lummi vessels). This BCR was applied to three forecast cases. Collision incidents for the forecast years 2019 are presented for predicted mean traffic levels with and without the proposed GPT project. The terminal is found to add 0.0104

potential collisions in 2019, with respect to the conservatively-predicted BCR. This increase amounts to a 16.7% increase over the baseline traffic without GPT.

Section 4.5.2 discusses five past collisions that were not between GPT-calling vessel types (bulkers and tugs) and fishing vessels. Section 4.5.3 details the two main components of the quantitative approach: a baseline collision rate of number of collisions per vessel traffic day is defined in Section 4.5.3.1, and forecast cases are defined in Section 4.5.3.2. Finally, the probability of collision is estimated by the product of a baseline collision rate and a forecast number of traffic days. The resultant predicted number of collisions and change in risk of collision with the addition of the proposed GPT project is discussed in Section 4.5.4.

4.5.2 Past Collisions

Collisions involving deep draft traffic, tugs, and fishing vessels between 1995 through 2010 were studied.[55] The historical incident and accident database for the years 1995 through 2010 contains the following collision history:

- Zero (0) collisions reported between tribal fishing vessels and bulkers or between tribal fishing vessels and tugs.
- Zero (0) collisions reported for tugs without barges.
- Three (3) collision records involving small fishing vessels. None of these three small fishing vessel incidents involved deep draft vessels. There have been no collisions in 16 years between the GPT-calling vessel types and tribal fishing vessels.
- Two (2) collision incidents involving deep draft vessels. One of these incidents is listed as involving a bulk carrier. The other was reported to involve a tank ship. Neither of these incidents involved a small tribal fishing vessel or small non-tribal fishing vessel.

Incidents are recorded by the United States Coast Guard (USCG) and/or the Washington State Department of Ecology (Ecology). Only the larger of the vessels involved in a collision is generally recorded. The other vessel involved in the incident is not always recorded; however, none of the past collisions were between deep draft vessels and fishing vessels.

The specific details of the individual recorded collisions were as follows:

a) G0458: The fishing vessel *Carol C* (under 60 feet) was involved in a collision with the fishing vessel *Jessica C* while maneuvering at 48.990200, -122.766180 on 1 October 2003. The *Carol C* had a small spill (1 gallon). The *Jessica C* did not. This incident was recorded by both USCG and Ecology.

b) G0526: The fishing vessel *Wolf* (14 GRT, 36-ft) was involved in a collision with the fishing vessel *Marian J* at 48.95000, -122.916667 on 4 October 2004. There was no spill. This was an incident that was only recorded by USCG and not by Ecology.

c) G1026: The commercial fishing vessel *Sundown* (23 GRT) was involved in a collision at 48.408333, -124.666667 on 20 March 2010. The USCG records do not indicate the identity of any second vessel. There is a report of a collision after "flooding" (i.e., the vessel was taking on water). There was no spill. This may again be a case of an

[55] The full dataset of incident types and vessel types from 1995-2010 are reported on in Appendix C.

allision that is reported as a collision. There is no further information on this incident. If the fishing vessel was struck by a larger vessel (e.g., a bulk carrier), there would likely have been damage (causing spillage) to the small fishing vessel. The fact that the initial report is of "flooding" and then a collision might also lean towards an allision rather than a collision. This was an incident that was only recorded by USCG and not by Ecology.

d) G0325: The product tanker *Allegiance* (34,946 DWT, IMO number 7728716) was reported to have been involved in a collision on 19 January 2002 at 48.355000, -122.895000 with the towing vessel *Sea King*. No spill occurred. This was an incident that was only recorded by USCG and not by Ecology.

e) G0470: The bulk carrier *Norsul Vitoria* (51,500 DWT, IMO number 8126381) was reported to have been involved in a collision on 28 December 2003 at 48.21667, -123.50000. There is mention of loss of maneuverability. USCG records do not indicate the name of the other vessel, if any. The vessel did not spill oil, but was considered a "total loss" due to damage. There is no more information on the subject. If another vessel had been damaged, there would have been another report under this case number. This incident was recorded by USCG but not by Ecology.

Case (e) above may have been an allision that was recorded as a collision. In the 16-year dataset baseline, there were no spills from collisions involving deep draft vessels.

GPT-calling bulkers, GPT-docking tugs, and Lummi fishing vessels are a smaller subset of the vessel types with past collision events studied in this report. The risk of collision between these project-specific vessel types would be smaller than for the larger set of deep draft, tug, and fishing vessel types.

4.5.3 Approach

The available traffic data make it possible to use a statistical, cumulative approach to quantify the probability of collision. A 17-year traffic total is consistent with the following vessel types:

- Tankers.
- Tank barges.
- Bulkers.
- General cargo & container.
- Tugs.
- Fishing vessels.
- Passenger vessels.

Note that although Fishing Vessels and Passenger Vessels are grouped into the same category in Section 3.2, they are divided into separate categories in this analysis due to its focus on fishing practices. A 17-year traffic total was calculated for the Lummi fishing fleet from the data in Section 4.4.

Since the historical accident database indicates that no collisions in 16 years occurred between GPT-calling vessel types and tribal fishing vessels (Section 4.5.2), in order to model the change in collision risk, the conservative assumption was made that one collision incident occurred in the year before or the year after the data set. Thus, to calculate the BCR, it was assumed that there was one collision in 17 years.

There is a possibility of collision in the subareas within the project study area where there are both Lummi and GPT vessels. The available annual traffic data mapped to project-specific subareas or subarea groups were used to predict a conservative annual probability of collision between GPT-calling vessels and Lummi fishing vessels.

4.5.3.1 Baseline Collision Rate

A baseline collision rate was calculated from past traffic data (Section 3.2 and Section 4.4). Traffic data were combined and scaled to a 17-year baseline to estimate the amount of overlap between GPT traffic and Lummi fishing vessels within the study area where a collision would have been possible. This section details the baseline collision rate calculation, which was comprised of two main components: Lummi traffic, and vessel traffic.

Lummi Traffic

Lummi fishing days on the water are presented in Section 4.4. The number of days that fishing boats are on the water is repeated in the following Table 142. The number of vessel days per year is the 6-year average from 2006 through 2011. Northern Economics, Inc. (NEI) found that fishing activity varied considerably year to year, however this report uses the same assumption as NEI proposes in their report that the annual average traffic level for 2019 is the same as the 5-year average. Additionally, it was assumed that this average level is also constant over the database time period, 1995 through 2010.

Table 142 Lummi annual water-day areas

Subarea	Days Boats are on the Water (Vessel Days)
Strait of Juan de Fuca West	0.0
Strait of Juan de Fuca East	20.3
Haro Strait – Boundary Pass	32.6
Rosario Strait	31.2
Saddlebag	70.3
Guemes Channel	15.9
Cherry Point	104.4
Total	274.8

The majority of the area bounded by the Cherry Point subarea to the north, Rosario Strait subarea to the east, Strait of Juan de Fuca East subarea to the south, and the Haro Strait-Boundry Pass subarea to the west is within the Lummi U&A, but outside of the study area. The Lummi do not fish in the Strait of Juan de Fuca West. The Lummi fish in the study subareas of Juan de Fuca East (portion only), Rosario Strait, Haro Strait, Saddlebag, Guemes Channel, and Cherry Point. These six subareas are referred to in this report as the Lummi Fishing Subareas.

In addition to the study subareas described, the Lummi U&A includes the waterways around the San Juan Islands, where Lummi fishers routinely engage in fishing operations. Bulkers do not transit these waters, but in an exceptional circumstance, tugs supporting the GPT-calling bulkers may either transit through these waters or loiter within these waters while waiting assignment. The Lummi have reported tugs crossing this area. Tugs assisting GPT vessels are assumed to be deployed from existing sites in Bellingham Bay and Anacortes and would rarely transit outside of the study area. Therefore, GPT traffic within the San Juan Island Lummi U&A was not included as part of this study. This additional traffic, though not included in this quantitative analysis, may also interfere with Lummi fishers.

Vessel Traffic in the Study Area

Section 3.2 presents the number of traffic days for the VTS vessel types: tankers, tank barges, bulkers, general cargo, containers, tugs, fishing vessels over 60 feet, cruise ships, and ferries. Cruise ships and ferries are grouped as passenger vessels. Four vessel activities are presented in Section 3.2 (underway, maneuvering, at dock, at anchor); however, only the time spent underway and maneuvering contribute to the risk of collision. Underway and maneuvering are grouped as the in-transit activity. The number of days VTS vessels spent in transit between 1995 through 2010 within the six Lummi Fishing Subareas found from the vessel traffic study (Section 3.2) is presented by vessel type in Table 143.

Table 143 Total VTS vessel traffic days in-transit by vessel type in Lummi fishing subareas, 1995-2010 (Non-GPT)

Vessel Type	VTS Vessels In Transit (Days)
Tanker	7,094
Tank Barge	6,131
Bulker	12,098
General Cargo & Container	9,412
Tugs	26,490
Fishing Vessels	2,492
Passenger Vessels	10,822
Total	74,539

Baseline Traffic

VTS and Lummi traffic is shown scaled to sixteen and seventeen year baselines in Table 144. The baseline traffic does not include GPT traffic. GPT traffic is included in the VTS traffic in the forecast. Non-GPT, VTS vessel days in-transit and Lummi vessel days on the water are summed into total traffic days.

Table 144 Baseline traffic days in-transit by VTS and by Lummi in the Lummi fishing subareas (Non-GPT)

Baseline Period*	VTS Vessels (Days)	Lummi Vessels (Days)	Total Traffic (Days)
Annual	4,659	275	4,934
16-year total	74,539	4,397	78,936
17-year total	79,198	4,672	83,870

*For VTS Vessels (second column), the annual baseline period was calculated by dividing the 16-year total (Table 143) by 16; for Lummi vessels, the 16-year total was calculated by multiplying the annual baseline period (Table 142) by 16.

Baseline Collision Rate

It was assumed that there is one collision between a GPT-calling vessel type and a tribal fishing vessel in 17 years (83,870 traffic days). This resulted in a baseline collision rate (BCR) of 1.192×10^{-5} collisions per traffic day (0.1192 per 10,000 days):

$$Baseline\ Collision\ Rate\ (BCR) = \frac{Number\ of\ Collisions}{Traffic\ Days} \qquad 4\text{-}5$$

In the baseline average year with 4,934 traffic days, 0.0588 potential collisions are predicted. The return period for this assumed baseline collision is 17 years.

This is a conservative assumption; however, it is unknown to what extent the assumption is conservative. The baseline rate is used here to estimate a relative change in collision frequency, and it should not be literally interpreted as the absolute probability of a collision between a GPT-calling bulker or GPT-docking tug and a Lummi fishing vessel.

4.5.3.2 Forecast Cases

The effect of adding GPT vessels in 2019 to the VTS study area was studied and is displayed in Table 145. Traffic days for Baseline Traffic are shown, along with traffic days for three other forecast cases:

- Case A: Existing vessel traffic forecast to 2019, and expansions completed since 2010 or currently under construction and completed by 2019.
- Case B: Case A traffic plus GPT vessel traffic (Case A + GPT).
- Case C: Case B traffic plus projects expected to take place in the study area in the near future (Case B + Cumulative).

As discussed 2.7.1, cumulative traffic is traffic from projects for which vessel traffic volume and routing in the study area can reasonably be determined, but are not expected to begin operation by 2019. All quoted traffic vessel days are predicted mean values. There is a range of uncertainty about the mean. This uncertainty is modeled in Section 3.4, but not in this analysis.

Table 145 Vessel traffic days in-transit by VTS and by Lummi in the Lummi fishing subareas for 2019

Case	VTS Vessels (Days/Year)	Lummi Vessels (Days/Year)	Total Traffic (Days/Year)
Baseline Annual	4,659	275	4,934
Case A = Baseline 2019	4,950	275	5,225
Case B = Case A + GPT	5,825	275	6,100
Case C = Case B + Cumulative	6,253	275	6,528

4.5.4 Results

The number of potential collisions in each forecast year is calculated by multiplying the averaged base collision rate (*BCR*) with the total number of traffic days (*TD*). Symbolically, this is expressed by:

$$Number \quad of \quad Collisions \quad per \ Year \ = BCR \times TD \qquad 4\text{-}6$$

where baseline collision rate *(BCR*) is expressed in collisions per vessel traffic day, and traffic days (*TD*) are expressed as vessel traffic days per year. The proposed GPT is predicted to add 0.0104 collisions in 2019. This amounts to a 16.7% increase, respectively, over the Baseline traffic in Case A. The cumulative traffic adds another 0.0051 potential collisions in 2019, a total percent increase of 25% over the Baseline traffic in Case A. Although the increase with both GPT and cumulative traffic (25%) may seem like a large increase, this increase should be considered with respect to a very conservative assumption to determine the BCR.

Table 146 Change in frequency of collision over annual baseline and three 2019 Cases

Case	Collisions (average per year)	Change in Collisions (over prior Case)	Percent Change (%) (over prior Case)
Baseline Annual	0.0588	n/a	n/a
Case A = Baseline 2019	0.0623	0.0035	5.9%
Case B = Case A + GPT 2019	0.0727	0.0104	16.7%
Case C = Case B + Cumulative 2019	0.0778	0.0051	7.0%

Section 5 Risk Reduction Options

5.1 Introduction

The Vessel Traffic and Risk Assessment Study (VTRAS) included two discussion sessions, during which a list of risk reduction measures (or Risk Reduction Options –RROs) were identified. The discussion group included members of Glosten's technical staff, as well as representatives of the Lummi Nation, the Department of Ecology and PIT. The RROs represent a non-exhaustive list of those measures that could apply to traffic management, anchoring, vessel mooring and servicing, and spill containment and cleanup that may have the potential to reduce risk. Potential risks included: marine vessel incidents, spills of cargo oil, bunker fuel oil, and bulk cargo, and the impact of ballast water discharge. Risks associated with terminal operations were not included. The discussion did not produce a detailed description of the measures, nor did it include an assessment of the measure effectiveness, means of or responsibility for implementation, or applicability to any or all categories of vessel traffic, including traffic specific to the Gateway Pacific Project. The intervention stages of a risk event that a measure may affect are discussed (Section 5.2), and the individual RRO's are listed in Section 5.3.

Separate vessel traffic management alternatives, developed solely by Glosten experts, are discussed in detail in Section 2.3.3. These alternatives are qualitatively ranked by potential effectiveness, and include mandatory tug escorts, voluntary speed reductions, standby response tugs, area transit plans, complements to the existing traffic separation scheme, and supplemental aids to navigation.

5.2 Risk Event Stage Description and Assignment Approach

Intervention stages discretize the event chain of undesired or unexpected events. Each intervention stage presents an opportunity to implement one or more RROs. The main intervention stages considered by the workgroup are shown in Table 147.

Table 147 Risk event stages

Stage No.	Intervention Stage
0	No cause No risk or inadequacies are assumed in the system. A Stage 0 RRO is simply preventive and proactive. It studies or supports the underlying, base conditions in the system and may also indirectly reduce risk in one or more later stages.
1	Basic and root cause Inadequate skills, knowledge, equipment, management, maintenance
2	Immediate cause Human error, equipment failure
3	Incident Propulsion failure, steering failure, navigational aid failure, bunker error, cargo transfer error, Other non-impact errors, and impact incidents

Stage No.	Intervention Stage
4	Spill Collision, Allision, Grounding or other incidents that have resulted in a spill
5	Spill volume Consequence in this context is spilled contaminant volume. The project is concerned with contaminants: cargo oil, bunker fuel oil, and bulk cargo. Only bunker fuel oil, bulk cargo, and ballast water are applicable for GPT-calling vessels.
6	Environmental impact The impact of ballast water discharge is considered along with the impact of contaminant outflow.

Stages 1 and 6, with some varied vocabulary, are common to risk assessment work. Stage 0 has been introduced for this study. Stage 0 RROs are preventative or proactive. They would improve the underlying base condition of the system, even before the basic or root cause (Stage 1) of an incident. Stage 0 would include studies on the existing system and proactive education programs. Management RROs that add to the underlying system would be Stage 0, however, management measures that change the underlying management system are considered to intervene starting at Stage 1. The early stage RROs typically have a longer time scale to implement. Mostly, they would not intervene, incite action, or respond on the short notice given that a later stage has now occurred.

An RRO can intervene at one or more stages. Predicted intervention stages are marked with a checkmark (✓) in Table 148. If a stage has been predicted, then the RRO may reduce either the likelihood of that stage's occurrence, or the extent to which that stage occurs. The RRO may be implemented at a stage given that the previous stage has occurred. Some checkmarks are dependent on further details of the RRO not developed here.

5.3 Identified Risk Reduction Options

There is risk and uncertainty associated with the addition of the proposed GPT beyond the risk introduced from marine vessel traffic and beyond the marine vessel traffic risk variables modeled from historical patterns. The discussion group considered this broader context, in addition to these more narrowly focused risks: the spread of invasive species by ballast water discharge and spills of both bunker fuel and dry bulk cargo. The potential for the effect of an RRO to interact with another RRO was not assessed. The discussion group reviewed past Risk Mitigation studies (References 23, 135, 131, 79, and 47) in preparation for the brainstorming session. The discussion group then focused on risk introduced by the addition of the GPT from the perspective of the vessel traffic study. Identified RROs and their predicted invention stages are listed in Table 148.

Table 148 Risk Reduction Options (RROs)

	Risk Reduction Option	Intervention Stage						
		0	1	2	3	4	5	6
		Preventive & Proactive	Basic/Root Causes	Immediate Cause	Incident	Spill	Spill Volume	Impact
Vessel Traffic Risk Assessment and other study								
1	Operational risk assessments and workshop (Bulkers and tugs, including hiring agent).	✓	✓	✓	✓	✓	✓	✓
2	Review protocol and applicability of Harbor Safety Committee Standard of Care to larger, Capesize vessels.	✓						
Vessel Traffic Management								
3	Vessel traffic separation. *Establish voluntary traffic guidelines in the vicinity of the Cherry Point and Ferndale facilities.* *See Section 2.3.3.5.*	✓	✓	✓				
4	Vessel speed. *Reduce vessel speed to:* • *Reduce the potential mechanical energy of powered groundings and collisions.* • *Provide for better situational awareness.* *See Section 2.3.3.2.*		✓	✓	✓			
5	Vessel arrival phasing. *Schedule vessel arrivals to reduce queuing.* *See Section 2.4.5.4 Just-in-Time Arrival Management.*		✓	✓	✓			
6	Vessel routing (port access, one-way schemes). *See Section 2.2.*		✓					
7	Anchorage management for tugs and tank barges supporting GPT-vessels.	✓	✓					
8	Pilots and VTS should coordinate movements outside the shipping lanes.		✓	✓				
Vetting Programs and Vessel Inspection								
9	Vetting program (bulkers and tugs).	✓	✓	✓			✓	✓

	Risk Reduction Option	Intervention Stage						
		0	1	2	3	4	5	6
		Preventive & Proactive	Basic/Root Causes	Immediate Cause	Incident	Spill	Spill Volume	Impact
	Additional voluntary vessel inspection to assess compliance with regulations or performance beyond requirements.							
10	Employ, train, and deploy additional inspector(s), as needed.	✓	✓					
11	Request insurance – for both bulkers and tugs. Insurers may request vetting.		✓					
Crewing								
12	2nd officer on the bridge (west of PA).		✓	✓	✓			
13	Bridge resource management. *As per Standards of Training, Certification, and Watchkeeping (STCW) (Reference 59).*		✓	✓	✓			
14	Engine room management. *As per STCW.*		✓	✓	✓			
On-Board Technology								
15	New technology (i.e. Navigation systems, rudder monitor).	✓	✓	✓	✓	✓	✓	✓
16	Redundant technology, Redundant propulsion.	✓	✓	✓				
17	Internally protected fuel tanks. *Locate fuel tanks within double hull, so that fuel tank bulkheads are isolated from outer hull.*						✓	
18	Tow bit integrity on bulk cargo ships.	✓						
High Risk Vessels								
19	Pre-deploy tugs under 'high-risk vessel' by vessel profiling.	✓	✓					
Data Collection of Risk Assessment, Emergency Notification & Risk Communication								
20	Near-miss reporting system for vessels' overall time in the system spent: Underway, Maneuvering, At Anchor, or At Dock.	✓						

	Risk Reduction Option	Intervention Stage						
		0	1	2	3	4	5	6
		Preventive & Proactive	Basic/Root Causes	Immediate Cause	Incident	Spill	Spill Volume	Impact
Standard Operational Procedures (SOPs) - Vessels								
21	Fuel switching requirements. *Encourage adoption of Puget Sound Harbor Safety Committee Standards Of Care (Reference 105) for fuel switching to reduce likelihood of propulsion failures.*		✓	✓	✓			
22	Conditional equipment monitoring program with sufficient crewing and training.	✓	✓	✓				
23	Closed hatches. *Close hatches when able to reduce fire/explosion risk during cargo transfer ops an transit.*	✓	✓					
Ballast Water (BW) Systems and Operations								
24	Ballast water (BW) treatment systems on vessel.							✓
25	Emergency Ballast water treatment systems deployable from dock.							✓
26	Offloading all untreated ballast water to onshore.							✓
27	Ballast water open ocean exchange program. *Empty ballast tanks and re-fill with local water mid-trans-oceanic voyage.*	✓	✓	✓				✓
28	Ballast water open ocean exchange monitoring and testing.	✓						✓
Standard Operations Procedures (SOPs) & Technology - Mooring								
29	Complete engineering study of vessel mooring equipment and procedures.	✓						
30	Mooring line technology specification; Winches, (quick release, dock lines, etc.)		✓					

	Risk Reduction Option	Intervention Stage 0 Preventive & Proactive	1 Basic/Root Causes	2 Immediate Cause	3 Incident	4 Spill	5 Spill Volume	6 Impact
31	Mooring lines deployment and management procedures. *To reduce the chance of a vessel break-away:* • *Monitor mooring line tension on all facility mooring line hooks.* • *Establish wind/wave thresholds for doubling mooring lines or arranging a standby tug.*		✓					
Standard Operations Procedures (SOPs) & Technology – Oil transfer operations								
32	At-dock transfer: Dock watchstanding.		✓	✓	✓	✓	✓	
33	At-dock transfer: Limit other operations ongoing (e.g. Bunker, internal fuel transfer).		✓					
34	At-dock internal transfer: Pre-booming around vessels and under dock.		✓	✓				✓
35	Bunkering: Effective training, testing, and staffing.		✓					
36	Bunkering: Spill response equipment pre-staged.			✓	✓	✓		
37	Bunkering: Study preferable alternative bunkering locations, including at the wharf. If study indicates the wharf is a preferred location, then study safety and potential special procedures for bunkering there.	✓	✓	✓	✓			
Standby, Rescue, Escort, and Assist Tugs								
38	Standby emergency response towing vessel. *Study potential effectiveness by location.* *See Section 2.3.3.2.*		✓	✓				
39	Escort tugs for Capesize ships. *See Section 2.3.3.1.*	✓	✓	✓	✓	✓		
40	Review tug capacity (horsepower) available and needed for larger vessels.	✓						
41	Review procedures of Canadian tugs handling Capesize vessels.	✓						

	Risk Reduction Option	Intervention Stage						
		0	1	2	3	4	5	6
		Preventive & Proactive	Basic/Root Causes	Immediate Cause	Incident	Spill	Spill Volume	Impact
42	Tug pilot training program for handling large ships (simulation).	✓						
43	Tug standby protocols. *To limit inference with traffic and fishing:* • *Establish protocols.* • *Provide a queuing buoy or standby facility.*	✓	✓	✓				
44	Study tug routing. In or out of lanes? Practice avoidance.	✓	✓					
45	New technology in assist tugs (e.g. line handling and personnel safety).	✓	✓	✓	✓	✓	✓	✓
46	"Team training" for tugs and bulkers at and near dock. Simulate stoppage. Practice maneuvers. Appropriately pair fittings.	✓	✓					
Other Actions								
47	Educational program for small vessel operators.	✓						
48	Partnership with tribal nations (GPT, OTB).	✓	✓					
49	Increase visibility of small vessels.			✓				

5.4 Future Discussion Considerations

The brainstorming session was not limited by who is responsible or how to model, select, fund, or implement the identified RROs. RROs are not presented with any priority order or endorsement. The list is not considered exhaustive and in many cases the items are not fully developed. Accordingly, this list is offered only as a starting point for future discussion and consideration.

Considerations for further study may include:

- Life-cycle cost and benefit.
- Performance: efficacy, reliability, sustainability.
- Public support.

- Existing and future regulatory jurisdiction and resources for support and enforcement.
- Entity (or entities) responsible for the implementation.
- Forecasted level of risk to be mitigated.
- Existing RROs in place or lack thereof.
- RROs successfully implemented elsewhere.
- Deployment location.
- Further brainstorming on RRO identification.
- Readiness, ease of implementation.
- Additional benefit to non-GPT-calling vessels and terminals.

5.5 Summary

With a focus on the risk introduced by additional marine traffic associated with the proposed GPT, a group of project participants identified 49 RROs and assigned intervention stages to each RRO. The list of RROs is neither prioritized nor exhaustive, but the list does serve as an effective starting point for future discussion and consideration.

Gateway Pacific Terminal (GPT)

Vessel Traffic and Risk Assessment Study Appendices

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Appendix A Analysis Format and Vessel Traffic Data

Analysis Format and Vessel Traffic Data

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November 2014

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Abbreviations

AIS	Automatic Identification System
AMHS	Alaska Marine Highway System
ANS	Alaska North Slope
ATB	Articulated Tank Barge
B.C.	British Columbia
bopd	Barrels of Oil per Day
BST	BST Associates
CCG	Canadian Coast Guard
CFEC	Alaska Commercial Fishing Entry Commission
CP	Trawl Catcher Processor
CV	Trawl Catcher Vessel
DWT	Deadweight Tons
GPT	Gateway Pacific Terminal
ITB	Integrated Tank Barge
L.E.	Limited Entry
mtpa	millions of metric tons per year
MX	Marine Exchange of Puget Sound
nm	nautical miles
NRT	Near-Real Time
OD	origin and destination
PIT	Pacific International Terminals, Inc.
ro-ro	roll-on roll-off
USCG	United States Coast Guard
VEAT	Washington Department of Ecology's Vessel Entries and Transits
VTS Puget Sound	Vessel Traffic Service Puget Sound
WDOE	Washington Department of Ecology
WTI	West Texas Intermediate

Executive Summary

A Vessel Traffic and Risk Assessment Study is being conducted by The Glosten Associates for the proposed Gateway Pacific Terminal (GPT). The purpose of the study is to assess how construction and operation of GPT will affect vessel traffic risk in North Puget Sound. Northern Economics, Inc. is contributing to the risk assessment by summarizing existing vessel traffic volumes and forecasting future traffic volumes. This report summarizes Northern Economics' analysis and results.

The area studied includes the designated Puget Sound vessel transit lanes, the maneuvering area near GPT, the local anchorage areas, and the transit routes for tugs assisting GPT traffic. GPT will be a multimodal, deep-water terminal intended to support the movement of dry bulk commodities. The proposed terminal will include a deep-draft wharf with access trestle, dry bulk materials handling and storage facilities, and rail transportation access. The three-berth deep-draft wharf with ship-loading equipment will allow the terminal to load large, oceangoing vessels efficiently for shipment of commodities to Asian and other international markets (Pacific International Terminals [PIT] 2011).

In addition to ships designed to handle dry bulk materials (bulkers), GPT traffic includes tugs assisting with docking and undocking maneuvers. Assist tugs are included in the definition of "GPT-calling vessels." Tugs and tank barges associated with bunkering of GPT-related vessels are also included in the analysis. At full operational capacity, approximately 487 vessels (179 Capesize vessels and 319 Panamax vessels) per year are expected to call at Gateway Pacific Terminal (Table ES-1).

Table ES-1. GPT Vessel Capacity

Approximate Year (estimated)	Total Nominal Maximum Terminal Capacity (mtpa)	Capesize/yr		Panamax/yr		Total
		Serving East Loop	Serving West Loop	Serving East Loop	Serving West Loop	
2019	54	138	31	259	59	487

Note: mtpa – millions of metric tons per year
Source: PIT, 2011

In order to meet project objectives, the study team forecasted the volumes of study area vessel traffic in 2019, under three different traffic scenarios. Components of the forecasted scenarios—Case A, Case B, and Case C—are described in Figure ES-1.

Figure ES-1. Forecast Cases

Case A (Baseline)	Case B	Case C
• Existing vessel traffic forecasted to 2019 • Additional traffic from port expansions or new ports completed since 2010 or currently under construction and completed by 2019.	• Case A traffic • Gateway Pacific Terminal vessel traffic	• Case B traffic • Projects expected to take place in the study area in the near future

The results of the vessel traffic forecasts are summarized in Table ES-2 and Table ES-3, which show the predicted mean values for traffic volumes.

Table ES-2. Study Area Vessel Traffic Volumes, in Vessel Traffic Days, Summed across All Vessel Types and Activity Types (2019)

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	2,316.0	3,296.0	749.0	3,622.0	3,004.0	254.0	2,039.0	15,281.0
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Case C	3,154.0	5,359.9	1,037.7	4,127.2	3,412.9	661.9	3,845.2	21,599.0
Percentage Changes								
Case A to Case B	11.6	27.1	1.4	3.5	6.3	21.0	32.9	15.4
Case B to Case C	5.0	3.4	16.7	-0.9	-0.2	-0.6	3.5	2.6
Case A to Case C	17.2	31.4	18.4	2.5	6.1	20.3	37.5	18.4

Source: Northern Economics, Inc. 2014

GPT is expected to increase the number of bulker traffic days, tug traffic days, and tank barge traffic days in the study area by 15.4 percent over the Case A forecast.

Table ES-3. GPT Vessel Traffic Volumes, in Vessel Traffic Days, Summed Across All Vessel Types and Activity Types (2019)

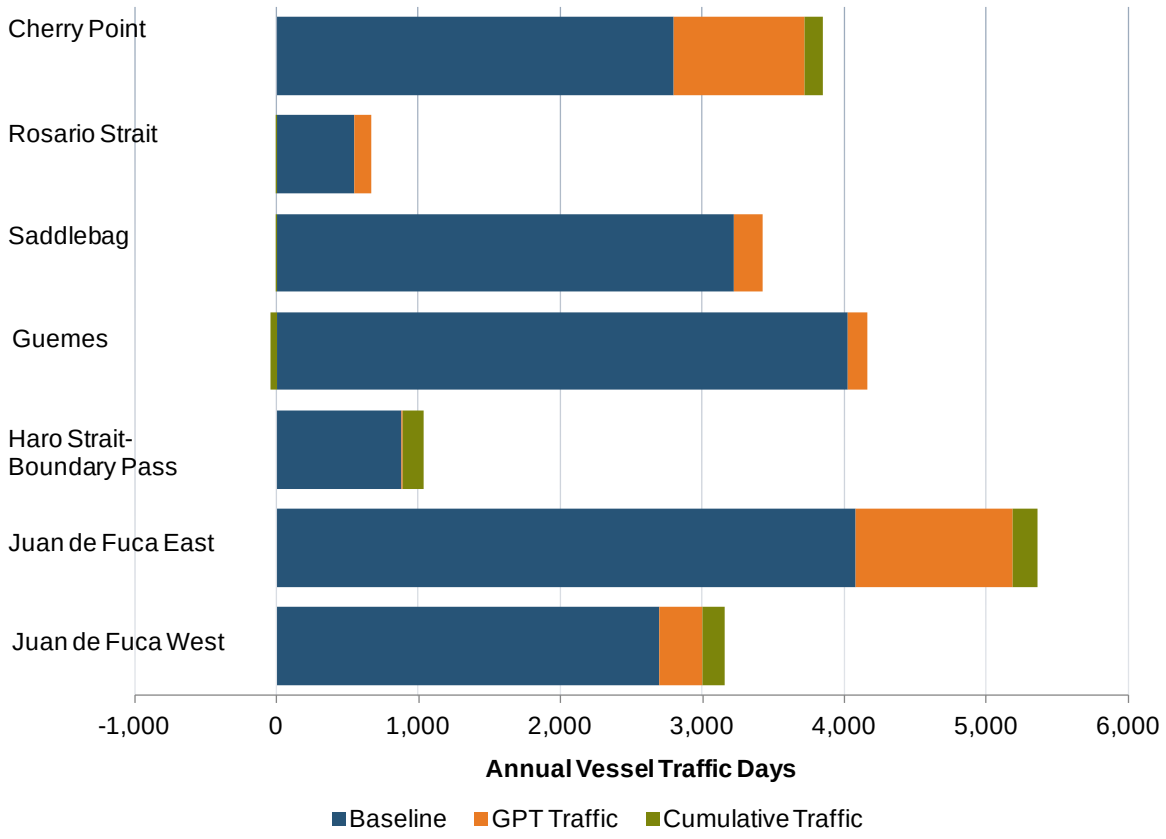
	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
GPT	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2

Source: Northern Economics, Inc. 2014

GPT will generate the greatest increase of vessel traffic days in the Strait of Juan de Fuca West, Strait of Juan de Fuca East, Saddlebag, and Cherry Point subareas. This is due to increased transit

time through the Strait of Juan de Fuca, time at anchor spent at Port Angeles and Vendovi, as well as time at GPT located in the Cherry Point subarea.

Figure ES-2. Study Area Vessel Traffic Volumes by Subarea and Component, Summed Across All Vessel Types and Activity Types, 2019



Source: Northern Economics, Inc. 2014

1 Introduction

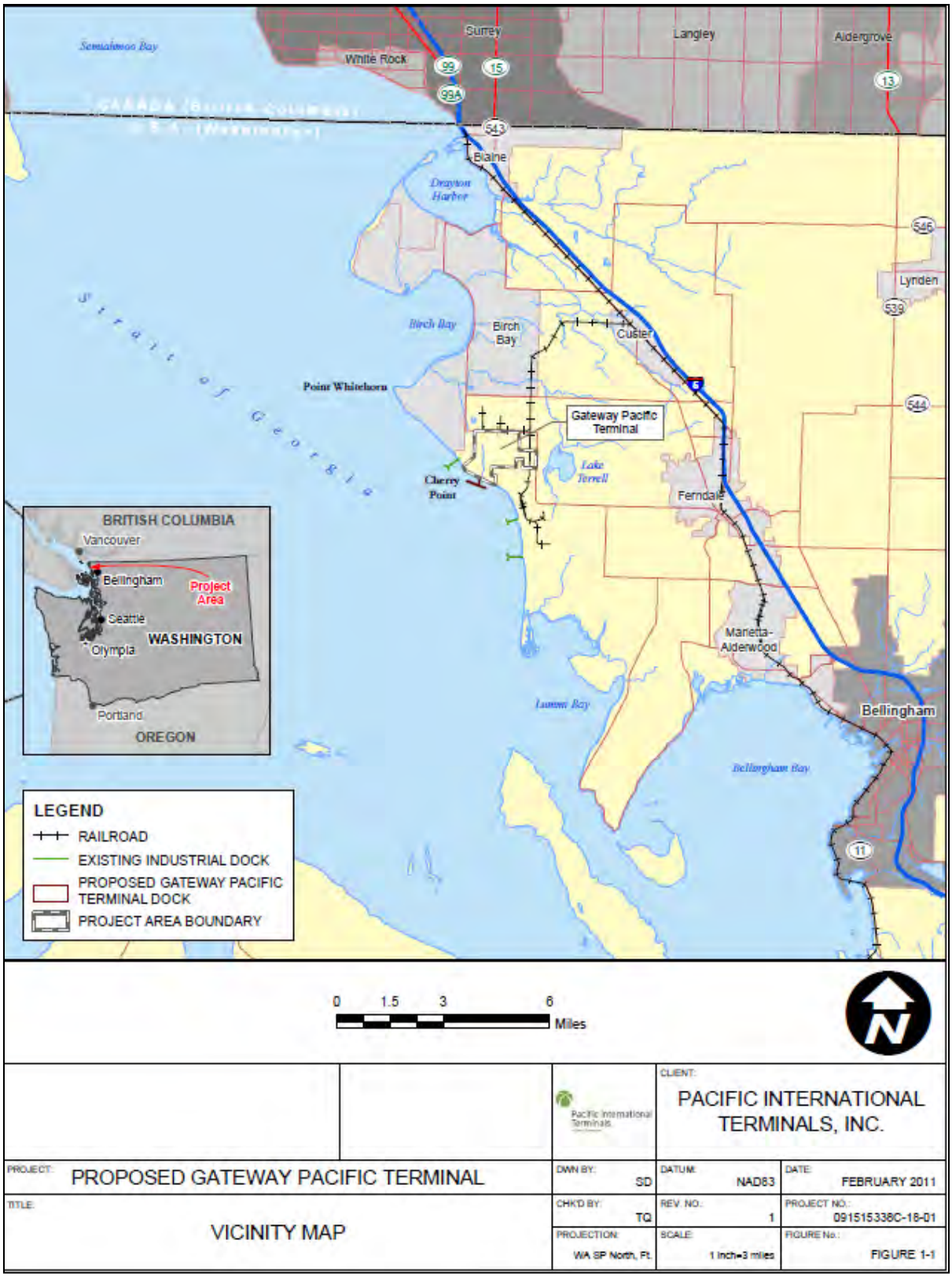
Pacific International Terminals, Inc. (PIT) proposes to construct and operate the Gateway Pacific Terminal (GPT), a multi-modal dry bulk commodities terminal at Cherry Point Washington. A Vessel Traffic and Risk Assessment Study is required before the terminal can be permitted, constructed, or operated. As part of the study effort, Northern Economics, Inc. examined the historic and current patterns of traffic in North Puget Sound, and used these data and other information to forecast vessel activity in the study area. This report summarizes Northern Economics' vessel traffic database and analysis; results and methodology are presented for each vessel type, activity type, and subarea.

1.1 Gateway Pacific Terminal

GPT will be a multimodal, deep-water terminal intended to support the movement of dry bulk commodities. The proposed terminal will include a deep-draft wharf with access trestle, dry bulk materials handling and storage facilities, and rail transportation access. The three-berth deep-draft wharf with ship-loading equipment will allow the terminal to load large, oceangoing vessels efficiently for shipment of commodities to Asian and other international markets (PIT 2011).

The Terminal would be developed on approximately 350 acres within a total project area of 1,200 acres. Shown in Figure 1, the project area is zoned for Heavy Impact Industrial use and is located in Whatcom County's Cherry Point Industrial Urban Growth Area (PIT 2011).

Figure 1. Proposed Facility Location



Source: PIT, 2011

GPT is expected to be fully operational by 2019; upon completion of the facility, it will be able to handle 54 million metric tons of bulk commodities per year (Table 1).

Table 1. GPT Commodity Handling Capacity

Approximate Year (estimated)	Capacity at West Loop (mtpa)	Capacity at East Loop (mtpa)	Total Nominal Maximum Terminal Capacity (mtpa)
2019	6	48	54

Note: mtpa – millions of metric tons per year
Source: PIT, 2011

In order to paint a comprehensive picture of future traffic volumes, the study team forecasted the volumes of study area vessel traffic in 2019, under three different traffic scenarios. This report describes how the study team estimated existing transits and calls, generated the vessel traffic data necessary to conduct the analysis, and forecasted future traffic volumes.

1.2 Report Organization

In the following sections we discuss how the vessels designed to handle dry bulk commodities (bulkers) travelling to and from the GPT 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.

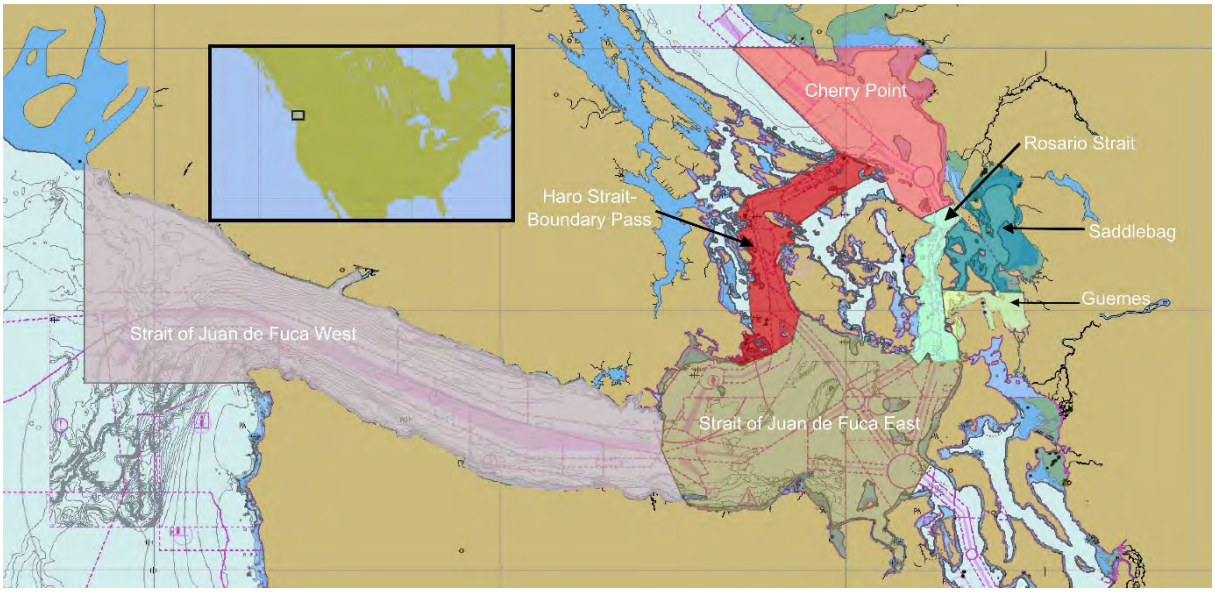
Section 4: Forecasting presents the 2019 estimates of vessel traffic days by area and activity type. A description of the forecasting methodology and approach is included.

2 Transits and Calls

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

The traffic analysis study area, shown in Figure 2, 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 study area, vessels which transit the study area en route to these destinations have been incorporated.

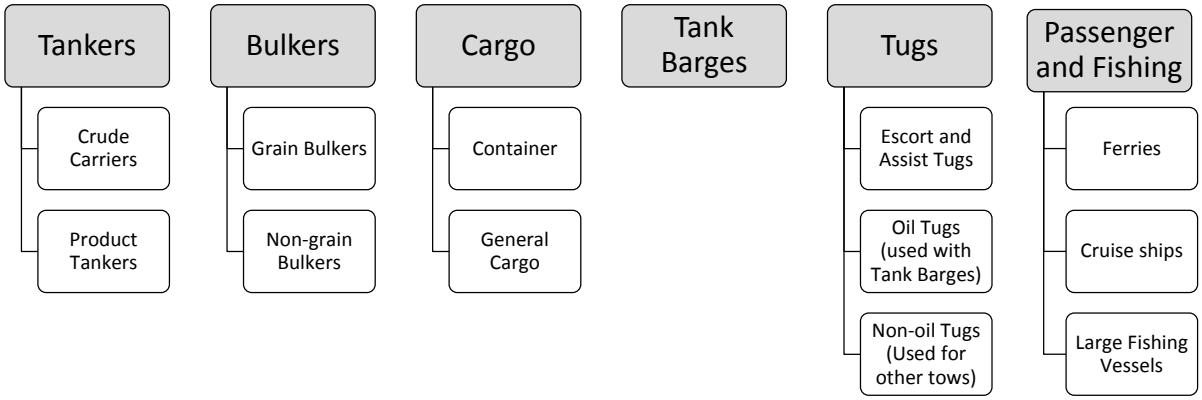
Figure 2. Project Study Area Showing Subareas (Locations)



Source: The Glosten Associates 2012

For the purpose of this analysis, vessel traffic includes tankers, bulkers, cargo vessels, tank barges, tugs, fishing, and passenger vessels. The hierarchy of vessels is illustrated in Figure 3.

Figure 3. Vessel Traffic Types



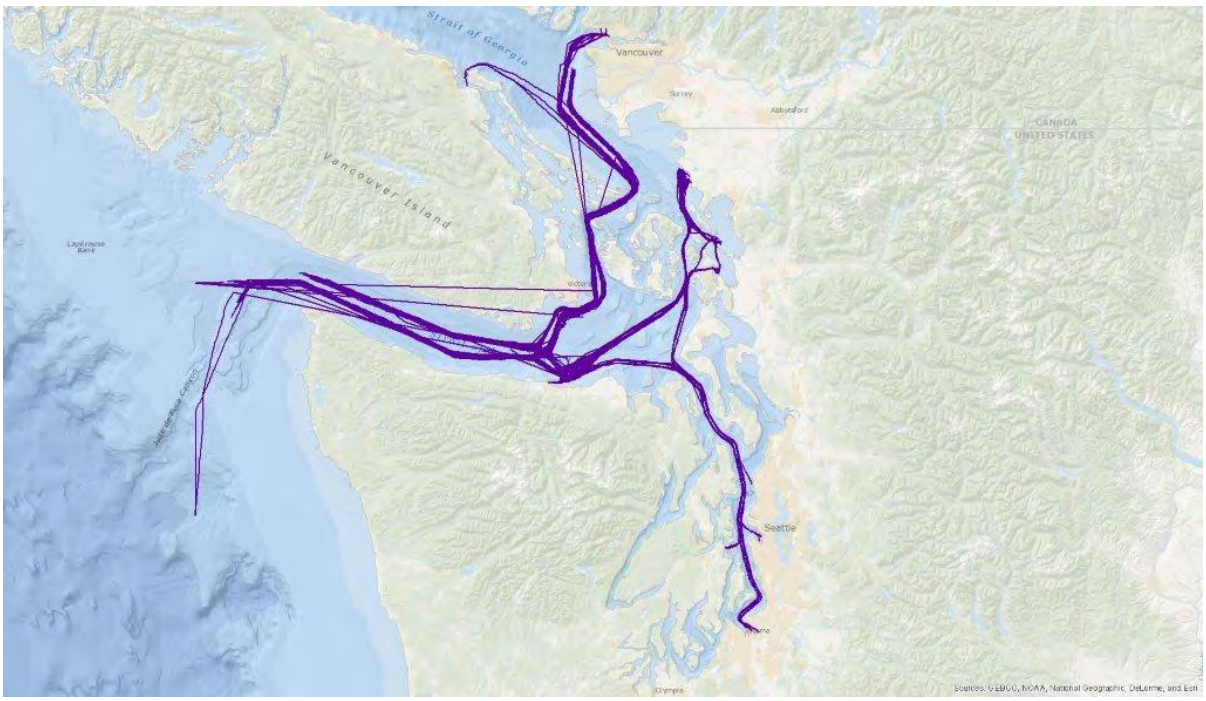
Source: Northern Economics, Inc. 2014

Small fishing, charter, Puget Sound and British Columbia pilot vessels and recreational watercraft were 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 tank vessels moving crude oil and petroleum product tankers (including articulated tank barges [ATBs] and integrated tank barges [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 4 illustrates one month of 2010 transit data for tankers to illustrate their unique traffic pattern.

Figure 4. 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.

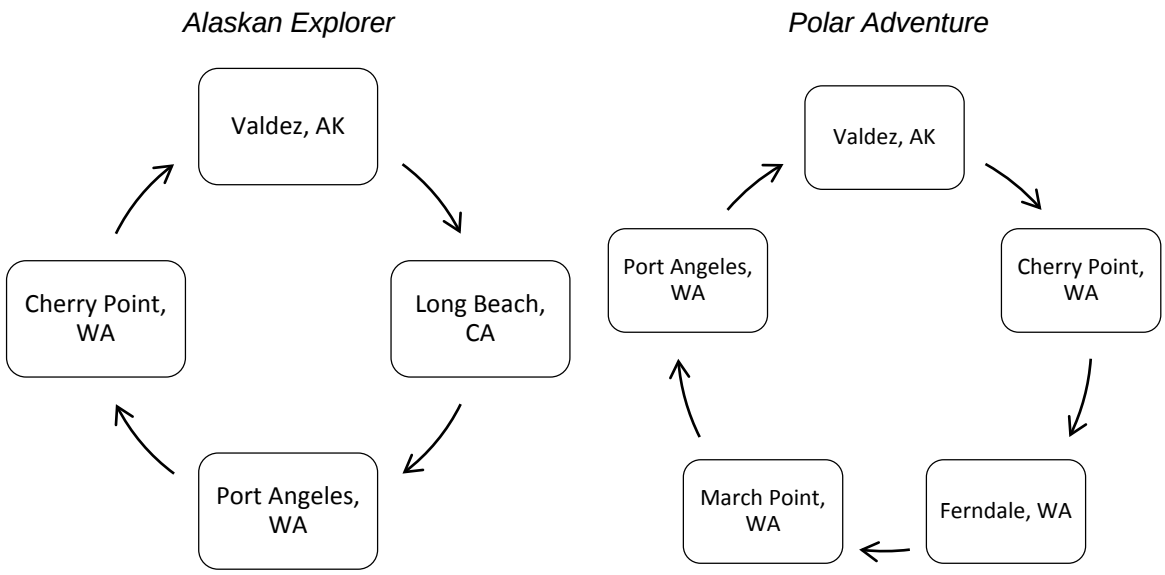
Crude tankers calling at Puget Sound refineries have carrying capacities which are restricted by law:

> Per 33 CFR§165.1303, all tank vessels, U.S. or foreign flag, larger than 125,000 deadweight tons 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 [ed.: American Bureau of Shipping] to add a special Puget Sound load line mark ("PS") to the domestic U.S. load line "ladder" for certain TAPS [ed.: Trans Alaska Pipeline System] 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 2013)

As indicated above, many of the vessels calling at 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 5. 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 5. Sample Tanker Itineraries, 2010



Note: The Port Angeles calls are predominantly either for maintenance or bunkering, not offloading crude
Source: Northern Economics, Inc. using Marine Exchange of Puget Sound (MX) data, 2012

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.

While the majority of tanker activity at Washington ports is attributable to domestic vessels on regularly scheduled routings, such as those shown in Figure 5, foreign-flagged tankers also call at refineries in Washington.[1] Foreign tanker moves can be more unpredictable than those made by domestic tankers. For example, in 2010 a crude tanker named 'Eurochampion 2004' called in the study area just once. This vessel traveled from Long Beach, CA to Port Angeles, WA, then on to the BP facility in Cherry Point, WA where it discharged crude. The tanker then went to anchor in Vendovi, where it sat for a week before returning to the BP dock to discharge additional crude. Ten days after entering the study area, 'Eurochampion 2004' sailed for West Africa, and did not return for the remainder of the year.

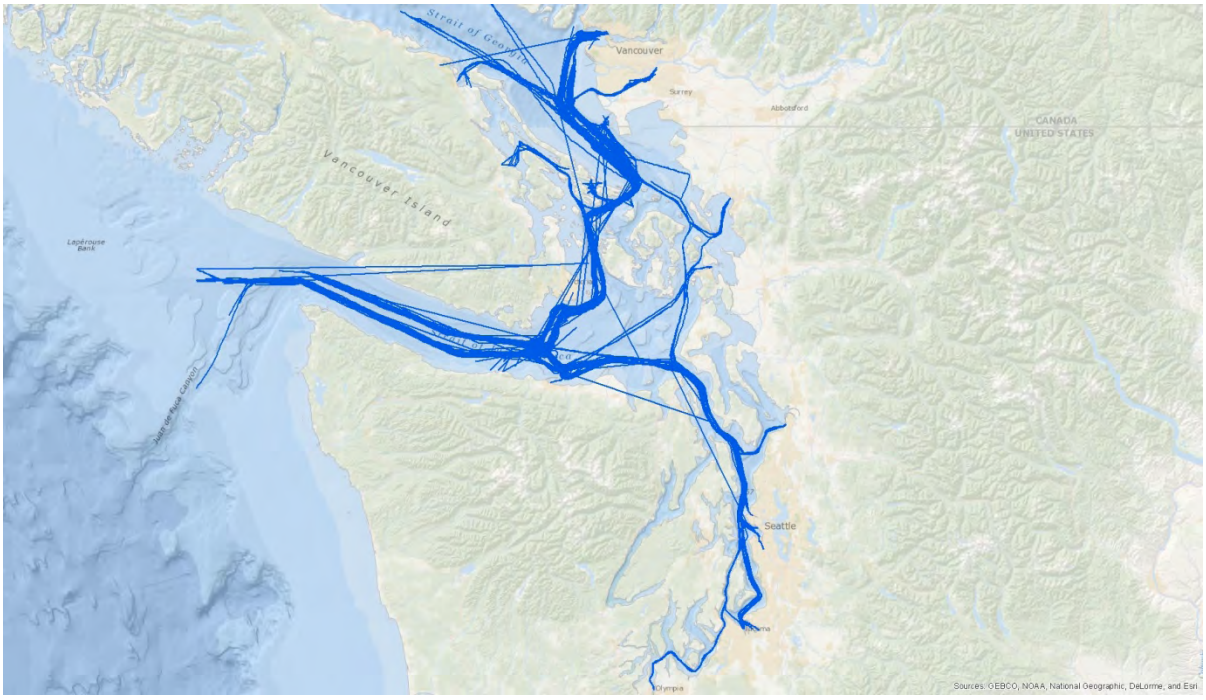
[1] Between 2006 and 2010, each year USA flag crude carriers account for 70-80 percent of total crude carrier moves recorded in the Marine Exchange data.

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 petrol, gas oil, diesel, gasoline, and jet fuels.

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 Anacortes, 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 2014). Figure 6 illustrates the July 2010 traffic pattern for bulkers.

Figure 6. 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.

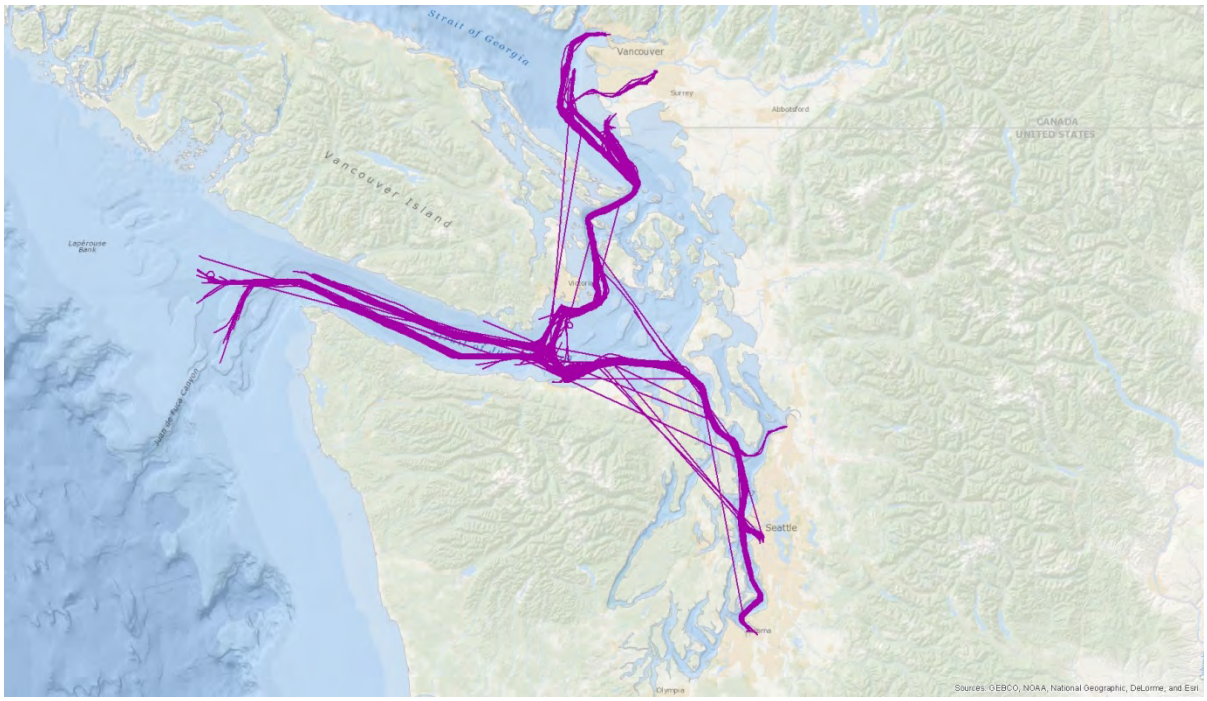
2.3 Cargo Ships

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 7).

Figure 7. Container Vessel Pattern (July 2010)



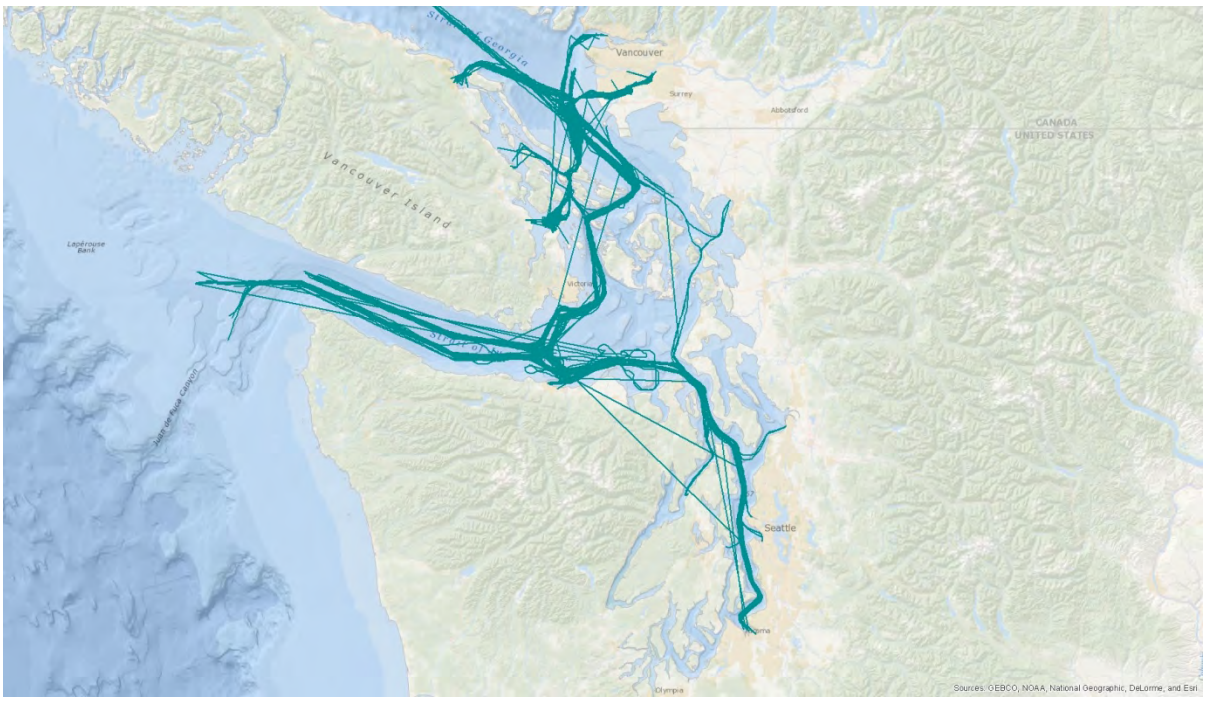
Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.
Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

Many of the container vessels calling at Vancouver also call at Puget Sound. The study team identified the number of container vessel transits from study area ports to Canadian ports and adjusted the vessel counts provided by Port Metro Vancouver to account for these. Transits which would have been double counted (represented in both the MX data and the Port Metro data) were omitted to maintain transit accuracy.

2.3.2 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 8). 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 GPT study area.

Figure 8. 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 data (USCG and CCG) 2010.

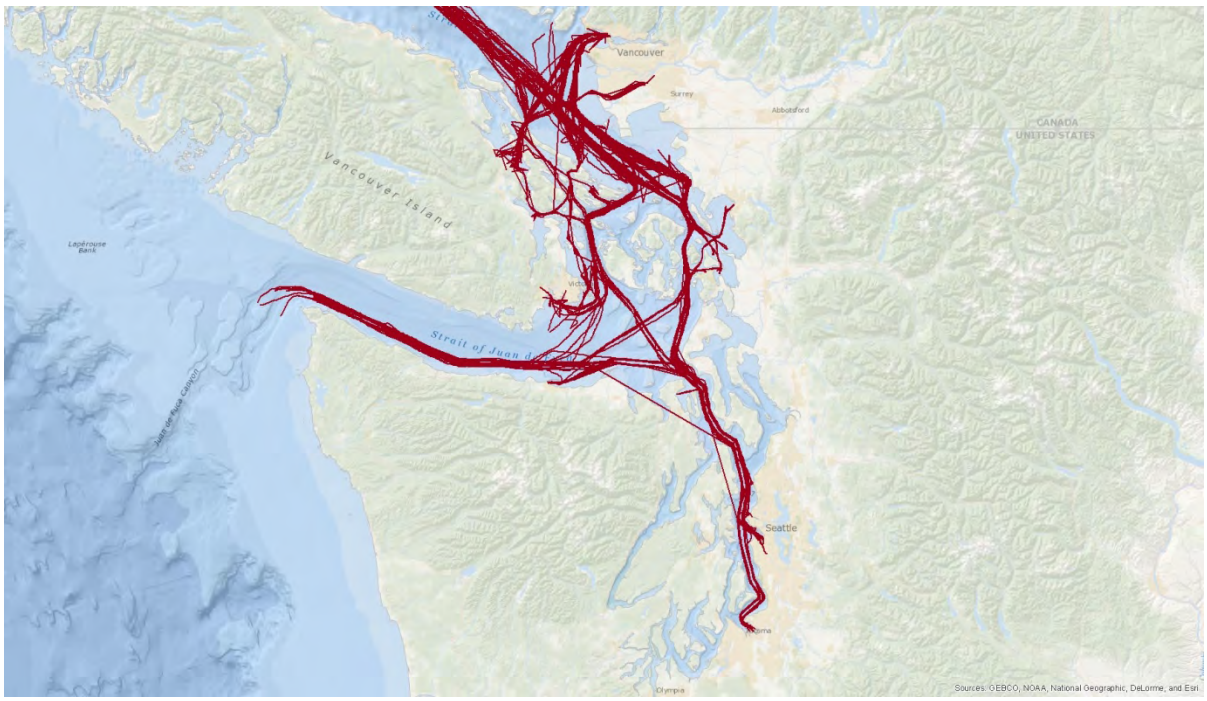
2.4 Tank Barges

Tank barges are defined as petroleum product or crude barges;[2] they are most often used to deliver petroleum products to customers or to fuel vessels (bunkering). 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. Please note that though a tug is necessary to move a tank barge, the risk for tug collisions has been incorporated into the tug vessel type and is discussed further in Section 2.5.

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 9 illustrates a single month of tug and tank barge transits.

[2] ATBs and ITBs are classified as tankers, not tank barges.

Figure 9. 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 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 and assist 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.

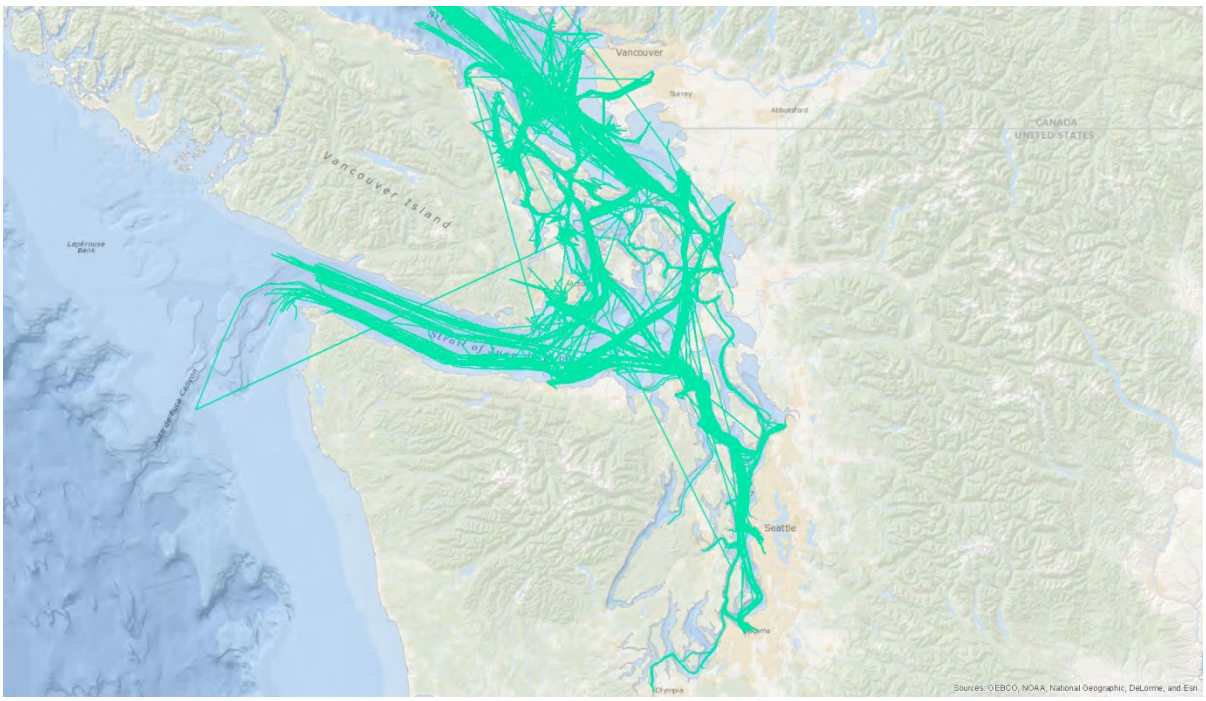
Oil-tugs typically move chemical or petroleum product tank barges.

Non-oil tugs typically move gravel, equipment, wood chip and other products.

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, tugs 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 9. Figure 10 illustrates movements of escort and non-oil tugs.

Figure 10. 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.

Non-oil tug and escort and assist 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.

2.6 Passenger and Fishing Vessels

The passenger vessel component of this combined category includes:

Cruise ships which are 300 gross tons or larger, deep draft, and require a Puget Sound pilot

Regularly scheduled ferry services in the study area

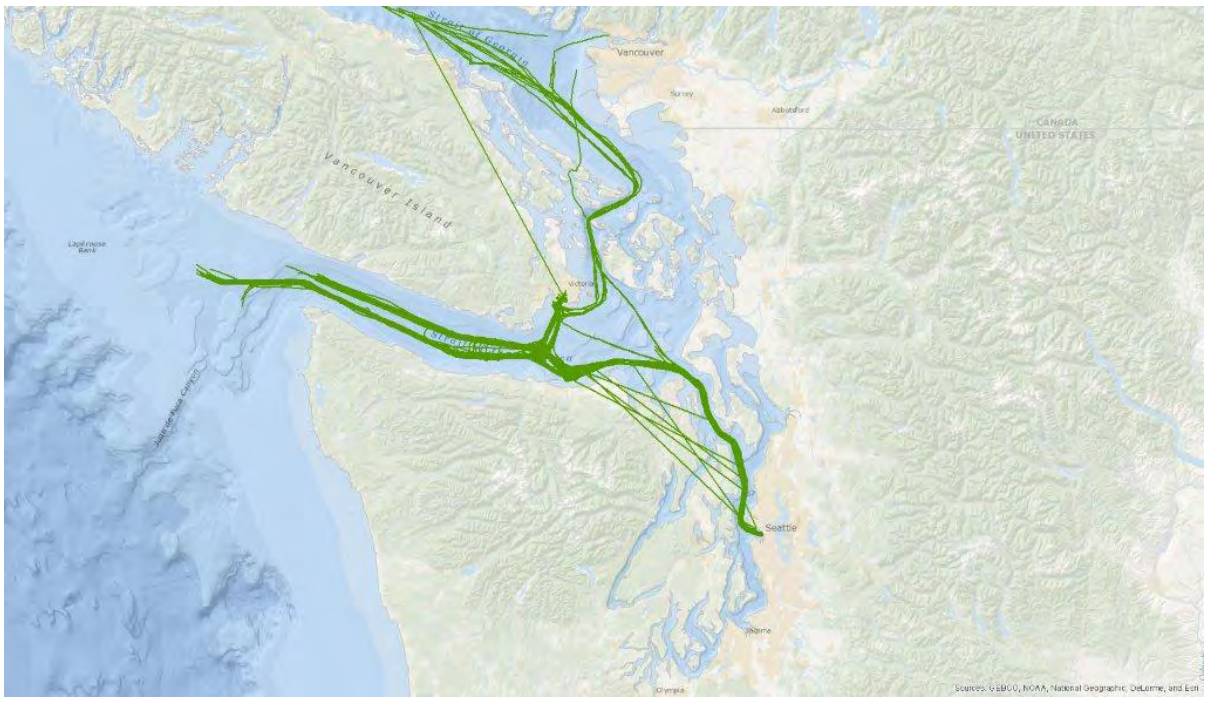
While many small charter and recreational boats also operate in the area, they are significantly different in size and behavior, and are not included in the passenger vessel category.

2.6.1 Cruise Ships

Cruise ships operating within the study area frequently travel between Washington State, British Columbia (Victoria), and Alaska. Figure 11 summarizes the transit patterns of large passenger vessels and ships operating within the study area.[3]

[3] The NRT data do not identify cruise ships specifically. Instead, cruise ships are categorized as passenger vessels or passenger ships, along with boats of a much smaller size. This illustration was generated by filtering out all

Figure 11. 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 ships tend to make a one-way transit through the study area. Like most other large vessels, cruise ships 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 stop in Seattle to pick up passengers, then travel north through Haro Strait and exit the study area via the Cherry Point subarea.[4] 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 often travel to the West of Vancouver Island, and enter the study area through the Strait of Juan de Fuca.

Cruise ships are assumed to use Haro Strait-Boundary Pass exclusively when traveling north and south within the study area.

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.

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 ships.

[4] Cruise ship itineraries frequently include a stop at a Canadian port such as Victoria or Vancouver to fulfill the requirement for a foreign call by non-U.S. flag ships.

2.6.2 Ferries

Three major public ferry systems operate within the study area, as well as several smaller, local, and 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 12).

Figure 12. 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 Washington State ferries only travel among Anacortes, the San Juan Islands, and Sidney, B.C. Figure 13 illustrates this route.

Figure 13. Washington State Ferry System

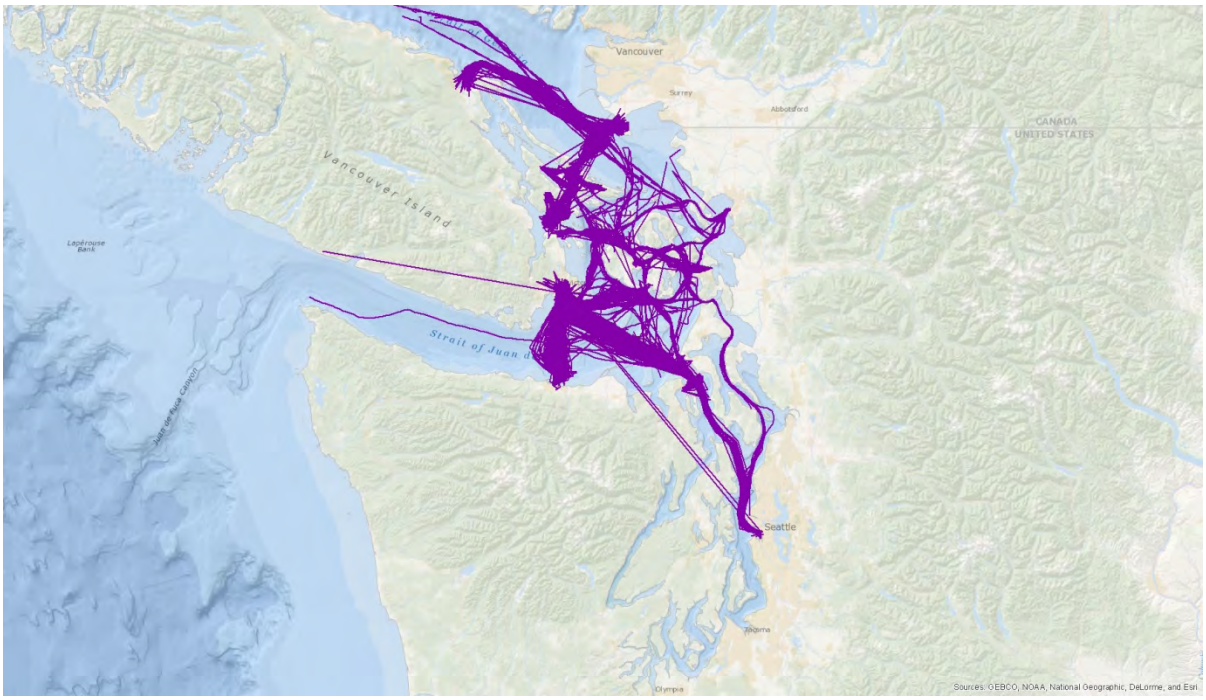
Source: Washington State Department of Transportation 2012.

Private and local ferries operating within the study area include:

- Whatcom County ferry between Gooseberry Point and Lummi Island
- 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 14 illustrates the July 2010 transit pattern for ferries operating within the study area.

Figure 14. 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 data (USCG and CCG) 2010.

2.6.3 Large Fishing Vessels

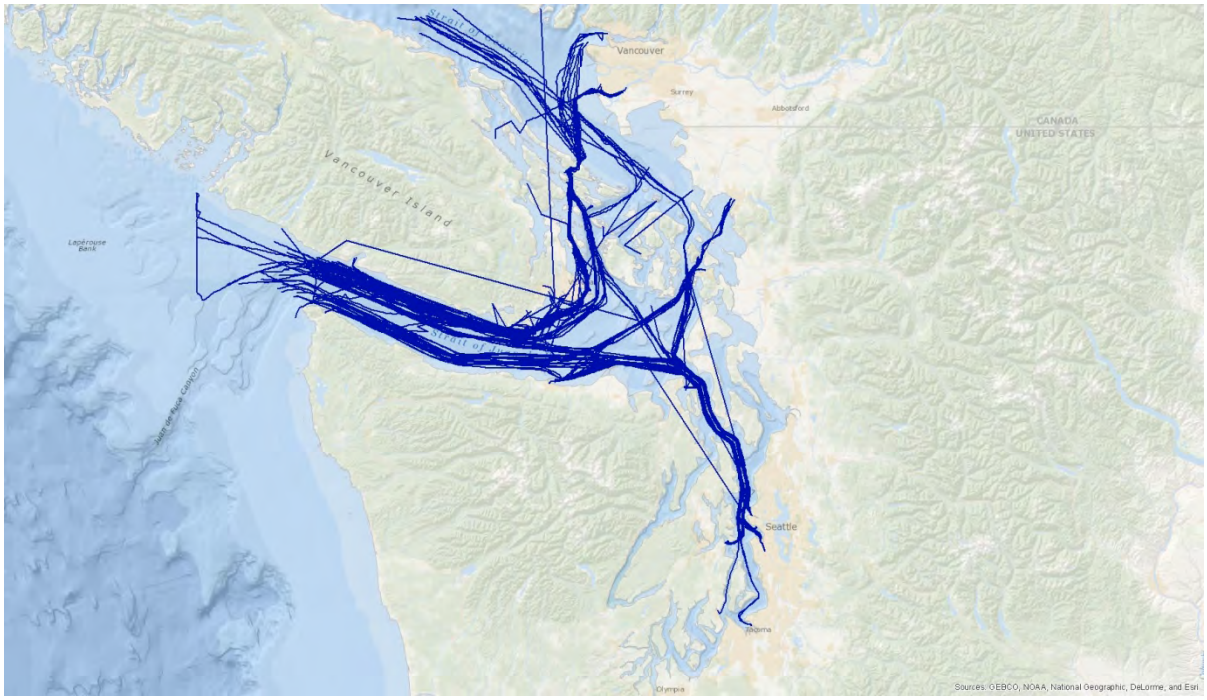
For purposes of this report, "large fishing vessels" are defined as vessels greater than 60 feet[5] length overall that are involved in commercial fishing or processing. It is assumed that in general, large fishing and processing vessels are not actively harvesting or processing fish during their transits—they 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 of an extended trip.[6]

[5] 60 feet was used as it approximates the regulation size for vessels that must carry AIS and is also the cutoff size for Alaska salmon boats; it is a common delineation size already used within the industry.

[6] Contacts in the local fishing industry indicated that much of the product delivered to Bellingham Cold Storage has already been processed and does not come directly from fishing vessels. Our assumption with respect to large vessels fishing within Puget Sound and the Strait of Juan de Fuca is based primarily on the types of fisheries that take place in these areas (i.e. seining and gillnetting for salmon and pot fishing for Dungeness crab). These fisheries are generally small boat fisheries, particularly the salmon fisheries. In general, we do not believe that operating large vessels in these low-volume near-shore fisheries would be cost effective or profitable.

Figure 15 illustrates the July 2010 transit patterns for large fishing vessels operating within the study area.

Figure 15. Large Fishing Vessels (July 2010)



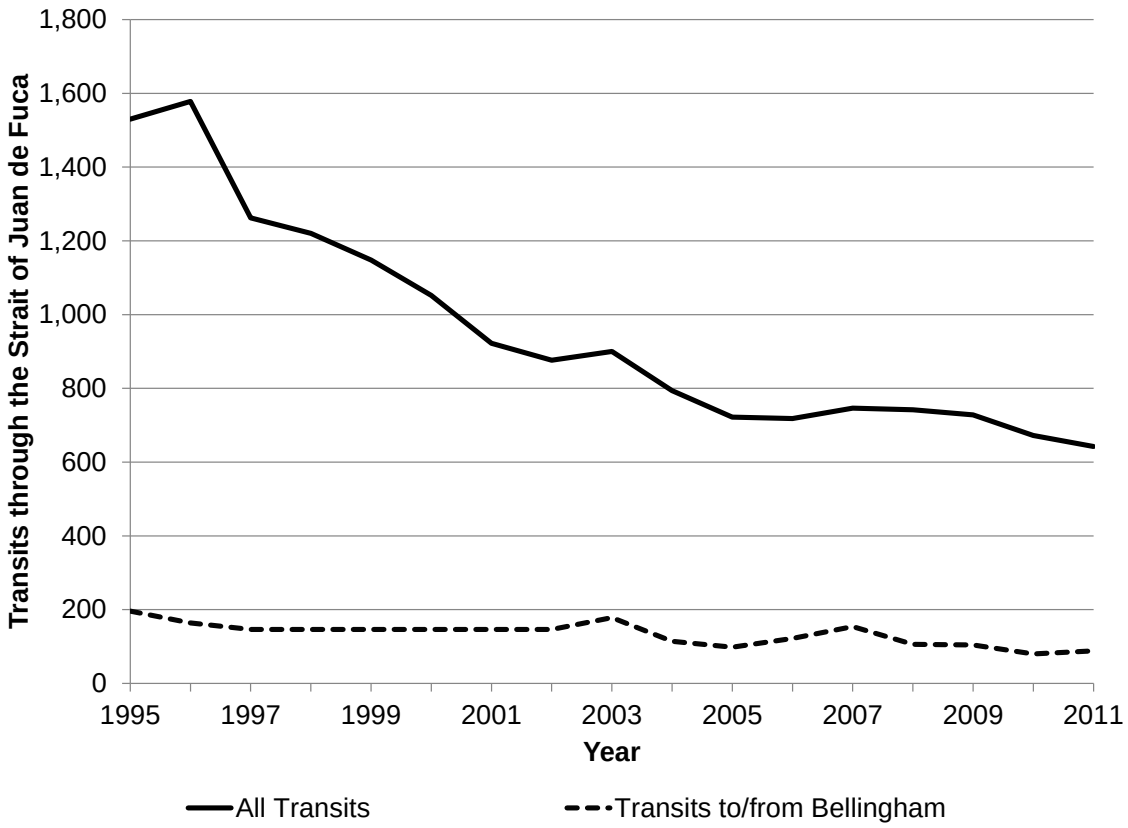
Note: Lines appearing to cross land may be the result of errors in the NRT data record or inconsistent signals being emitted from vessels, which can produce large gaps between data points.
Source: Northern Economics, Inc. using NRT data (USCG and CCG) 2010.

As shown in Figure 16, 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 regions are unrelated, but both have been transitioning to catch share management systems that in general result in fewer fishing vessels.[7]

[7] This is a modeling assumption made by the study team based on knowledge of the fishing industry. Should management regimes or market dynamics change, there is a possibility that fishing vessel transits could stay level or increase.

Figure 16. Declines in Large Fishing Vessel Transits in the Strait of Juan de Fuca, 1995–2011



Source: Developed by Northern Economics from multiple sources, 2014

2.7 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.[8] 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.

[8] VEAT data identifies Canadian-bound vessels; the proportion of vessels by type provided by Port Metro Vancouver for 2008-2011 were applied to the VEAT data to estimate historic transits by vessel type.

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

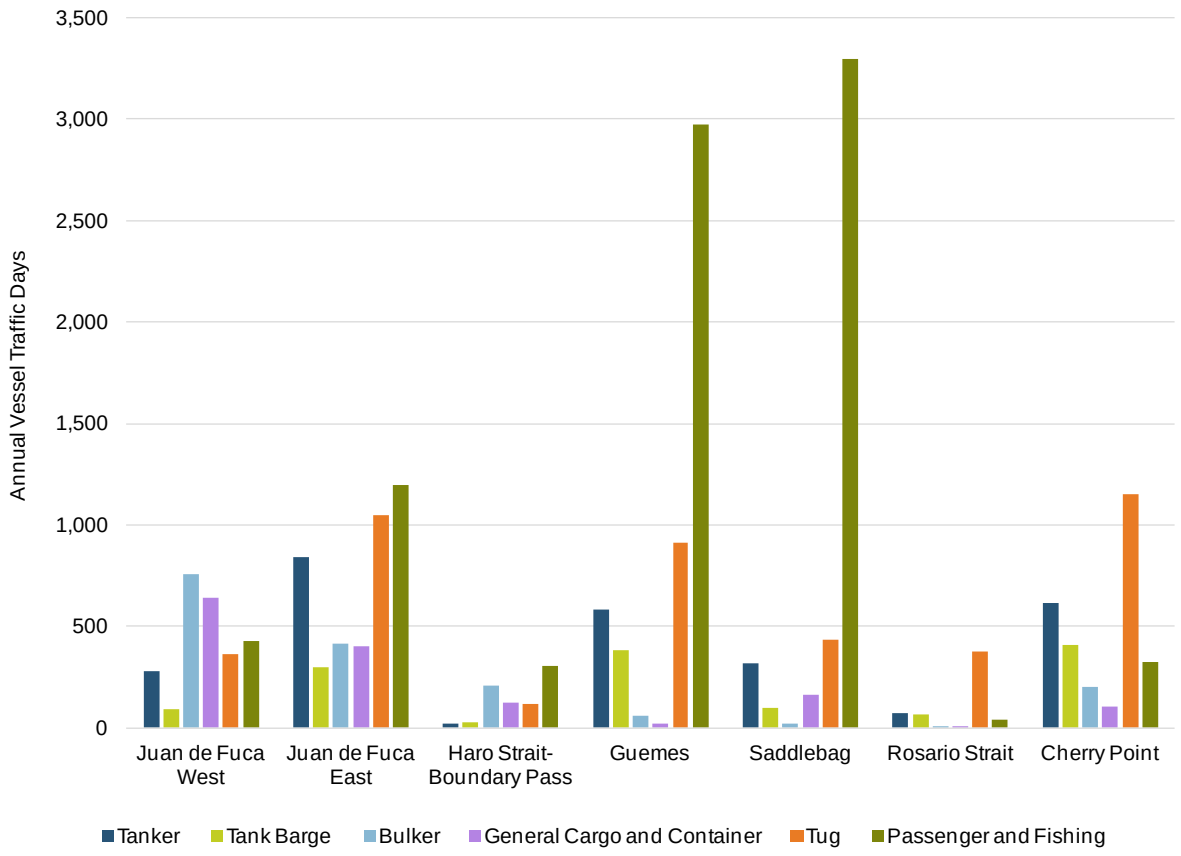
Vancouver Vessel Title	GPT Vessel Names	2008	2009	2010	2011	Average (%)
Bulk Carrier / Reefer	Bulk	1,321	1,250	1,398	1,488	49.2
Container	Container	855	754	708	817	27.0
Ro-Ro / Combination	General Cargo	290	254	257	262	8.7
Tanker	Tanker	241	255	271	206	6.8
Passenger	Passenger	255	258	183	200	6.6
Miscellaneous and Offshore	Excluded from Analysis	42	20	16	51	1.7
Total		**3,004**	**2,791**	**2,833**	**3,024**	**100.0**

Source: Port Metro Vancouver 2012

3 Vessel Traffic Data

To illustrate current traffic patterns, the study team used the movements described in Section 2, to generate estimates of vessel traffic days by activity type and subarea. Figure 17 summarizes the results, showing average annual vessel traffic days by subarea. Passenger and large fishing vessels account for the vast majority of vessel days spent in most subareas.

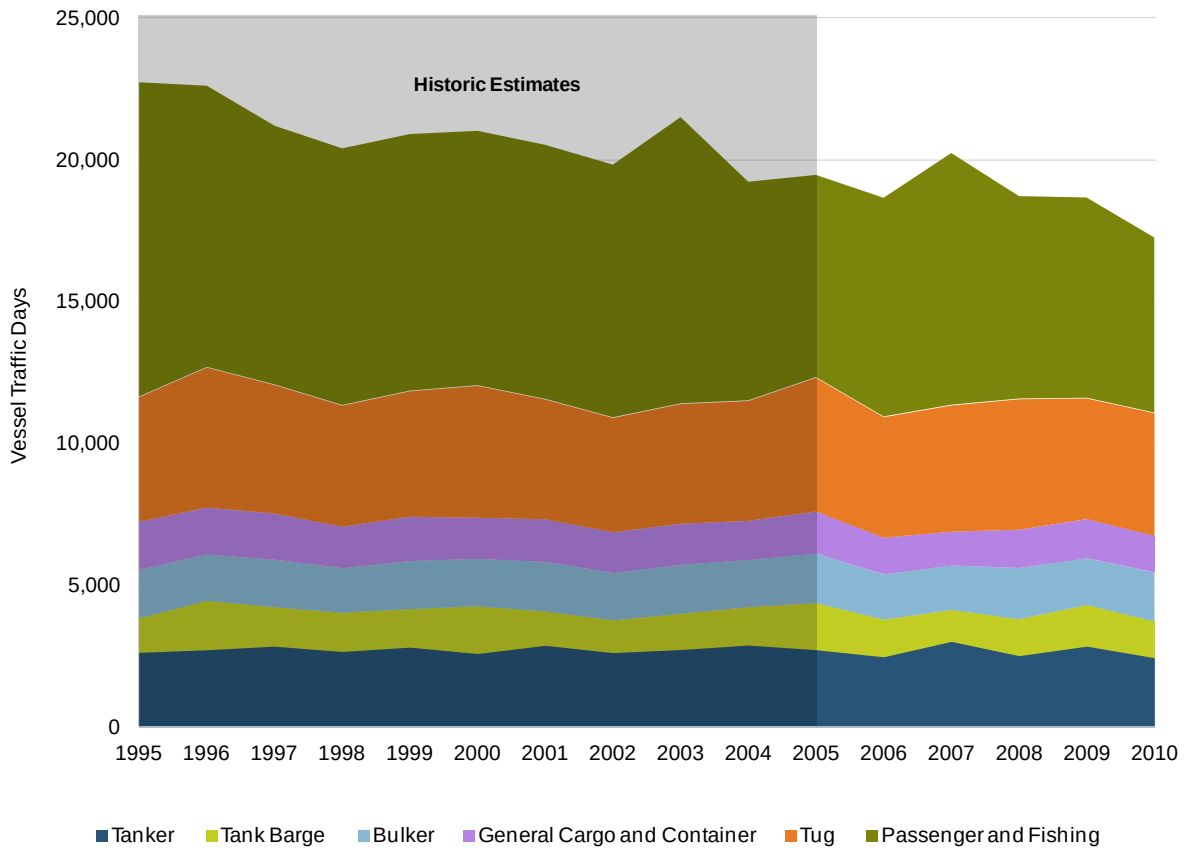
Figure 17. Vessel Days by Subarea and Vessel Type, Summed across All Activity Types, Average (1995–2010)



Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

Between 1995 and 2010, time spent by passenger and fishing vessels decreased significantly from 11,100 vessel days a year to less than 6,200 (Figure 18). The decrease is due primarily to a drop in the number of large fishing vessels transiting the study area. As mentioned in Section 2.6.3, 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 18. Total Vessel Days by Vessel Type, for All Subareas and Activity Types, Average (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

In the following subsections we detail the results of our analysis by vessel and activity type. All tables and figures generated in this section (Section 3) were produced using Northern Economics' estimates of vessel days by subarea and activity type.

3.1 Tankers

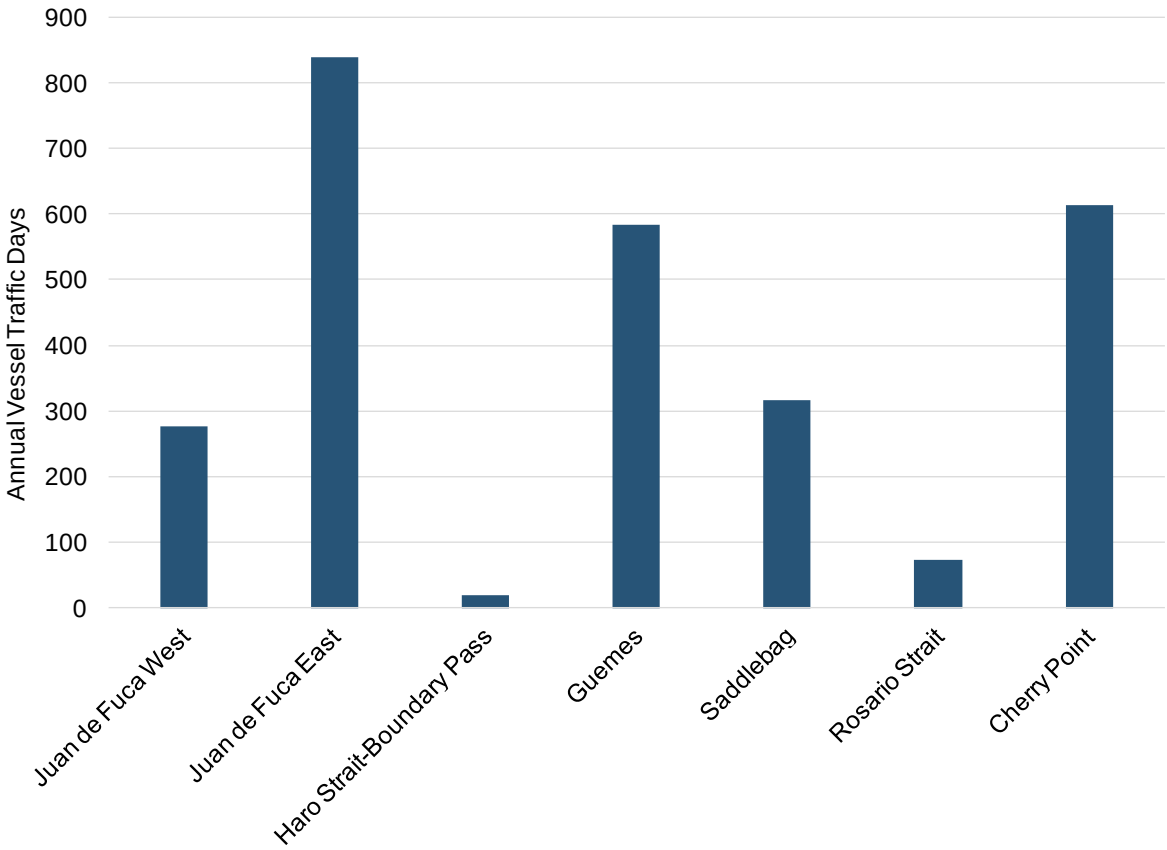
Tankers spend most of their transiting time in Strait of Juan de Fuca West; this is not surprising given the long distance travelled in this subarea (71 miles). However, transit time is overshadowed by time at anchor and time at dock. As shown in Table 3 and Figure 19, total time by subarea is greatest in Strait of Juan de Fuca East, Guemes Channel, and Cherry Point. The majority of the vessel traffic days in Strait of Juan de Fuca East and Guemes Channel are reflective of time at anchor at Port Angeles and Vendovi Island. The vessel days in Cherry Point are almost exclusively days spent at berth.

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

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	250.3	803.5	17.1	544.8	301.9	74.3	649.4	2,641.3
1996	260.2	839.6	16.3	563.6	298.5	77.5	674.8	2,730.4
1997	269.3	860.1	19.9	589.0	340.9	79.7	699.1	2,858.1
1998	250.9	798.7	19.4	550.1	326.2	74.0	651.4	2,670.7
1999	265.8	848.0	20.0	581.9	339.9	78.6	690.1	2,824.3
2000	251.8	824.3	11.6	538.0	246.1	75.7	652.0	2,599.5
2001	272.2	869.7	20.0	595.0	343.0	80.5	706.5	2,886.9
2002	252.6	820.4	14.0	543.8	270.6	75.5	654.6	2,631.6
2003	264.1	860.8	13.5	566.5	271.3	79.2	684.0	2,739.3
2004	278.1	903.1	15.4	598.7	297.8	83.2	720.6	2,896.9
2005	264.3	863.7	12.8	565.7	264.0	79.4	684.5	2,734.5
2006	318.4	846.5	27.6	582.3	261.4	62.7	387.2	2,486.2
2007	332.0	1,014.1	27.4	692.3	418.4	69.6	470.5	3,024.4
2008	289.7	751.8	26.0	558.2	325.2	67.0	507.2	2,525.1
2009	322.4	766.6	28.2	685.6	480.6	67.2	507.1	2,857.7
2010	295.9	741.4	30.1	577.3	272.1	61.5	475.3	2,453.7
Average	277.4	838.3	20.0	583.3	316.1	74.1	613.4	2,722.5

Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

Figure 19. Tanker Vessel Days by Subarea, Average (1995–2010)

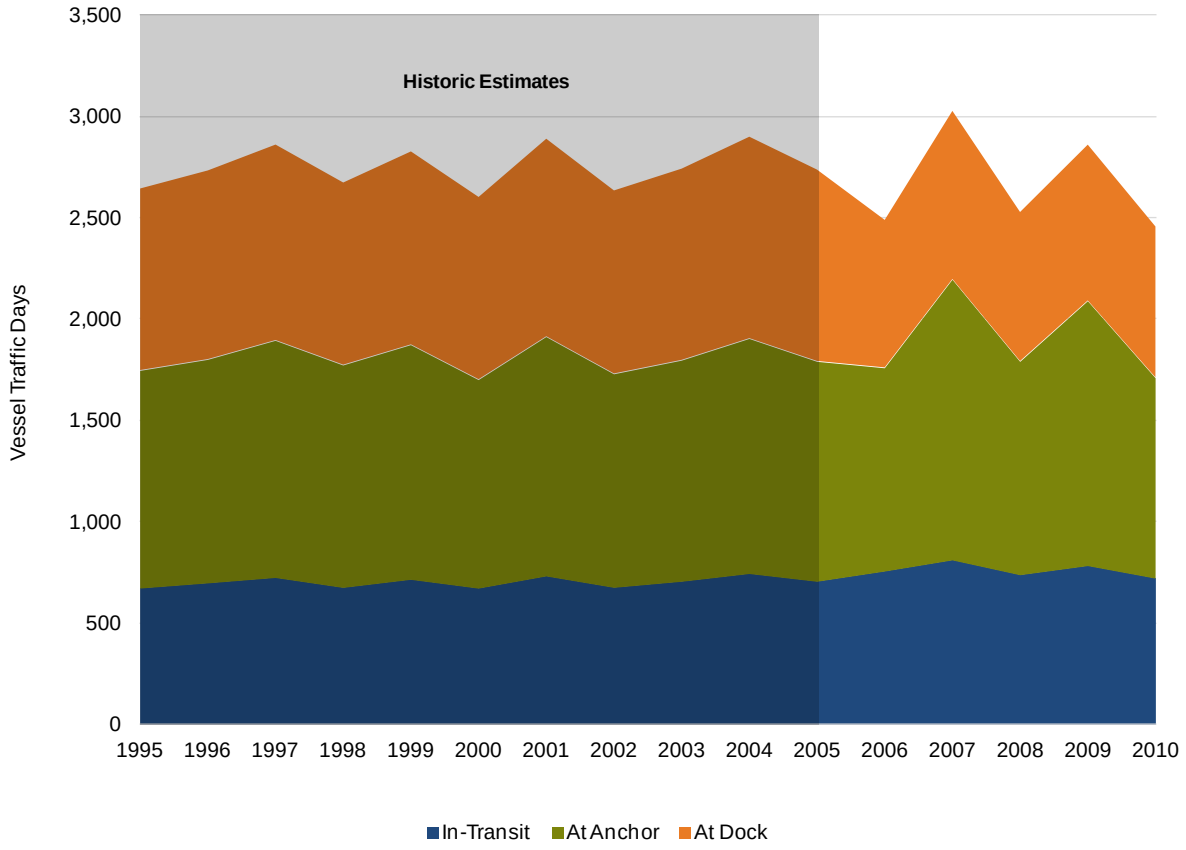


Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

Of total time spent by tankers in the study area, 26 percent of vessel days are spent in transit,[9] 32 percent of vessel days are spent at dock, and 41 percent of vessel days are spent at anchor (Figure 20).

[9] Transit time = underway plus maneuvering time.

Figure 20. Tanker Vessel Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

3.2 Bulkers

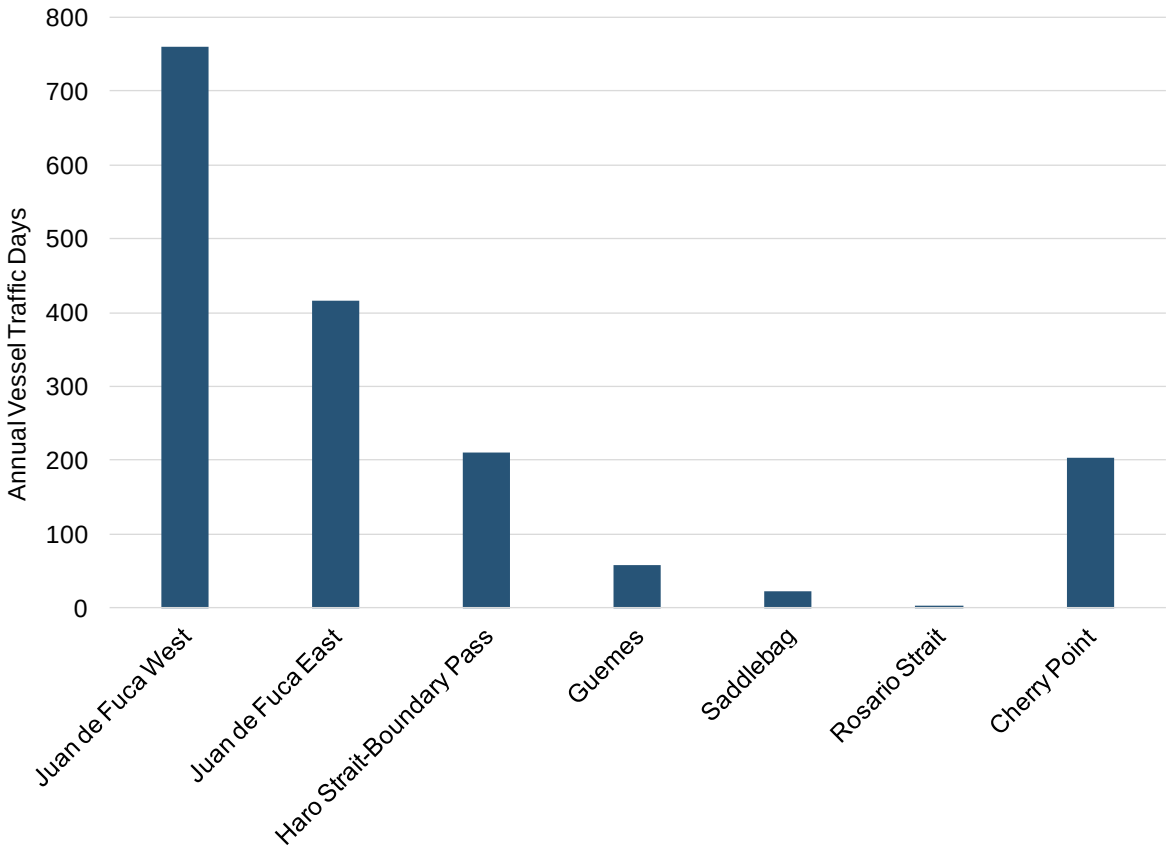
The vast majority of bulker vessels in the study area are transiting through en route to Canadian or South Puget Sound destinations. Those going north to Canada's Inside Passage use Haro Strait almost exclusively; very few transit days are spent in Rosario Strait (Table 4 and Figure 21). South Puget 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 Strait of Juan de Fuca East and Strait of Juan de Fuca West.

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

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	784.0	420.4	208.1	76.4	25.9	4.1	187.1	1,705.8
1996	747.1	400.9	196.4	75.3	25.5	4	176.7	1,625.9
1997	768.9	412.1	206.2	72.1	24.4	3.8	185.2	1,672.9
1998	718.3	384.7	195.6	63.5	21.5	3.4	175.4	1,562.5
1999	778.4	416.7	213.2	67.2	22.8	3.6	191.2	1,692.9
2000	767.7	410.4	215.1	59.9	20.3	3.2	192.5	1,669.1
2001	802.2	428.7	225.5	61.7	20.9	3.3	201.8	1,744.1
2002	765.0	408.9	214.6	59.4	20.1	3.2	192	1,663.1
2003	792.9	423.5	224.8	58.4	19.8	3.1	201	1,723.6
2004	764.6	408.3	217.6	55.3	18.7	2.9	194.5	1,662.0
2005	802.0	428.5	226.3	60.5	20.5	3.2	202.4	1,743.4
2006	703.2	391.8	199.6	61.0	22.3	1.9	207.9	1,587.7
2007	683.2	377.8	191.8	48.9	33.3	2.1	228.5	1,565.5
2008	796.5	444.0	221.5	48.9	20.0	1.8	269.2	1,801.9
2009	729.8	438.0	205.7	28.9	18.1	1.5	221.6	1,643.6
2010	756.0	464.2	208.7	35.5	22.4	1.7	237.6	1,726.1
Average	760.0	416.2	210.7	58.3	22.3	2.9	204.0	1,674.4

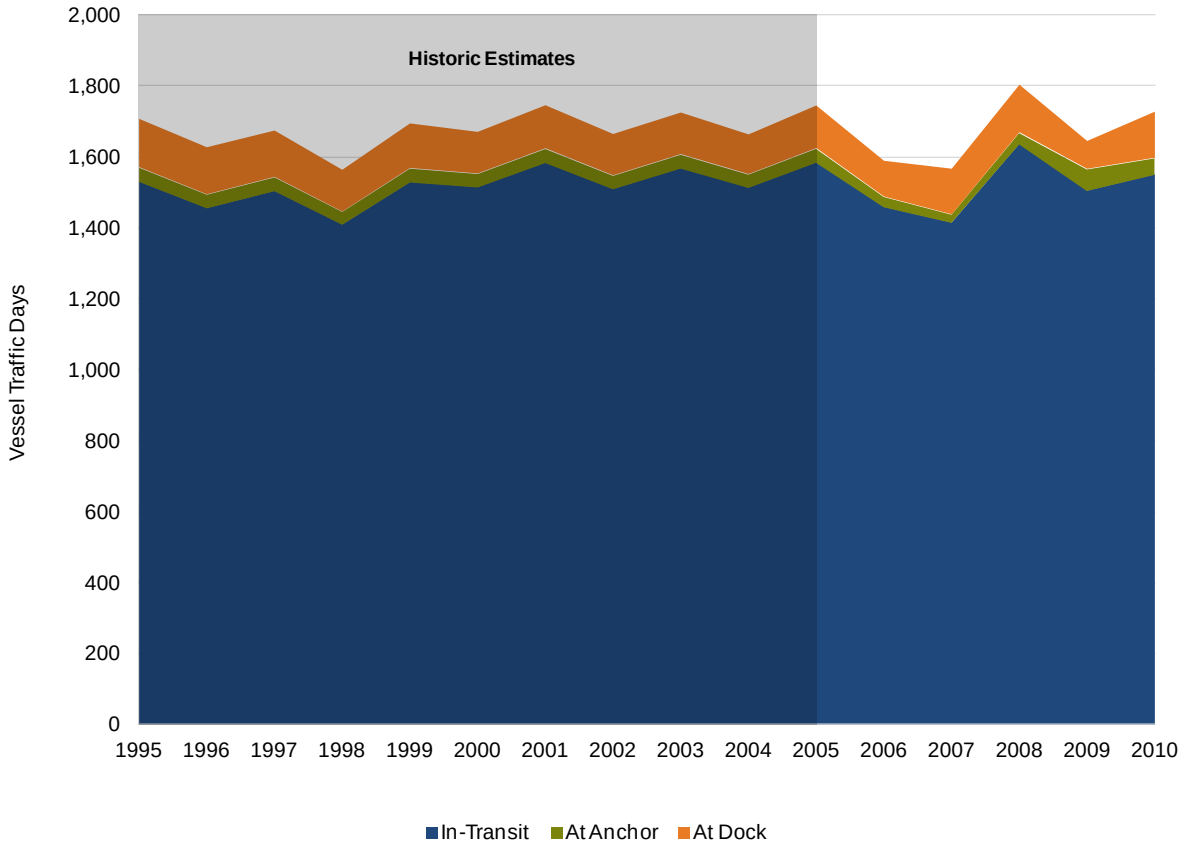
Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

Figure 21. Bulker Vessel Days by Subarea, Average (1995–2010)



Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

Figure 22. Bulker Vessel Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014.

3.3 Cargo Ships

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

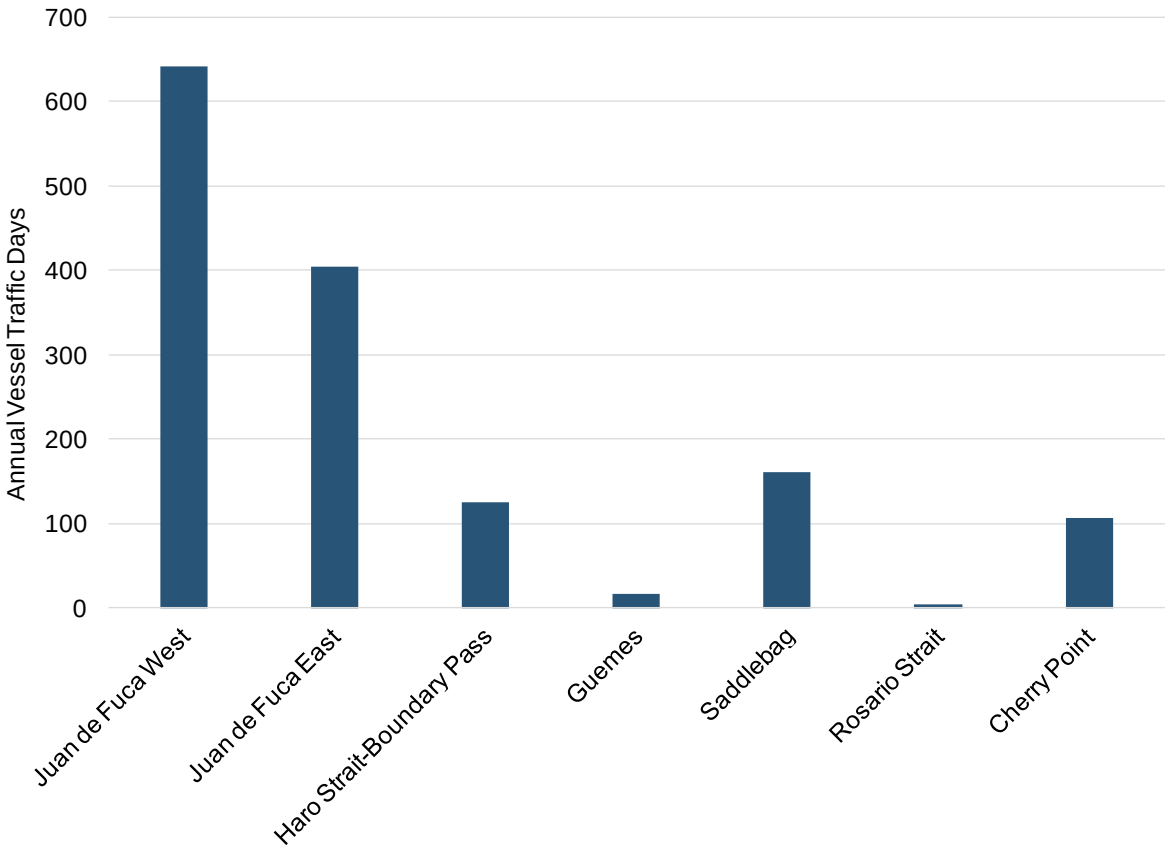
well as calls to Port Angeles (Strait of Juan de Fuca East) each year. The majority of general cargo vessel calls recorded by the MX data show transits to and from locations in South Puget Sound and the Canadian Inside Passage (i.e. Vancouver).

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

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	753.3	484.7	141.5	19.7	186.6	4.2	116.1	1,706.1
1996	733.9	472.8	136.4	19.4	184.0	4.2	112.0	1,662.7
1997	721.6	463.5	137.1	18.6	176.2	4.0	112.4	1,633.4
1998	650.1	416.7	125.8	16.4	155.2	3.5	102.9	1,470.7
1999	693.9	444.4	135.3	17.3	164.1	3.7	110.6	1,569.3
2000	645.1	411.4	129.6	15.5	146.5	3.3	105.6	1,457.0
2001	668.0	425.8	134.8	15.9	150.7	3.4	109.9	1,508.5
2002	640.9	408.7	129.0	15.3	145.2	3.3	105.1	1,447.4
2003	644.6	410.2	131.8	15.1	142.8	3.2	107.2	1,454.8
2004	614.9	391.0	126.4	14.3	135.1	3.1	102.8	1,387.5
2005	660.7	420.8	134.1	15.6	147.8	3.4	109.2	1,491.6
2006	575.6	348.7	105.6	15.4	154.5	3.3	99.7	1,302.8
2007	558.6	329.0	102.0	11.3	100.5	3.1	95.9	1,200.5
2008	587.0	365.0	118.3	7.4	165.2	3.2	111.7	1,357.9
2009	560.3	352.1	110.0	18.3	241.6	2.8	103.6	1,388.8
2010	556.1	325.4	111.6	33.2	165.3	2.9	105.7	1,300.2
Average	641.5	404.4	125.6	16.8	160.1	3.4	106.9	1,458.7

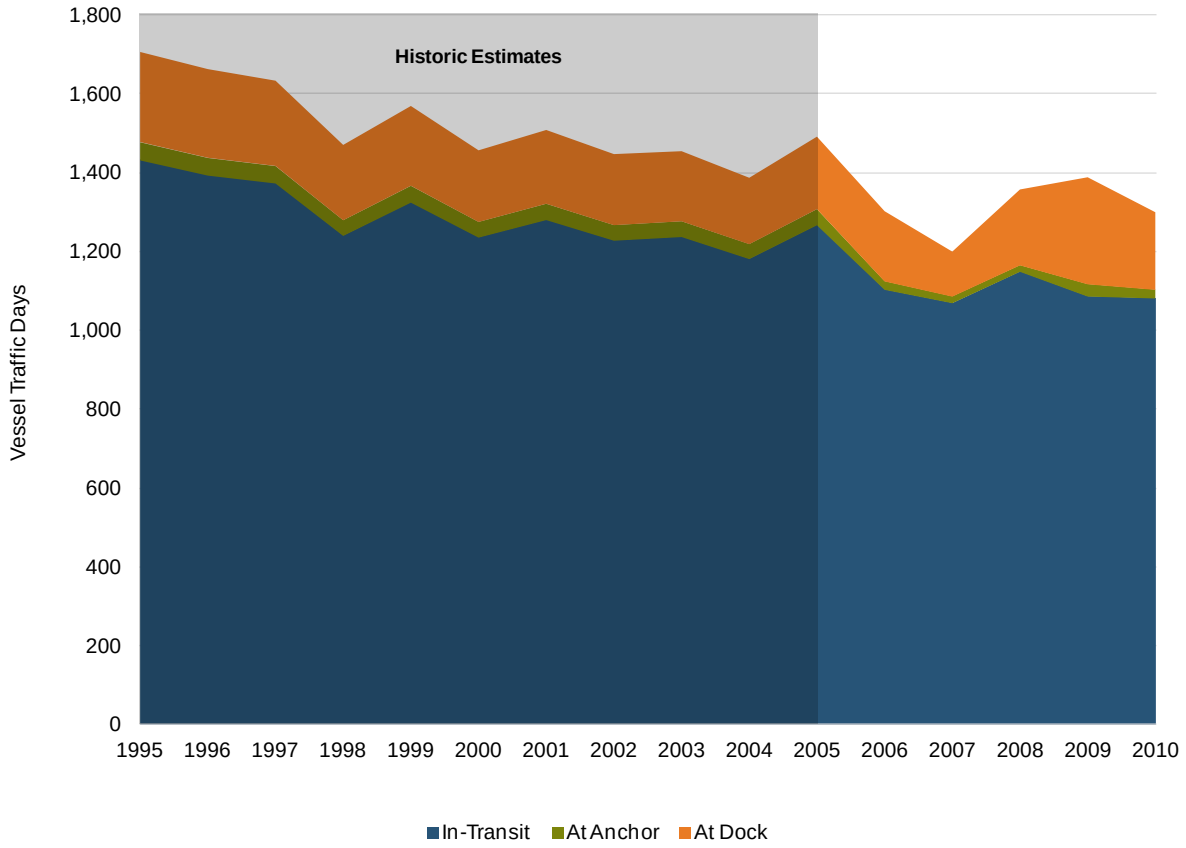
Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

Figure 23. Cargo Ship Days by Subarea, Average (1995–2010)



Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

Figure 24. Cargo Ship Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

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 Washington Department of Ecology (WADOE). 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.

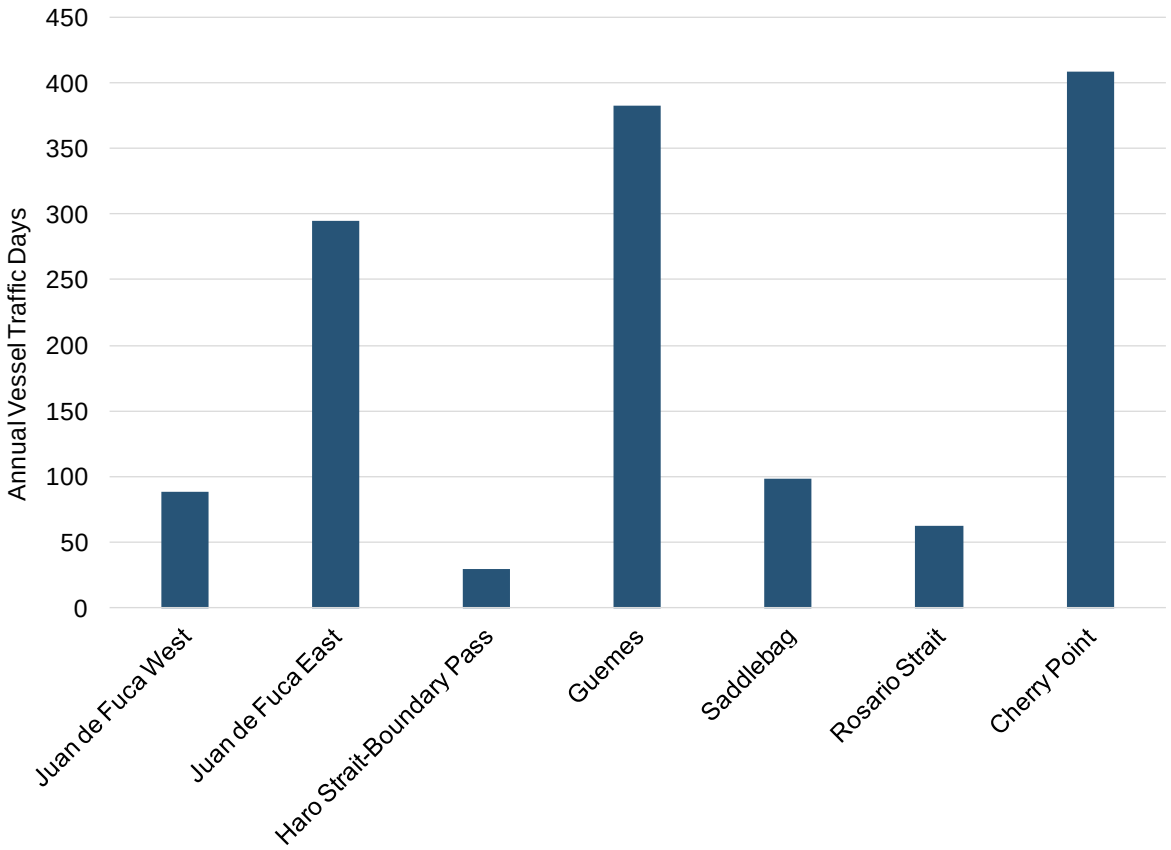
Tank barges are frequently moved within the study area, but unlike larger product tankers, do not frequent the ocean. This accounts for the much smaller proportion of total vessel days spent in Juan de Fuca West (Table 6 and Figure 25).

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

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	77.7	260.4	26.0	338.2	87.1	54.9	360.8	1,205.1
1996	112.0	375.3	37.4	487.5	125.5	79.2	520.2	1,737.1
1997	89.2	299.0	29.8	388.3	100.0	63.1	414.3	1,383.7
1998	89.0	298.1	29.7	387.2	99.7	62.9	413.2	1,379.9
1999	87.0	291.5	29.1	378.6	97.5	61.5	404.0	1,349.0
2000	107.9	361.6	36.0	469.7	120.9	76.3	501.2	1,673.7
2001	77.8	260.6	26.0	338.4	87.1	55.0	361.1	1,205.9
2002	74.0	248.0	24.7	322.1	82.9	52.3	343.7	1,147.6
2003	81.9	274.3	27.3	356.3	91.7	57.9	380.2	1,269.7
2004	86.7	290.7	29.0	377.5	97.2	61.3	402.8	1,345.2
2005	106.5	357.0	35.6	463.7	119.4	75.3	494.7	1,652.2
2006	85.1	285.1	28.4	370.3	95.3	60.2	395.1	1,319.5
2007	67.4	227.0	24.5	338.2	74.9	47.6	339.7	1,119.3
2008	80.9	249.0	30.6	384.5	90.6	57.1	401.4	1,294.2
2009	97.0	328.3	27.3	385.8	104.6	68.7	449.3	1,461.0
2010	87.6	310.7	27.1	340.8	103.0	62.1	354.9	1,286.2
Average	88.0	294.8	29.3	382.9	98.6	62.2	408.5	1,364.3

Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

Figure 25. Tank Barge Days by Subarea, Average (1995–2010)

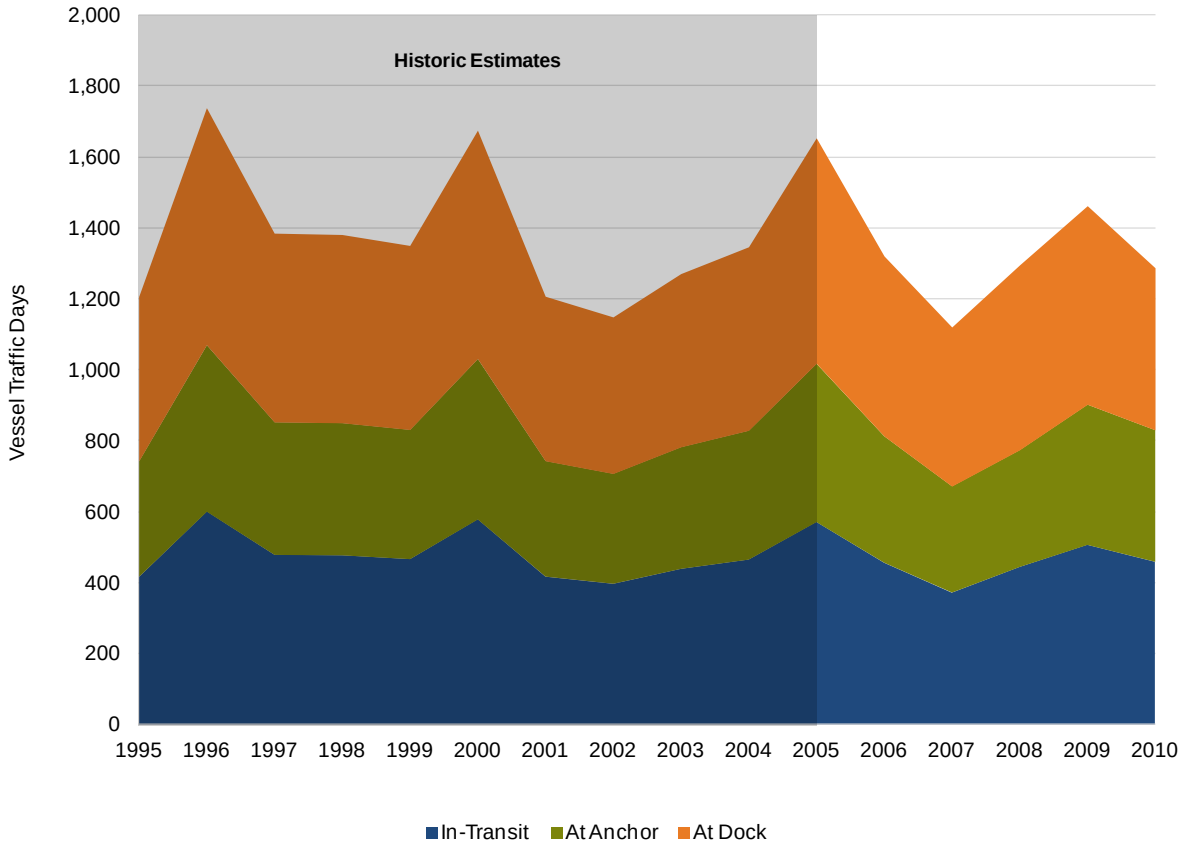


Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

Tank barges operating within the study area spend a relatively large portion of time at anchor and at berth (Figure 26).[10] 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.

[10] A portion of the time tank barges spend at anchor is used for bunkering; however, the portion of time spent bunkering cannot be determined given currently available data.

Figure 26. Tank Barge Vessel Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

3.5 Tugs

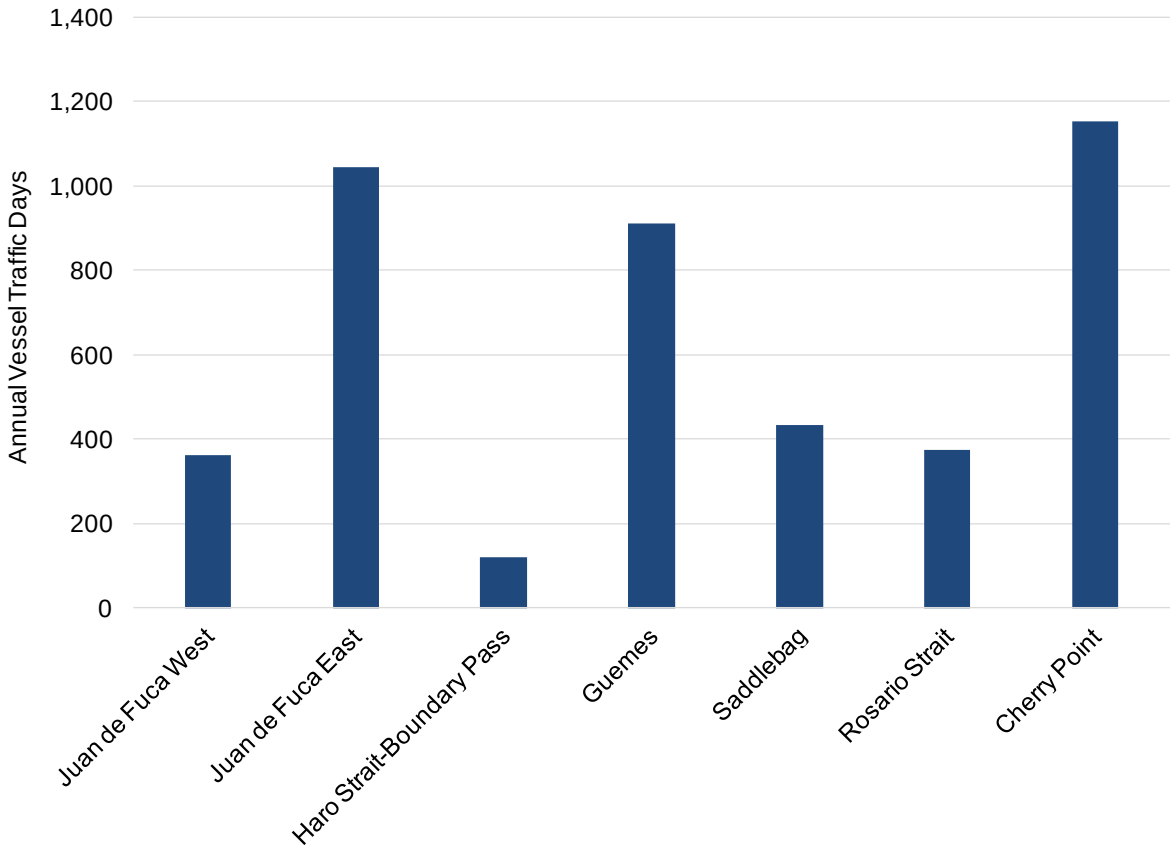
Tugs perform a variety of services; the time spent escorting, assisting and towing vessels within the study area contributes a significant amount of vessel days. Particularly high volumes of tug traffic are seen transiting Strait of Juan de Fuca East, Guemes, and Cherry Point.

Table 7. Tug Vessel Days by Subarea, 1995–2010

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	358.1	1,045.3	120.4	899.3	441.2	380.6	1,140.6	4,385.6
1996	408.8	1,167.1	131.5	1,035.8	470.1	412.9	1,303.1	4,929.3
1997	371.5	1,074.7	122.7	936.3	445.3	386.9	1,183.7	4,521.2
1998	351.5	1,011.5	114.9	887.6	414.7	361.7	1,119.9	4,261.7
1999	362.8	1,049.5	119.9	914.2	435.0	377.9	1,155.8	4,414.9
2000	385.6	1,098.2	123.4	977.9	440.1	387.3	1,229.1	4,641.6
2001	345.0	1,003.7	115.3	867.5	420.9	364.0	1,099.0	4,215.5
2002	329.1	957.5	110.0	827.3	401.7	347.3	1,048.2	4,021.0
2003	346.0	1,002.1	114.6	871.4	416.4	361.4	1,102.2	4,214.0
2004	347.5	1,001.4	113.9	877.0	411.7	358.7	1,107.1	4,217.3
2005	390.2	1,114.2	125.6	988.4	449.2	394.4	1,243.6	4,705.6
2006	349.0	1,008.1	114.9	880.0	416.5	362.2	1,111.9	4,242.6
2007	373.0	1,092.9	136.9	885.1	472.1	409.3	1,073.2	4,442.6
2008	360.2	1,015.5	121.3	1,005.9	466.5	392.0	1,230.4	4,591.9
2009	362.3	1,006.2	114.2	872.8	377.8	359.4	1,155.8	4,248.5
2010	346.9	1,072.1	105.7	866.2	431.8	353.8	1,134.6	4,311.1
Average	361.7	1,045.0	119.1	912.0	431.9	375.6	1,152.4	4,397.8

Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

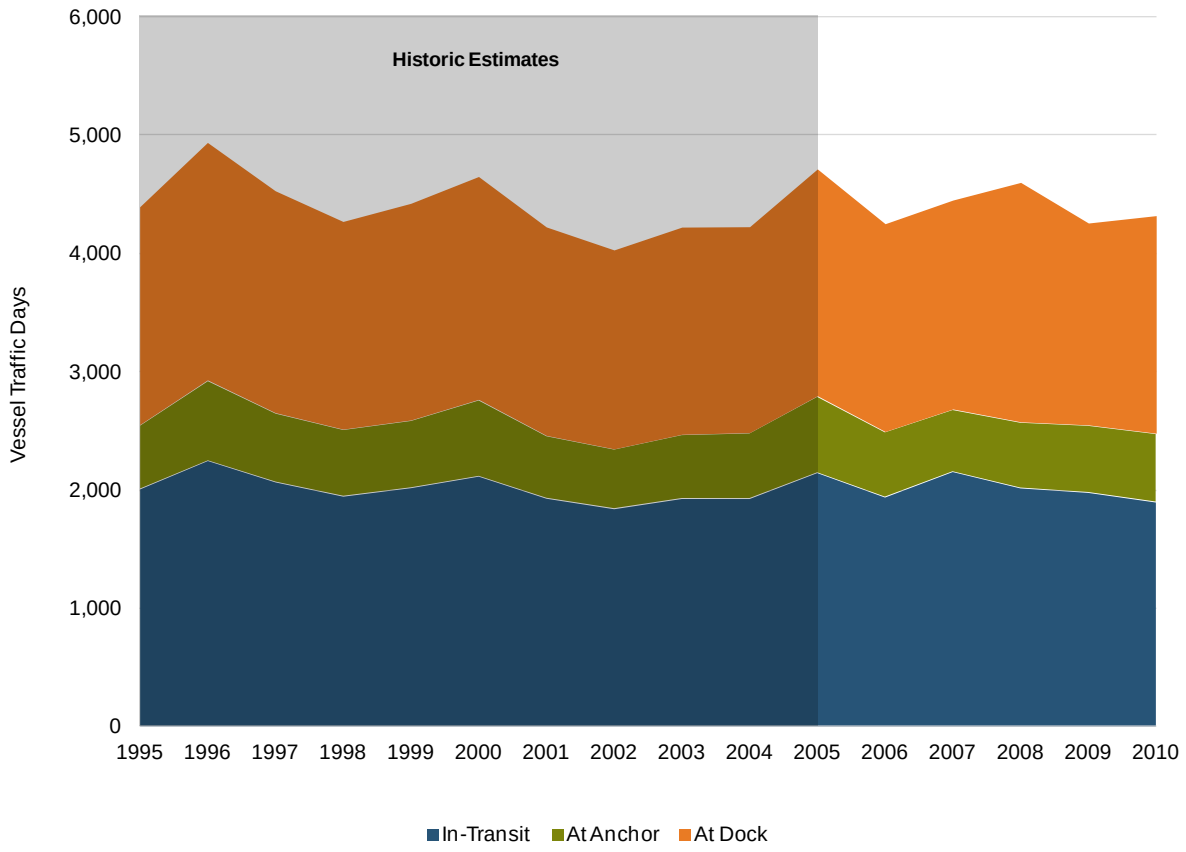
Figure 27. Tug Vessel Days by Subarea, Average (1995–2010)



Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

A large portion of tug vessel days are spent transiting (Figure 28). This activity pattern is to be expected as primary tug activities—towing, escorting and assisting—all contribute to in-transit time.

Figure 28. Tug Vessel Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

3.6 Passenger and Fishing Vessels

As shown in Table 8 and Figure 29, passenger and fishing vessels spend the most vessel days in Saddlebag and Guemes Channel subareas; the least amount of time is spent in Haro and Rosario Strait. Reasons for this traffic pattern include:

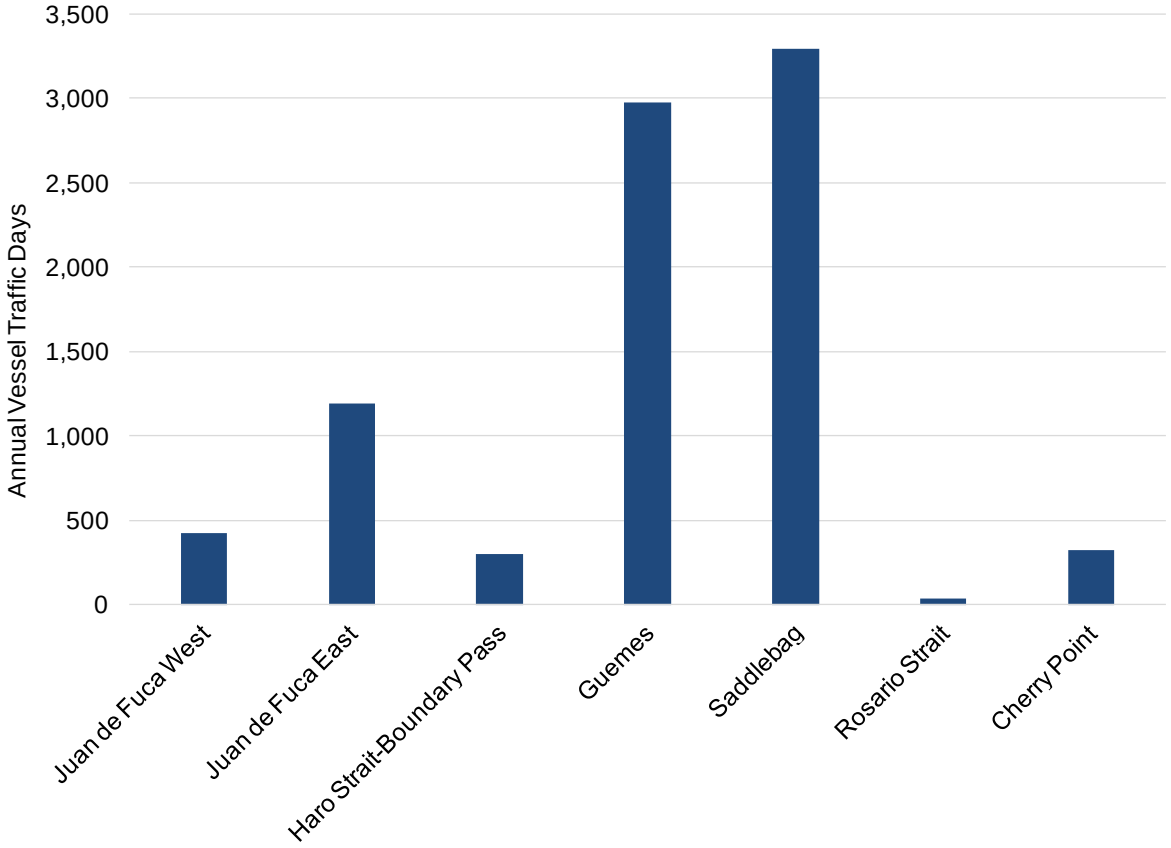
- High volumes of ferry traffic transiting and docking in Saddlebag and Guemes Channel
- High volumes of fishing vessels transiting Strait of Juan de Fuca East and docking for extended periods in Saddlebag and Guemes Channel.

Table 8. Passenger and Fishing Vessel Days by Subarea, 1995–2010

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
1995	611.1	1,370.4	311.3	3,885.7	4,530.6	38.8	331.2	11,079.1
1996	621.6	1,364.3	309.0	3,392.9	3,861.4	37.4	328.1	9,914.7
1997	527.3	1,319.7	309.4	3,115.6	3,484.9	36.7	328.5	9,122.2
1998	504.8	1,278.3	304.4	3,115.6	3,484.9	36.7	321.8	9,046.5
1999	490.4	1,293.4	308.5	3,115.6	3,475.8	36.6	326.0	9,046.4
2000	456.0	1,258.4	306.0	3,115.6	3,474.0	36.5	322.3	8,969.0
2001	424.4	1,255.9	308.4	3,115.6	3,486.7	36.7	327.5	8,955.2
2002	404.3	1,234.1	305.8	3,115.6	3,486.7	36.7	324.0	8,907.3
2003	415.1	1,242.4	307.0	3,608.5	4,156.0	38.0	325.6	10,092.7
2004	376.7	1,211.3	304.6	2,622.8	2,831.1	35.6	323.9	7,706.1
2005	360.0	1,224.6	308.0	2,376.4	2,495.6	35.0	329.1	7,128.7
2006	323.9	1,003.1	291.8	2,746.0	2,992.1	35.9	317.8	7,710.5
2007	330.2	1,000.5	289.8	3,238.9	3,662.7	37.2	315.0	8,874.3
2008	337.3	1,015.5	294.4	2,499.6	2,637.5	34.9	318.5	7,137.7
2009	335.3	1,017.9	292.2	2,468.8	2,596.5	34.8	313.8	7,059.4
2010	321.1	1,013.5	293.7	2,099.1	2,094.2	33.8	315.9	6,171.4
Average	427.5	1,194.0	302.8	2,977.0	3,296.9	36.3	323.1	8,557.6

Note: Data from 1995–2005 (shaded cells) are historic estimates.
Source: Northern Economics, 2014

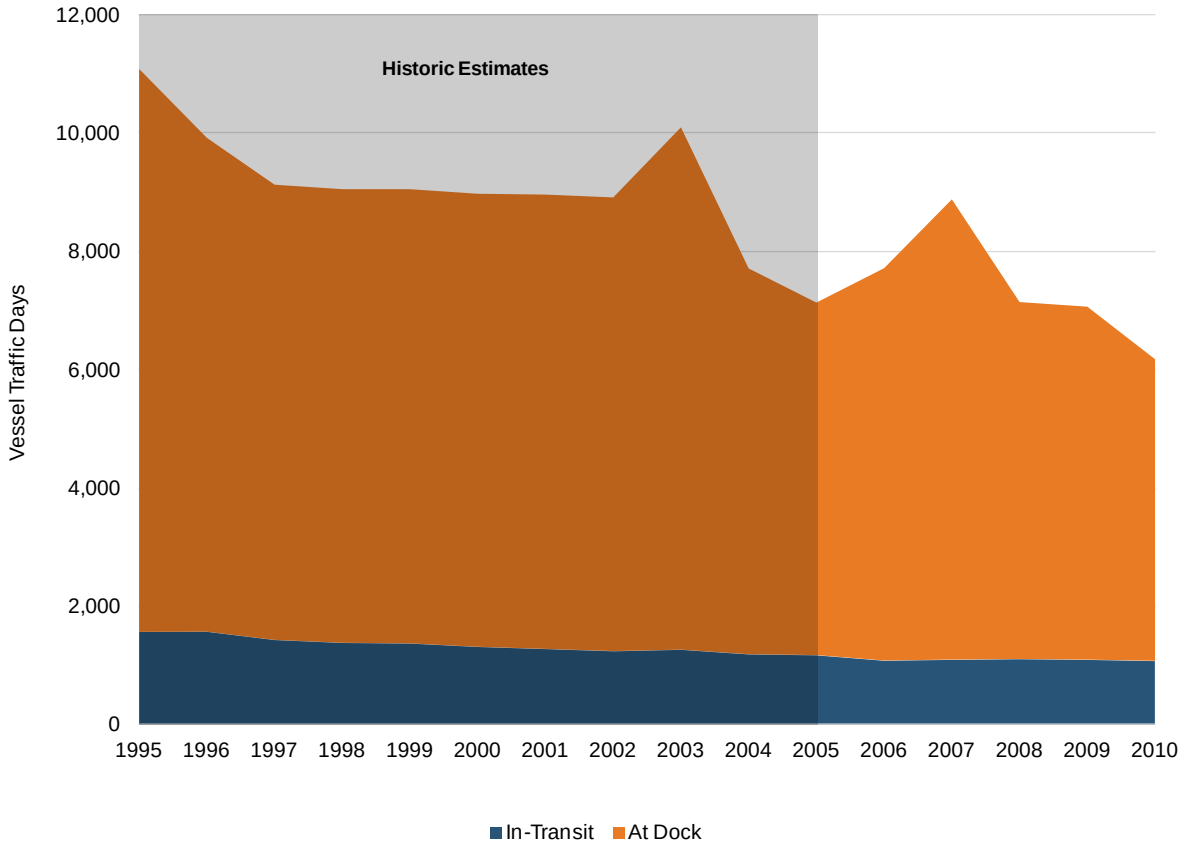
Figure 29. Passenger and Fishing Vessel Days by Subarea, Average (1995–2010)



Note: Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

A large portion of passenger and fishing vessel days are spent at dock, while none are spent at anchor (Figure 30). Passenger vessels typically transit from dock to dock without anchoring, though many of the ferries which operate as part of the Washington State Ferry System dock within the study area at night. Large fishing vessels typically transit straight through the study area en route to their homeports, where they spend long periods of time at dock in Bellingham or Anacortes.

Figure 30. Passenger and Fishing Vessel Days by Activity Type (1995–2010)



Note: Vessel Days are stacked in figure; top line represents total. Data from 1995–2005 are historic estimates.
Source: Northern Economics, 2014

3.7 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 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 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 Traffic 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 WDOE, is derived from Canadian and U.S. Coast Guard Vessel Traffic data. VEAT data 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 (WDOE 2011). VEAT data were available for the length of the study period (1995–2010) and were used to determine historic vessel 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.

None of the data sets mentioned above afforded a complete picture of the vessel traffic patterns in the study area; consequently, the study team had to combine sources to meet study objectives.

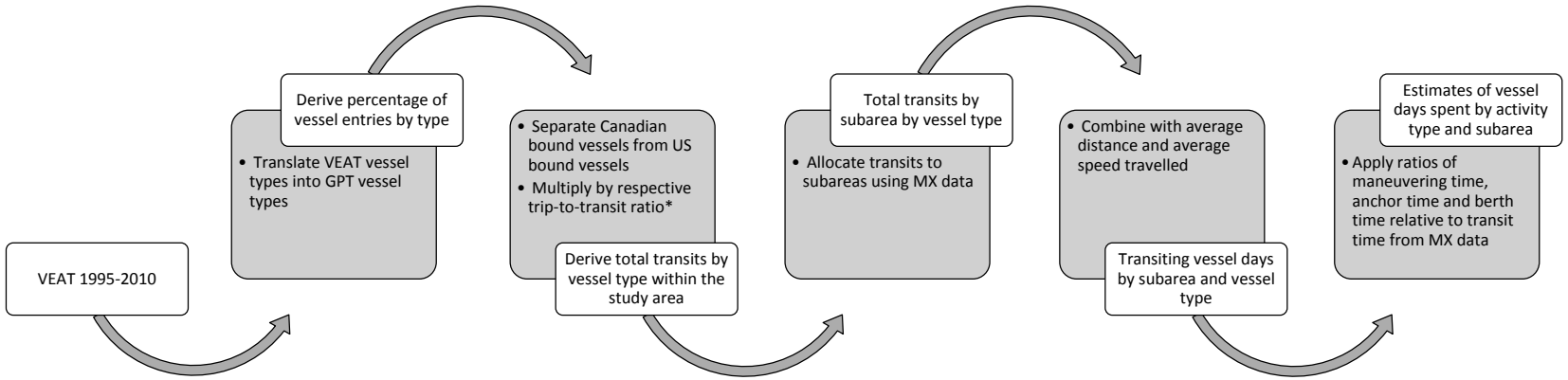
3.7.1 Tankers, Bulkers and Cargo Vessels

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 first step was to organize MX vessel traffic data into grouped origin and destination (OD) pairs, and generalize 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.

Time at anchor was estimated using the USCG anchorage database. 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 WDOE 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 31.

Figure 31. 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. It is derived using the ratio of moves to unique trips within the study area and varies by vessel type.

3.7.2 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, available NRT data were sampled. 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 NRT data were sampled for the following:[11]

- Number of tank barge moves by subarea;
- Number of tank barge moves in South Puget Sound relative to the rest of the study area;
- 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) 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.[12]

3.7.3 Tugs

Tug transits (both oil and non-oil) were estimated using the NRT data. Tugs with tows are identifiable within the data set and were categorized as moving either freight or oil barges. Tugs without tows may be escort and assist tugs, or they may be tugs transiting between tows. To gauge the volume of tugs moving, 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. Tugs were also categorized as either oil tugs[13] (those which typically move tank barges) or non-oil tugs (those which move freight or other non-tank barges, or are used for assist/escort work).

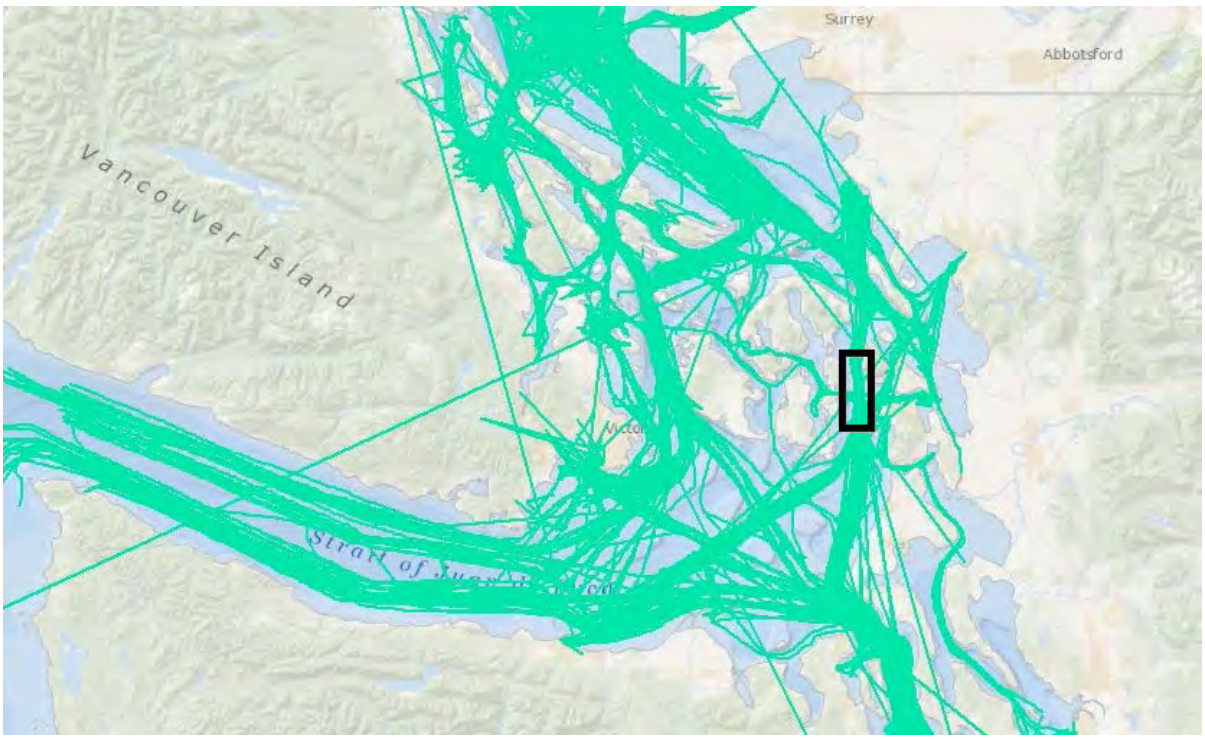
For example, in 2010, the sampled NRT data show 348 tug transits in Rosario Strait for tugs reporting a trip between Puget Sound and Alaska. The portion of Rosario sampled is shown below in Figure 32.

[11] Canadian Coast Guard VTS data sets (which cover some U.S. as well as Canadian waters) show when a tug moves an oil tow. Given the limited data available and the industry knowledge that tugs which move oil tows tend to primarily move oil tows, the study team labeled tugs moving oil tows in the Canadian data as 'oil tugs' and estimated the proportion of time they move with and without oil tows. The proportion was then applied to the oil tugs in the U.S. Coast Guard VTS data, which do not identify tows.

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

[13] While oil barges (tank barges) are included in the analysis, freight barges are not.

Figure 32. Rosario Strait Tug Transit Sample Region



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

The transit associated with this OD pair (Puget Sound and Alaska) is a distance of approximately 19.5 miles in Rosario Strait. At an average speed of 8.2 nautical miles per hour,[14] these transits account for 828 hours or 34.5 vessel 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.

3.7.4 Passenger and Fishing Vessels

Passenger Vessels

Passenger vessels are comprised of cruise ships and ferries. For the purpose of this analysis, only piloted, deep draft cruise ships 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 ships calling at Washington ports; in addition to vessels calling at Washington ports, many cruise ships calling at Canadian ports such as Vancouver, B.C. transit through the study area. Cruise ships calling in Canada directly were

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

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.[15]

The major ferry services operating within the study area are the Washington State Ferry, the Alaska Marine Highway System, 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 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 Strait of Juan de Fuca East, Haro Strait-Boundary Pass, Guemes Channel, Cherry Point and Saddlebag. Rosario Strait and Strait of 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 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.[16]

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,[17] data from the Alaska Commercial Fishing Entry Commission (CFEC),[18] and a set of fishing vessel profiles developed by Northern Economics for the North Pacific Fishery Management Council,[19] 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 the study area or south Puget Sound[20] 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.

[15] Transits which would have been double counted (represented in both the MX data and the Port Metro data) were omitted to maintain transit accuracy.

[16] Local fisheries typically use vessels smaller than those within this category.

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

[18] CFEC 2012.

[19] Northern Economics, Inc. 2001.

[20] The study team acknowledges that fishing vessels have also used shipyards in Bellingham, Anacortes and Victoria. We believe these are exceptions to the assumptions used for modeling.

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.

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.

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.

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.

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.

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 transits for shipyard work, but some of the vessels also participate in the West Coast Dungeness crab fishery.

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.

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.

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 Forecasting

In order to meet project objectives, the study team forecasted the volumes of study area vessel traffic in 2019, under three different traffic scenarios. Components of the forecasted scenarios – Case A, Case B, and Case C – are described in Figure 33.

Figure 33. Forecast Cases

Case A (Baseline)	Case B	Case C
•Existing vessel traffic forecasted to 2019 •Additional traffic from port expansions or new ports completed since 2010 or currently under construction and completed by 2019.	•Case A traffic plus... •Gateway Pacific Terminal vessel traffic	•Case B traffic plus... •Projects expected to take place in the study area in the near future

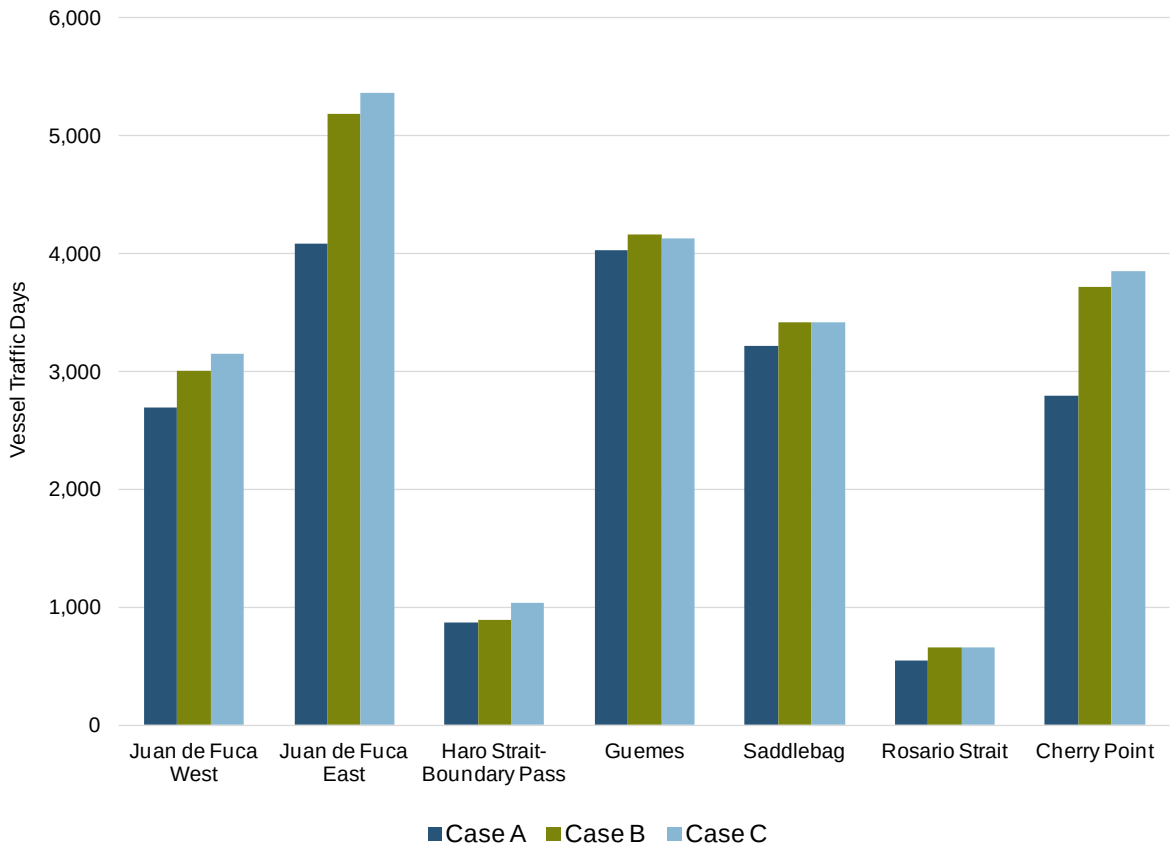
The results of the vessel traffic forecasts are summarized in Table 9 and Figure 34, which show the predicted mean values for traffic volumes. GPT is expected to increase the total number of vessel traffic days in the study area by 15 percent over the Case A forecast. The expected traffic increase can be attributed to increases in bulker, tug and tank barge traffic days (which individually may increase more than 15 percent).

Table 9. Study Area Vessel Traffic Volumes, in Vessel Traffic Days, Summed Across All Vessel Types and Activity Types (2019)

	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Case C	3,154.0	5,359.9	1,037.7	4,127.2	3,412.9	661.9	3,845.2	21,599.0
Percentage Changes								
Case A to Case B	11.6	27.1	1.4	3.5	6.3	21.0	32.9	15.4
Case B to Case C	5.0	3.4	16.7	-0.9	-0.2	-0.6	3.5	2.6
Case A to Case C	17.2	31.4	18.4	2.5	6.1	20.3	37.5	18.4

Source: Northern Economics, 2014

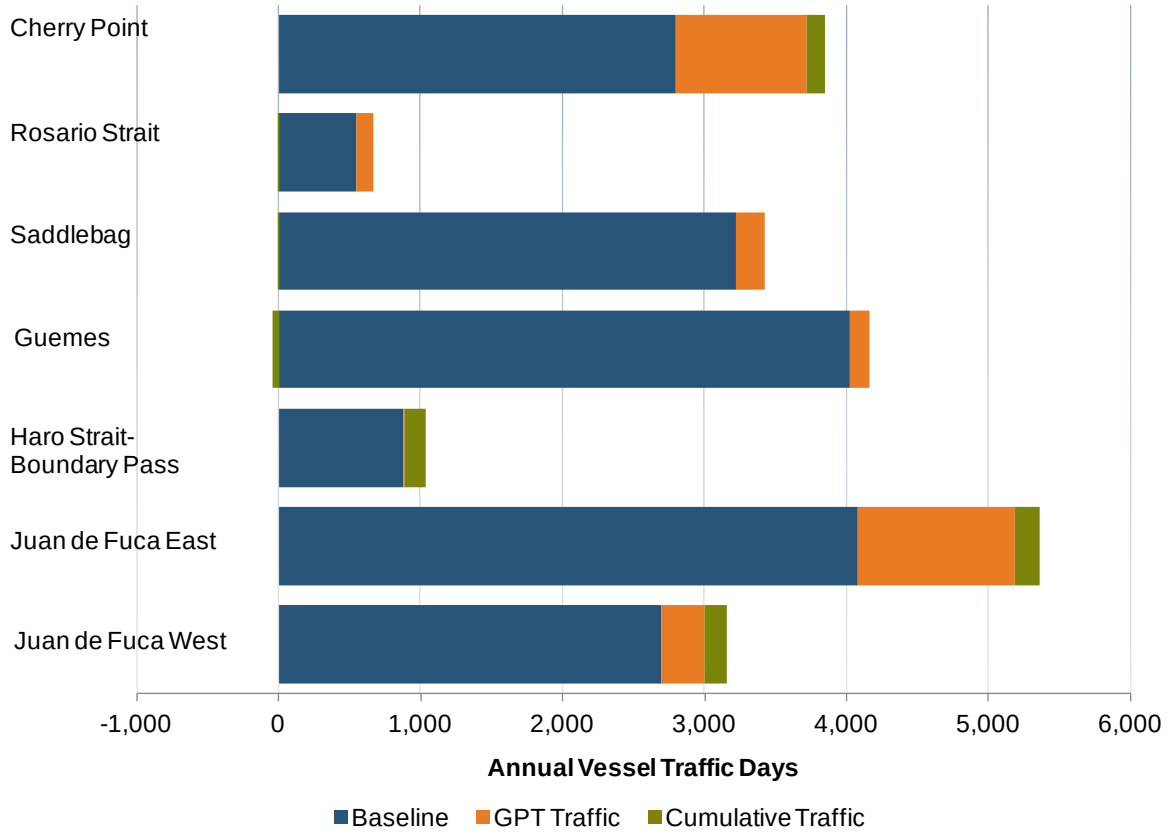
Figure 34. Study Area Vessel Traffic Volumes, by Subarea and by Case, including all vessel types and activity types (2019)



Source: Northern Economics, 2014

Figure 35 highlights the components of each case, highlighting the impact of GPT traffic relative to Case A baseline and Case C cumulative vessel volumes.

Figure 35. Study Area Vessel Traffic Volumes, by Component, Summed Across All Vessel Types and Activity Types (2019)



Source: Northern Economics, 2014

In the following sections we explain the methodology used to generate estimates of vessel activity by type and subarea. Forecast results are presented by case.

4.1 Case A

Case A consists of two components: the baseline forecast and baseline projects. The baseline forecast is the existing vessel traffic (2010) projected out to 2019 using regional economic forecasts. Baseline projects are those that are not included in the 2010 vessel traffic data, but will contribute additional vessel days to the study area by 2019. These include facility expansions completed since 2010 and those that are currently under construction or for which permits are not needed. The components of Case A are described in detail in Table 10.

Table 10. Case A Components

Case	Forecast Assumptions
A	Baseline Forecast: current data year (2010) vessel traffic increased to account for historic trends
	Baseline Projects: expansions completed since 2010 or currently permitted; traffic not captured in historic trends: **Tankers** Completed and ongoing expansion of crude by rail offloading facilities reduces demand for crude by tanker. Tesoro reduces calls by 11, BP reduces calls by 13, and Phillips 66 reduces calls by 7. This generates a corresponding decrease in escort and assist tug time. **Bulkers** Westshore expansions completed in 2012 increases capacity to 33 million tons or 62 Capesize and 28 Panamax additional vessel calls; equipment replacement to be completed by 2017 increases capacity to 36 million tons and an additional 16 Capesize vessels and 7 Panamax vessels Neptune expansion completed in 2015 results in an additional 36 Capesize and 16 Panamax vessel calls **Container Ships** Deltaport expansion completed in 2010 and vessel calls increase with historic trends

Note: the last year of data used to forecast baseline vessel traffic was 2010; data from later years is not reflected.
Source: Northern Economics, Inc. 2014

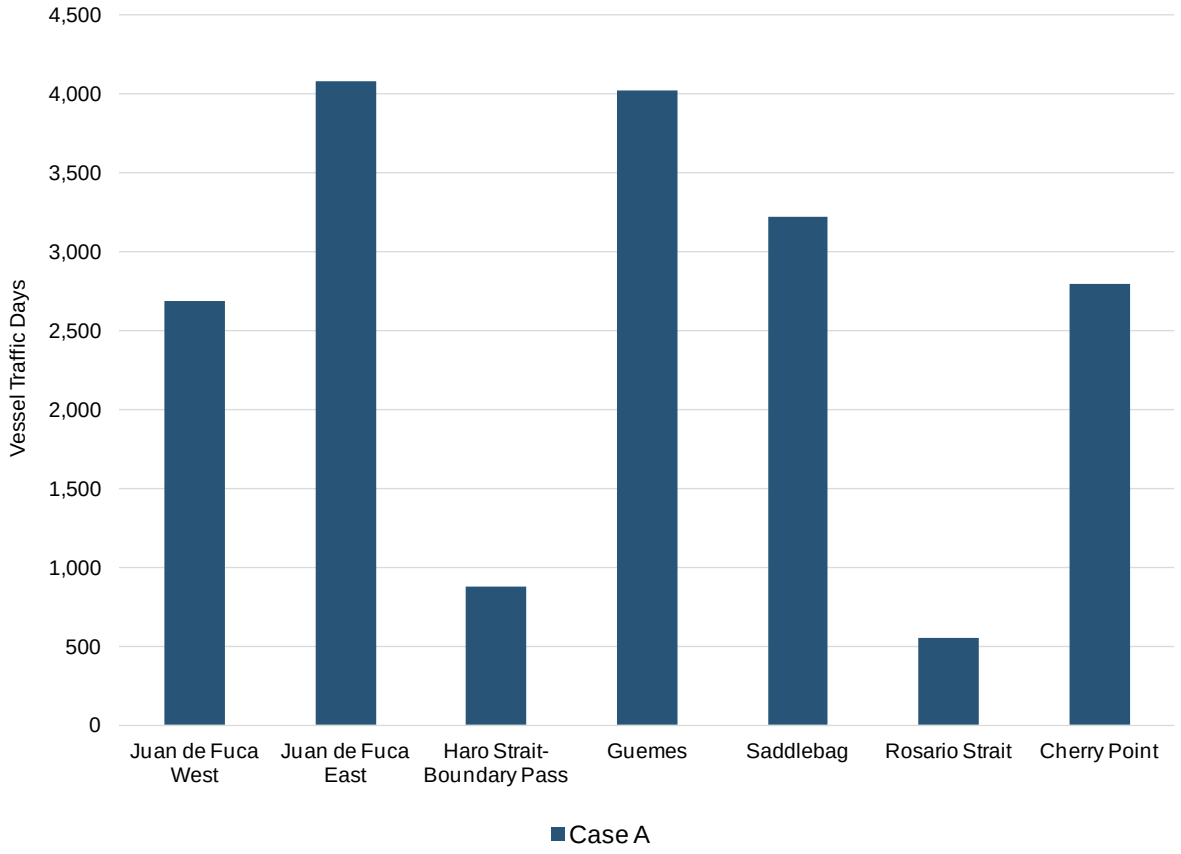
Using the forecast assumptions outlined above, the study team estimates that Case A will generate about 18,237 vessel traffic days in the study area in 2019 (Table 11 and Figure 36). The greatest portion of this time will be spent in the Strait of Juan de Fuca East; vessels travelling to south Puget Sound, Canadian ports and most study area destinations must transit through this subarea.

Table 11. Case A Vessel Traffic Days by Subarea for All Vessel Types and Activity Types (2019)

Component	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4

Note: Includes maneuvering time
Source: Northern Economics, 2014

Figure 36. Case A Vessel Traffic Days by Subarea (2019)

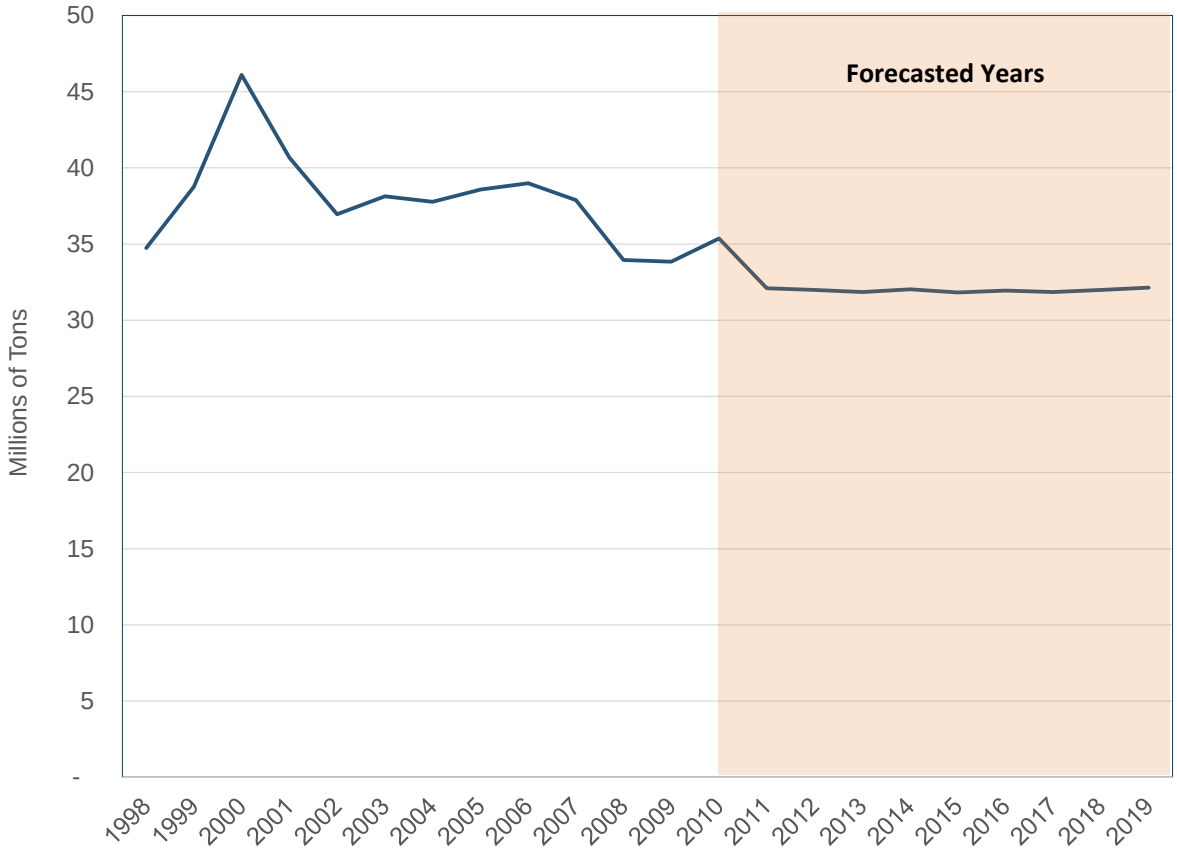


Source: Northern Economics, 2014

4.1.1 Tankers

Using historic transit and activity patterns, combined with local economic forecasts, the study team estimated tanker vessel traffic volumes by type and subarea in 2019. Between 2010 and 2019, liquid bulk commodity volumes travelling through Washington ports were expected to remain steady (Figure 37).

Figure 37. Liquid Bulk Commodity Volumes, 1998-2019



Note: Forecast begins in 2010 as 2011 and 2012 actual volumes were unavailable
Source: BST Associates (BST), 2011

While underlying bulk commodity volume forecasts show little change, rail terminal expansion projects at refineries within the study area will reduce demand for marine shipments of crude. Proposed oil terminals on the Columbia River and Grays Harbor could result in increased deliveries of crude oil by tank barge to study area refineries. However, the price differential between North Dakota crude oil and ANS West Coast price or Brent (foreign imports) prices would have to be very large to offset the estimated $10 cost per barrel to rail crude to the West Coast plus the cost of barging to study area refineries (RBN Energy 2013). Given that the proposed oil terminals are not yet permitted or under construction they are considered speculative at this time and not included in the analysis.

Over the past few years three of the major refiners in the study area (Tesoro, BP, and Phillips 66) have either built [21] or begun construction [22] of rail transport facilities to source crude oil from North Dakota to replace declining Alaska North Slope (ANS) crude and to access crude oil from North Dakota's Bakken field that is lower cost than ANS or foreign crude oil.

[21] Tesoro in 2012 and BP in 2013

[22] Phillips 66

The Tesoro rail terminal has a daily capacity of about 50,000 bopd, BP's rail terminal is about 60,000 bopd, and the Phillips 66 rail terminal will have a capacity of about 30,000 bopd. Summing this rail terminal capacity and anticipating a practical throughput of 90 percent of maximum capacity results in approximately 126,000 barrels of oil per day which will be operational prior to GPT being completed in 2019. The effect of these rail terminals will be to decrease the number of foreign or ANS crude oil tanker calls at study area refineries by approximately 31 per year.

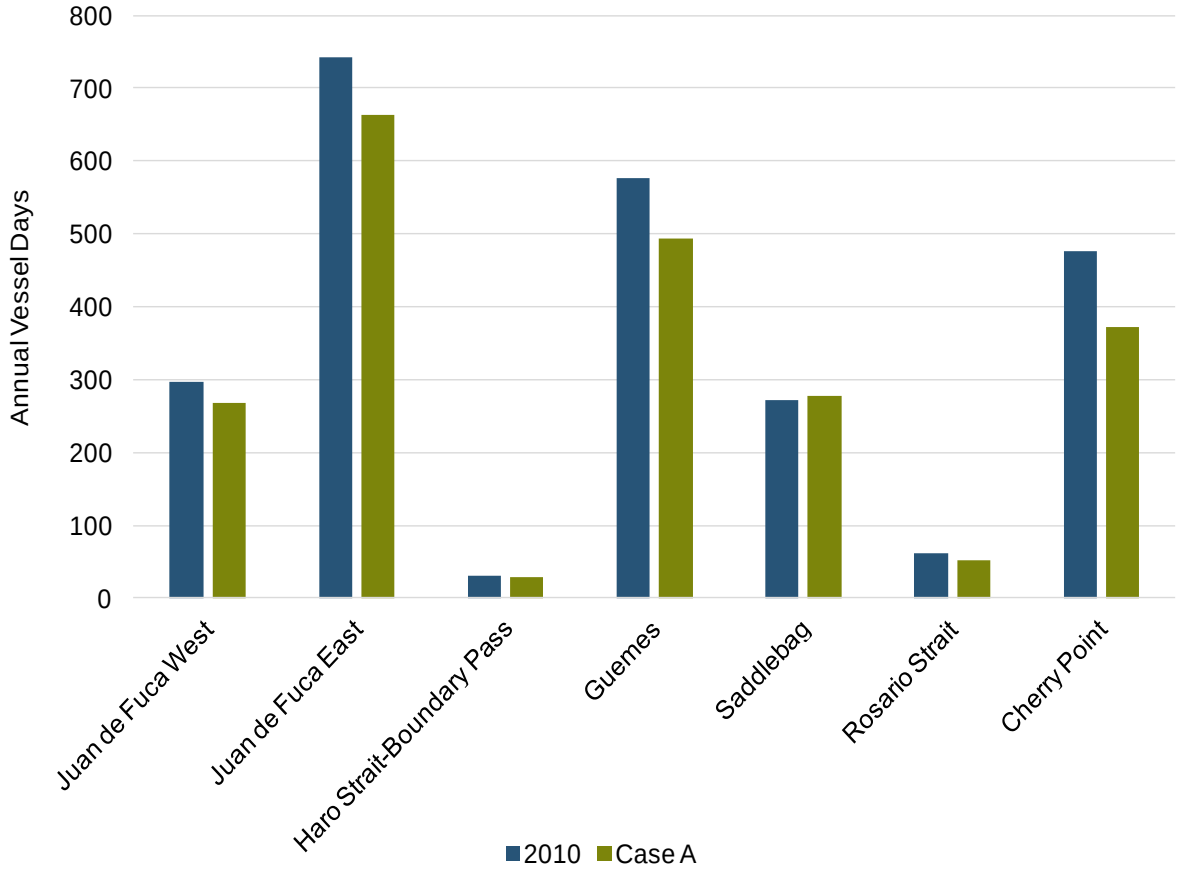
The results of our tanker Case A forecast are summarized in Table 12 and Figure 38. In Case A, tanker vessel days in all subareas except for Saddlebag are expected to drop.

Table 12. Tanker Vessel Traffic Days, by Subarea, For All Activity Types, 2010 and Case A (2019)

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	295.9	741.4	30.1	577.3	272.1	61.5	475.3	2,453.7
Case A	268.3	662.4	29.5	493.0	277.9	52.6	371.2	2,154.8
Percent Change (2010 to Case A)	-9%	-11%	-2%	-15%	2%	-15%	-22%	-12%

Source: Northern Economics, 2014

Figure 38. Tanker Vessel Traffic Days by Subarea, for All Activity Types, 2010 and Case A (2019)



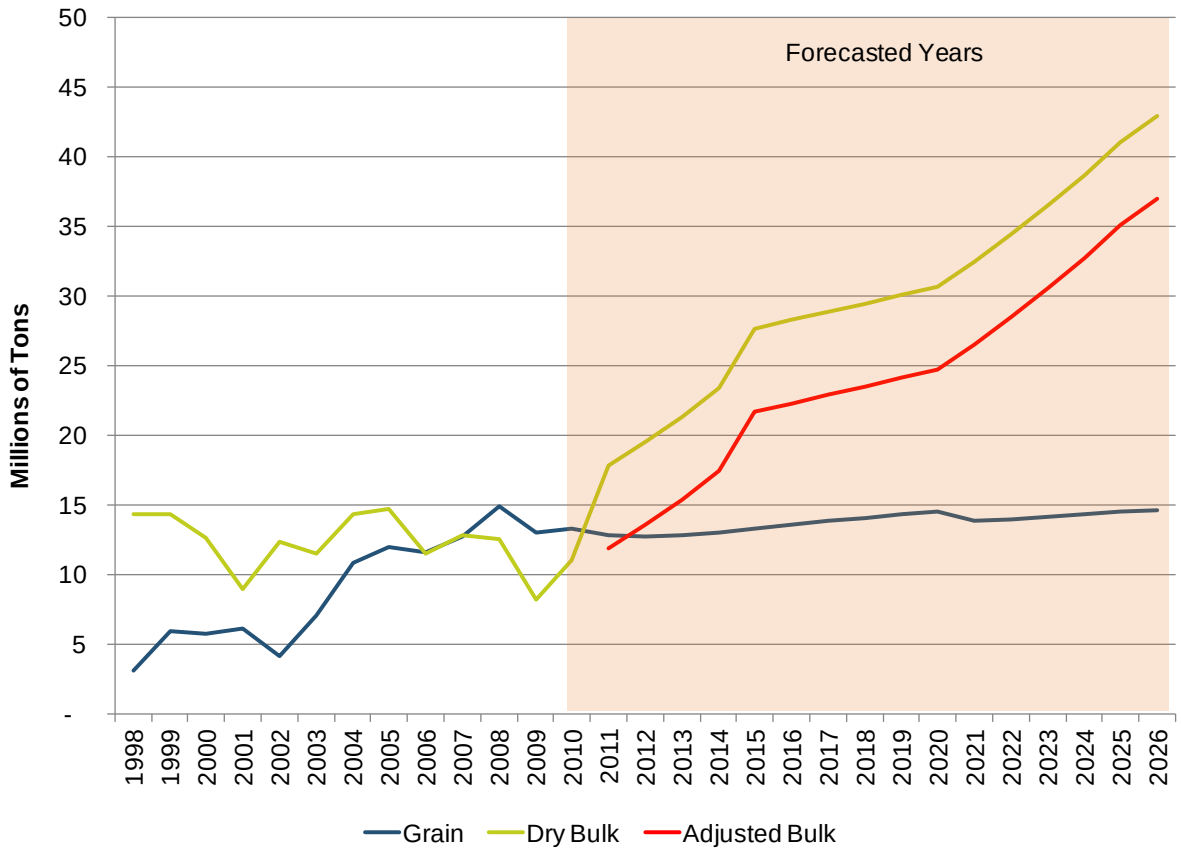
Source: Northern Economics, 2014

4.1.2 Bulkers

BST commodity volume forecasts for dry bulk and grain were used to forecast non-GPT bulker traffic volumes (Figure 39). BST's 2011 forecast anticipated 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. In the long run, GPT is expected to capture most of the BNSF Railway coal shipments, as well as some Canadian potash exports (Winningham 2012).

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 by effectively removing the large volume step in the original forecast, and mapped in GPT-calling bulkers separately to account for this discrepancy. The red "adjusted bulk volumes" shown in Figure 39 were used to forecast non-GPT bulker vessel volumes.

Figure 39. Grain and Dry Bulk Commodity Volumes, 1998-2026



Source: Northern Economics, 2014 and BST Associates 2011

In addition to the economic forecast the study team modeled growth in bulker volumes due to expansions at Westshore Terminal and Neptune Terminal in Vancouver, B.C.

Westshore

Westshore Terminals, which operates the dry bulk terminal at Roberts Bank in Port Metro Vancouver, is the largest coal export facility in Canada and on the North American West Coast. In 2012 they completed an expansion of the facility which increased their throughput to 33 million metric tons per year. They have announced that they are upgrading some of their older equipment (i.e., loaders and reclaimers) and that process will be completed by 2017. These upgrades will increase capacity to 36 million tons per year (Westshore Terminals Limited Partnership, 2014). Samples of vessel calls at Westshore Terminals were used to estimate the ratio of Capesize and Panamax vessels calling at Westshore Terminals (Westshore Terminals, Limited Partnership, 2013)

Neptune

Neptune Terminals is in the process of expanding their dry bulk commodity terminal in Port Metro Vancouver to handle approximately six million additional metric tons, or about one additional ship per week (Neptune Terminals, 2012). No data are available on the size of ships calling at Neptune

although the berths are capable of handling Capesize vessels so the analysis assumes the same ratio of Capesize to Panamax vessels as documented for Westshore.

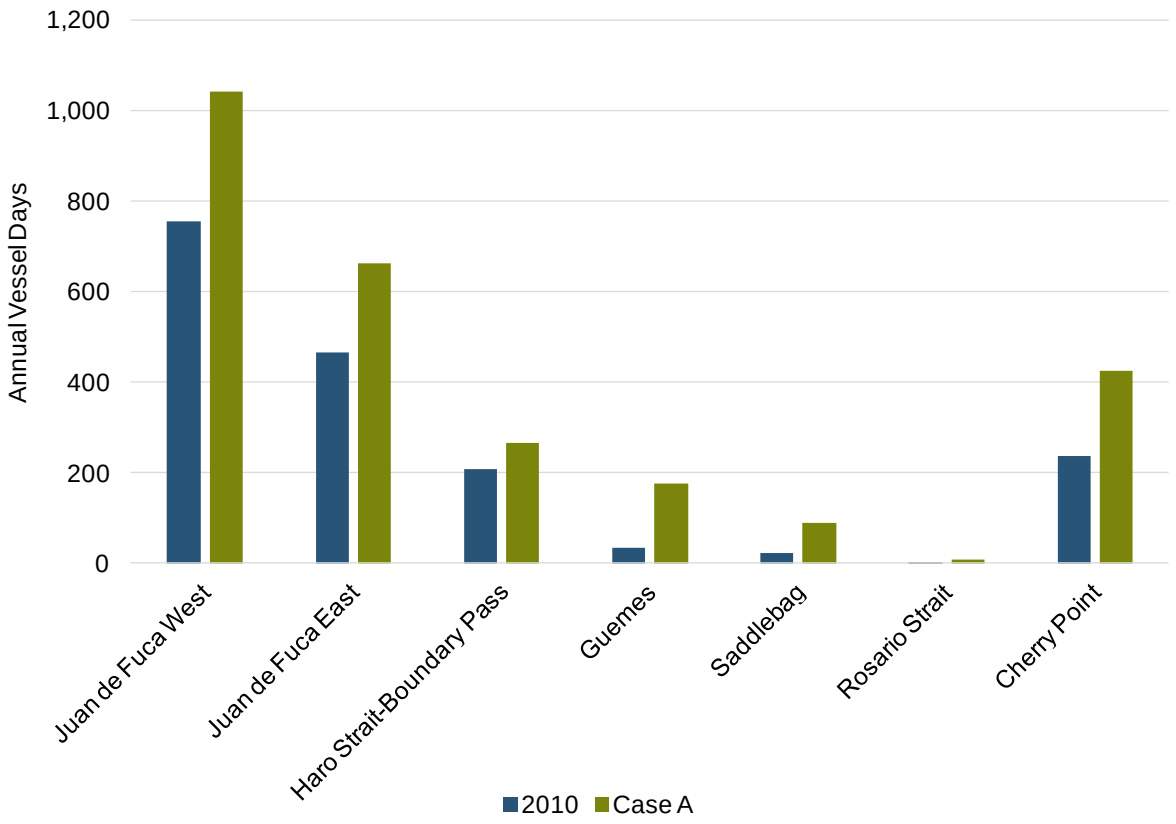
The results of our non-GPT bulker forecast are summarized in Table 13 and Figure 40. Current trends are expected to continue, with increasing vessel days in all subareas where current bulker activity takes place. Growth is particularly high in Strait of Juan de Fuca West and Strait of Juan de Fuca East; bulkers transiting to Canada or south Puget Sound overlap in both portions of the Strait of Juan de Fuca, accounting for the large increase in vessel days forecasted.

Table 13. Bulker Vessel Traffic Days, by subarea, for all activity types, 2010 and Case A (2019)

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait – Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	756.0	464.2	208.7	35.5	22.4	1.7	237.6	1,726.1
Case A	1,042.4	662.9	265.5	177.2	89.9	7.4	424.6	2,669.9
Percentage Change: (2010 to Case A)	38%	43%	27%	400%	302%	338%	79%	55%

Source: Northern Economics, 2014

Figure 40. Bulker Traffic Days by Subarea, for All Activity Types, 2010 and Case A (2019)

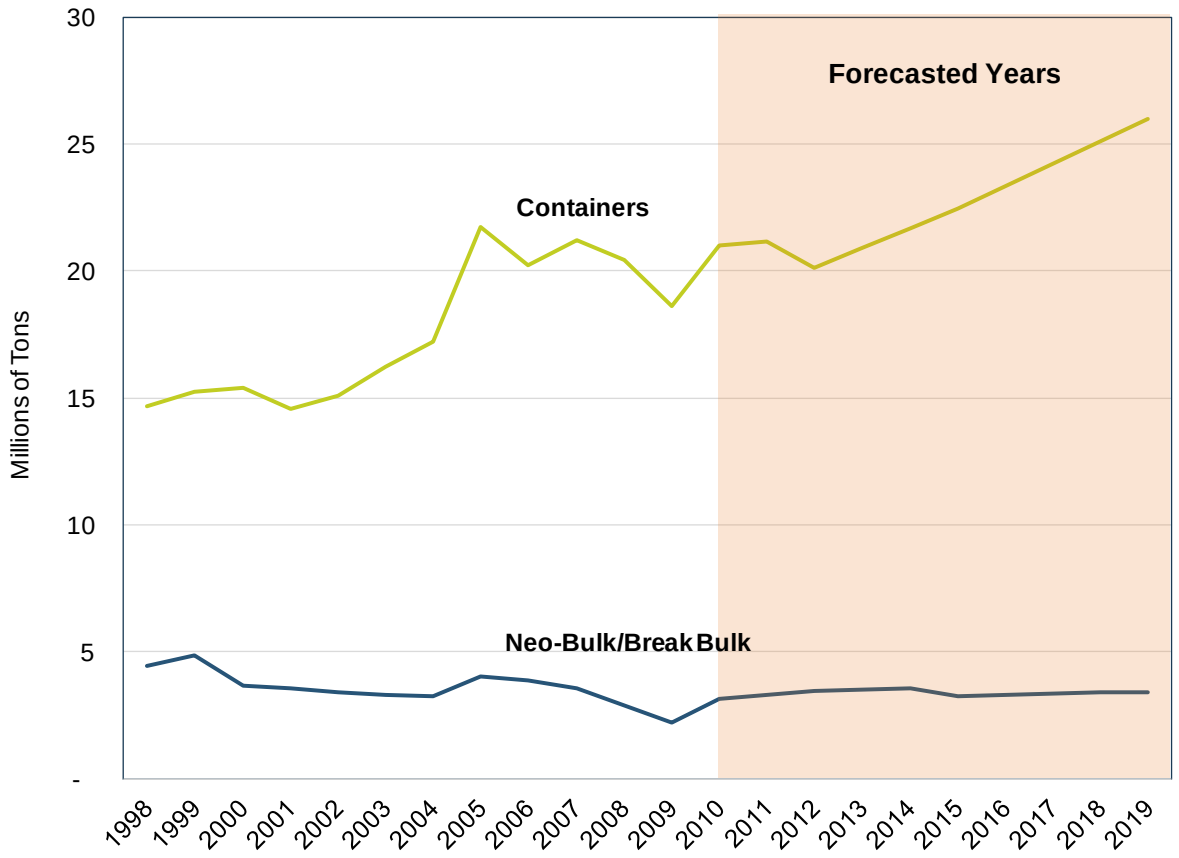


Source: Northern Economics, 2014

4.1.3 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 contain 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 41. Container and Neo Bulk/Break Bulk Commodity Volumes, 1998-2019



Note: BST forecast is for Washington Ports and does not include cargo volumes transiting directly to or from Canada.
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 2019.[23] As shown in Table 14, total vessel days within the study area are expected to rise by 10 percent, from 1,300 to 1,430, over this same period.

Table 14. General Cargo Traffic Vessel Days, by subarea, for all activity types, 2010 and Case A (2019)

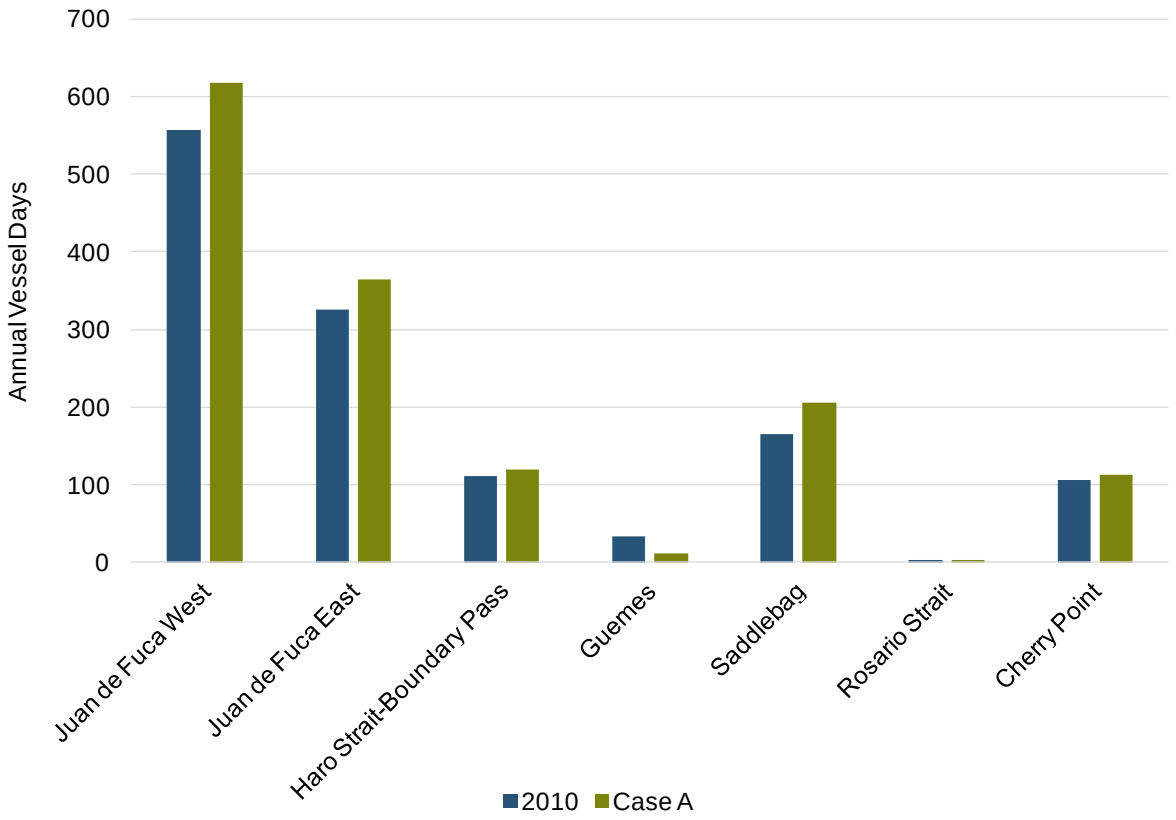
Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	556.1	325.4	111.6	33.2	165.3	2.9	105.7	1,300.2
Case A	617.1	364.6	120.1	11.7	205.6	3.0	112.6	1,434.7
Percentage Change: 2010 to Case A	11%	12%	8%	-65%	24%	5%	6%	10%

[23] The forecast includes an underlying increase in vessel size over time, which actually lowers the number of vessel calls (as compared to holding vessel size constant).

Source: Northern Economics, 2014

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 42 summarizes vessel day changes by subarea.

Figure 42. Cargo Ship Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)



Source: Northern Economics, 2014

4.1.4 Tank Barges

Tank barge transits are forecast using the historic transits reported by WADOE. Similar to tanker forecasts, the study team used the pattern of growth expected for liquid bulk volumes to project future baseline tank barge numbers (Figure 37). In addition to baseline traffic, projects expected to significantly alter the volume of tank barges operating within the study area in Case A include the aforementioned expansions at the Neptune and Westshore terminals in Vancouver, B.C.

The additional tanker calls resulting from the two Port Metro Vancouver terminals are expected to increase the demand for bunker from close-proximity refineries in the study area. If the current ratio of tank barge transits to vessel calls at the Vancouver, B.C. area remains constant, the 348 additional Kinder Morgan tankers are expected to generate 715 additional tug and tank barge transits between the Cherry Point subarea and Port Metro. These additional calls are incorporated into Case A. (Table 15).

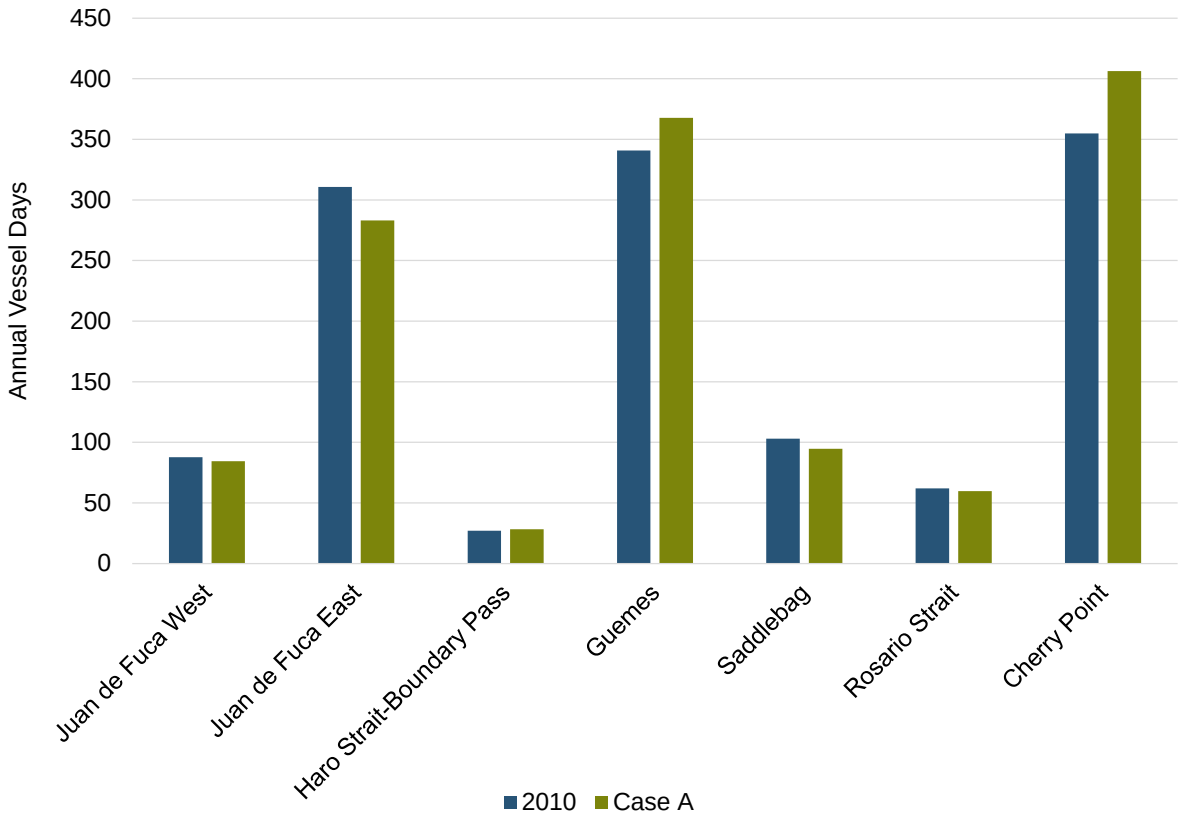
Table 15. Tank Barge Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	87.6	310.7	27.1	340.8	103.0	62.1	354.9	1,286.2
Case A	84.5	283.1	28.2	367.7	94.7	59.7	406.4	1,324.2
Percentage Change: 2010 to Case A	-4%	-9%	4%	8%	-8%	-4%	15%	3%

Source: Northern Economics, 2014

Figure 43 summarizes the changes in tank barge volumes expected between 2010 and Case A (2019).

Figure 43. Tank Barge Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)



Source: Northern Economics, 2014

4.1.5 Tugs

Tug volumes within the study area are forecasted using total traffic volumes. As the number of non-tug vessel days spent in the subarea increases, so do the expected number of tug days.[24] Case A projects expected to affect tug traffic beyond underlying trends include the rail facility expansions and the Port Metro Vancouver terminal expansions. As the number of tankers calling at Washington refineries decreases due to increased rail service, there is a corresponding reduction in tug escort and assist time. This decrease dampens overall tug vessel days in the study area.

In the Cherry Point subarea tugs moving tank barges between study area refineries and Port Metro Vancouver (to support bunkering of additional tankers) generate an increase in tug vessel days. Forecasted tug traffic days are summarized in Table 16 and Figure 44.

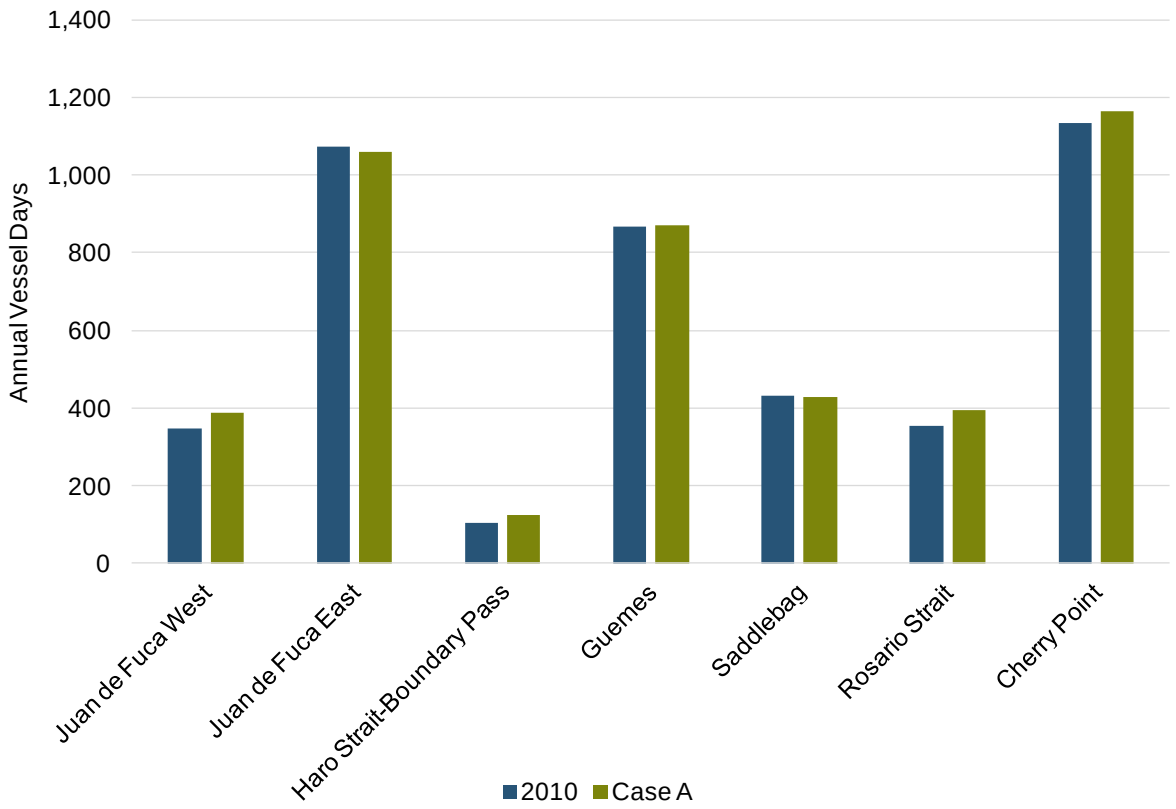
Table 16. Tug Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	346.9	1,072.1	105.7	866.2	431.8	353.8	1,134.6	4,311.1
Case A	386.4	1,057.9	126.3	871.3	429.5	394.1	1,164.6	4,430.0
Percentage Change: 2010 to Case A	11%	-1%	19%	1%	-1%	11%	3%	3%

Source: Northern Economics, 2014

[24] Tug activity time was calculated separately for oil tugs and non-oil tugs. Oil tug activity was calculated as the sum of moves with a tank barge and moves without a tank barge. Non-oil tug activity time was calculated using a ratio comparing historic non-oil tug moves to moves by other vessel types in the study area, equal to 1.36 for the 2006-2010 period. This ratio was applied to projected vessel activity in the study area to forecast future non-oil tug activity.

Figure 44. Tug Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)



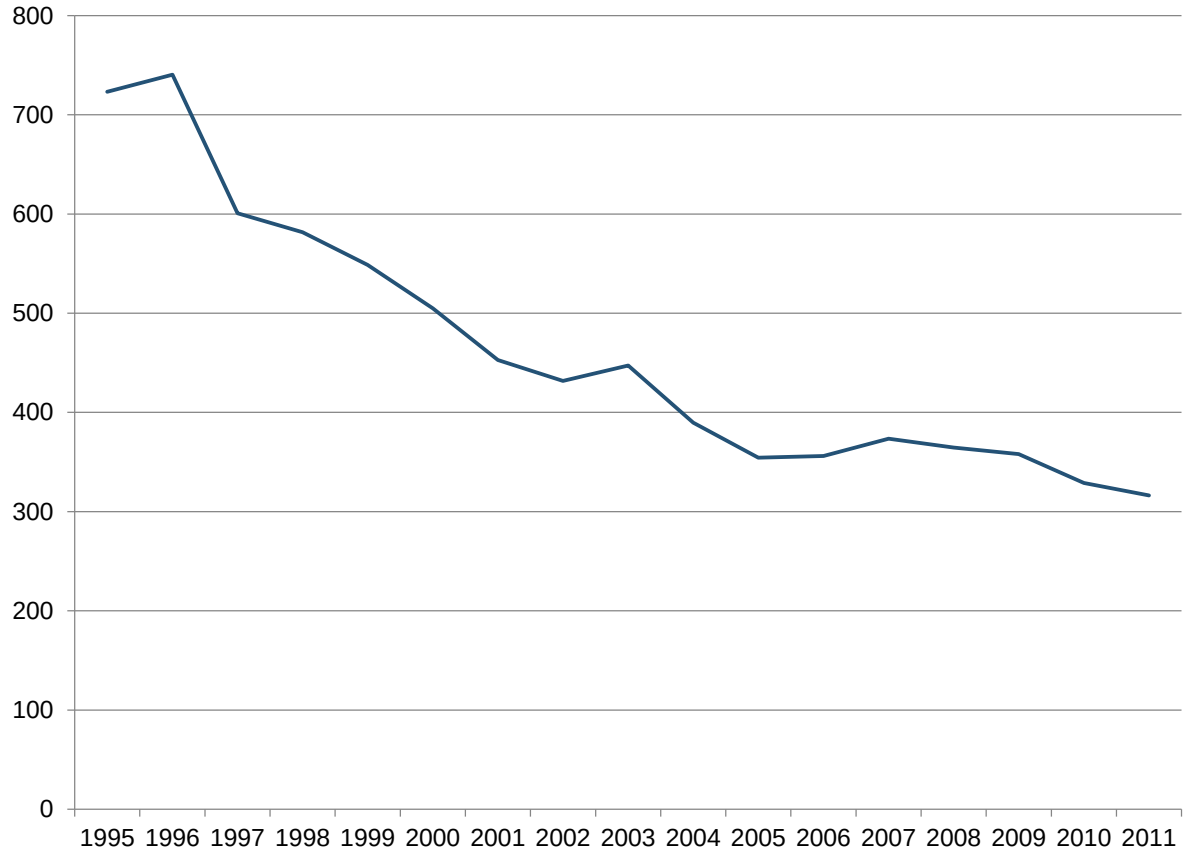
Source: Northern Economics, 2014

4.1.6 Passenger and Fishing Vessels

Passenger vessels and fishing vessels are collectively expected to spend the most time in the study area in 2019. Much of this time is expected to be at-dock as both vessel types homeport in the study area. Between 2010 and 2019, passenger vessel days will increase due to forecasted growth in cruise ship transits.[25] This growth will be offset by a reduction in large fishing vessel transits, which are forecasted to decline in-line with recent patterns. The historic reduction in fishing vessel transits is depicted in Figure 45.

[25] Cruise ship forecasted growth is based on an analysis of historic trends completed by the study team.

Figure 45. Study Area Fishing Vessel Transit Days (1995-2011)



Source: Northern Economics, 2014

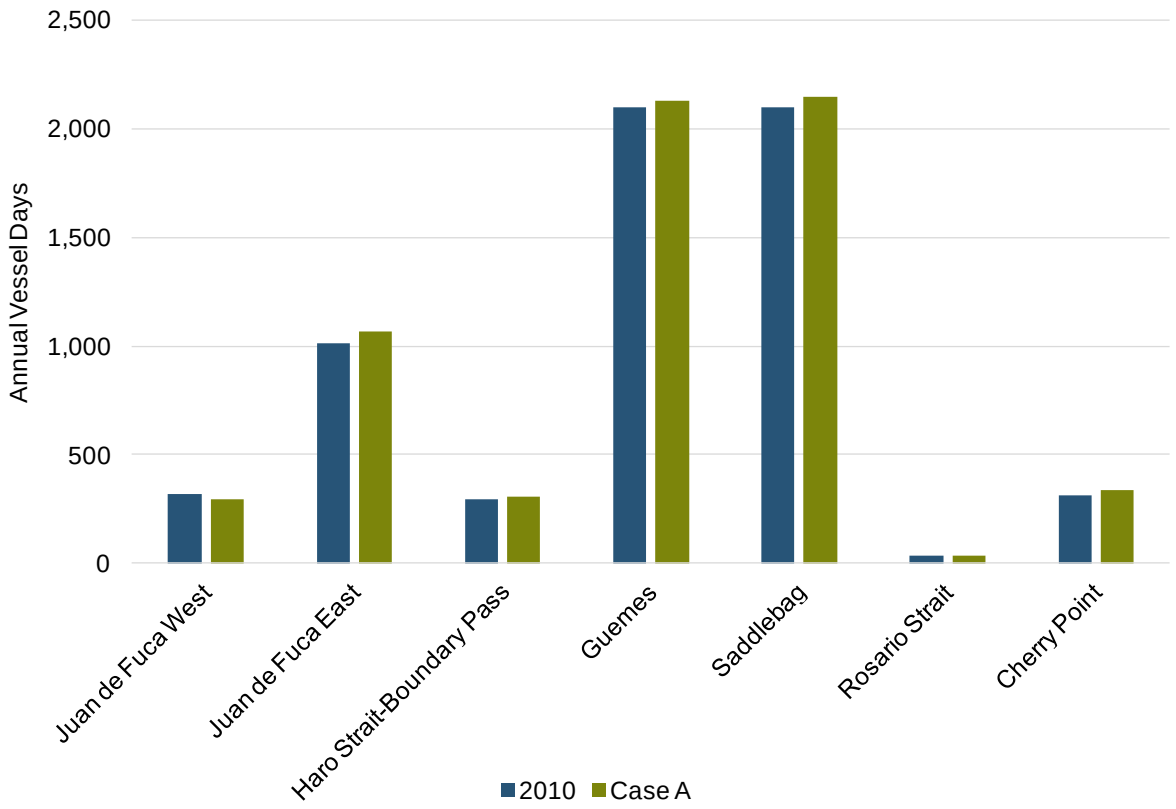
Forecasted passenger and fishing vessel traffic days are summarized in Table 17 and Figure 46.

Table 17. Passenger and Fishing Vessel Traffic in Vessel Days, by Subarea, for All Activity Types, 2010 and Case A (2019)

Year	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait - Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	321.1	1,013.5	293.7	2,099.1	2,094.2	33.8	315.9	6,171.4
Case A	293.4	1,065.3	307.2	2,129.8	2,145.7	33.7	335.8	6,310.9
Percentage Change: 2010 to Case A	-9%	5%	5%	1%	2%	0%	6%	2%
								2%

Source: Northern Economics, Inc. 2014

Figure 46. Passenger and Fishing Vessel Traffic Days, by Subarea, for All Activity Types, 2010 and Case A (2019)



Source: Northern Economics, 2014

4.2 Case B

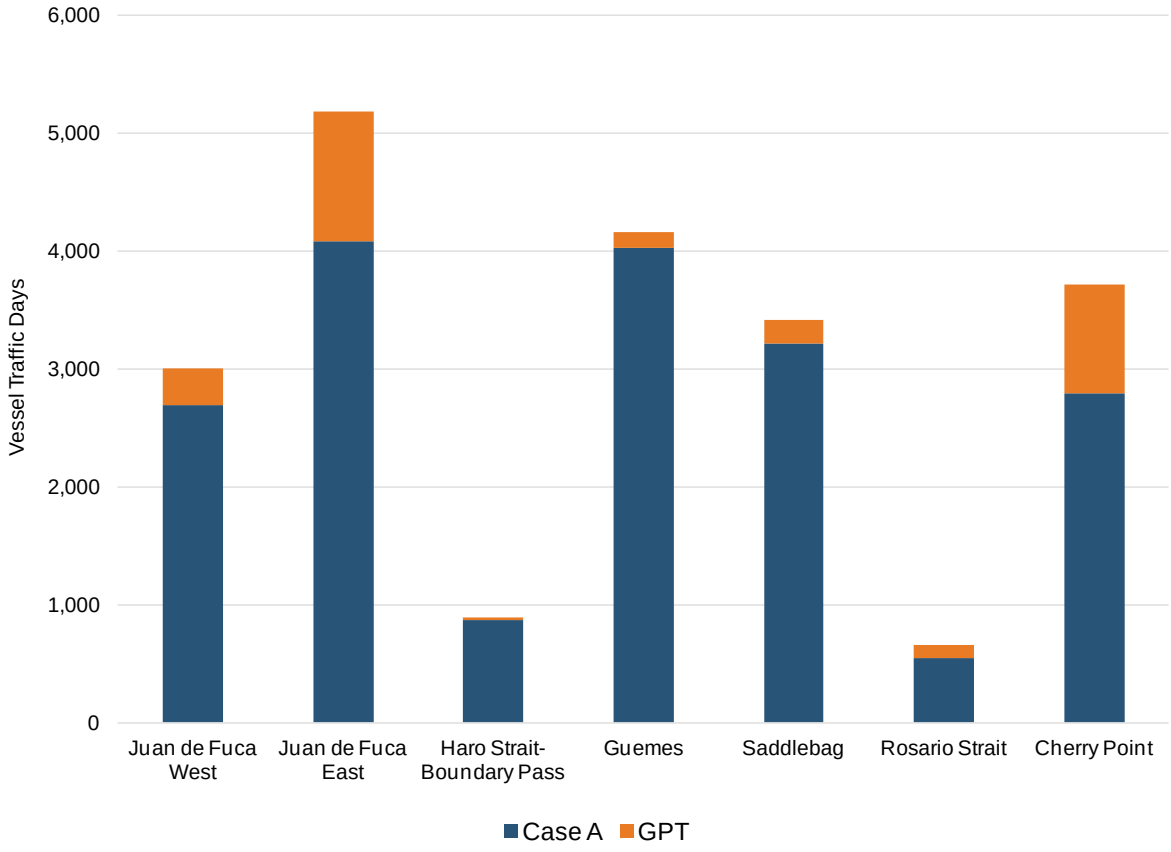
Case B is the combination of the baseline traffic estimates generated in Case A and the forecasted GPT 2019 traffic volumes (Table 18 and Figure 47). GPT will introduce a new source of vessel traffic to the regional traffic flow; this vessel traffic study is designed to predict and analyze the risk posed by vessels bound to or departing from GPT (GPT-calling vessels) and bunkering activity associated with these GPT-calling vessels. GPT-calling vessels were mapped separately from other bulker traffic (in Case A) so that GPT traffic impacts could be isolated.

Table 18. Case B Vessel Traffic Days by Subarea and by Component, for All Vessel and Activity Types (2019)

Component	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
2010	2,315.9	3,296.1	748.8	3,622.5	3,004.4	254.2	2,039.2	15,281.1
Case A	2,692.0	4,079.0	876.8	4,025.0	3,217.9	550.5	2,796.3	18,237.4
GPT	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Percentage Change: Case A to Case B	12%	27%	1%	3%	6%	21%	33%	15%

Note: Includes maneuvering time
Source: Northern Economics, 2014

Figure 47. Case B Vessel Traffic Days by Subarea and Component, for All Activity Types (2019)



Note: Case B is sum of Case A and GPT
Source: Northern Economics, 2014

4.2.1 GPT Vessel Traffic

The study team projected GPT traffic volumes at full capacity in 2019. In addition to bulkers, GPT traffic includes tugs assisting with docking and undocking maneuvers, as well as tugs and tank barges expected to bunker the GPT-calling bulkers. At full operational capacity, 487 vessels per year are expected to call at Gateway Pacific Terminal (International Pacific Terminals, Inc., 2011). All of these bulkers will require tug assists to berth, and a portion of them will also require tug and tank barge support to facilitate bunkering.

The study team mapped GPT vessel activity into the model for the year 2019. Based on current vessel traffic patterns and bulker activity, the study team used the following transit pattern:

- Bulker vessels calling at GPT will originate from outside the study area;
- GPT-bulkers will transit in and out of the study area using the Strait of Juan de Fuca; these vessels will transit Strait of Juan de Fuca West, Strait of Juan de Fuca East, either Haro or Rosario Strait. Pilots currently estimate that 95 percent of bulkers use Rosario Strait, and 5 percent use Haro Strait – Boundary Pass. Due to increased traffic by 2019, 85 percent will use Rosario Strait, and 15 percent will use Haro Strait – Boundary Pass;
- GPT-bulkers will travel between 12 and 13 knots, in line with the bulker speeds currently seen in the study area;
- We model two movements (one in and one out) if vessels go straight to a berth, and three movements (to anchor, to dock and out of the study area) if they must wait to berth. 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. Based on the queuing analysis, GPT bulkers are expected to make 2.8 transits per call;
- GPT-bulker anchorage time is distributed to four subareas based on availability and order of assignment, as per USCG. GPT-bulkers are expected to spend 88% of their at-anchor time in Strait of Juan de Fuca East and 12% in Saddlebag;
- GPT-bulkers are expected to take between 1 and 2 hours to maneuver to anchor or berth;
- Each bulker call at GPT will require two assist tugs, each making two transits. Assist tugs will homeport in either Anacortes (Crowley) or Bellingham (Foss), and are expected to travel through the study subareas of Guemes Channel, Saddlebag, Rosario Strait, and Cherry Point when travelling to and from GPT;
- A portion (between half and all) of GPT bulkers will bunker within the study area;
- Bunker fuel will be supplied to Port Angeles via tank barges from the Tesoro refinery in Anacortes; these tug and tank barge movements have been included as GPT-related vessel traffic.

Using the parameters outlined, the study team estimated the GPT-bulker, tug and tank barge time by activity type and subarea. Table 19 summarizes GPT vessel time by vessel type and subarea.

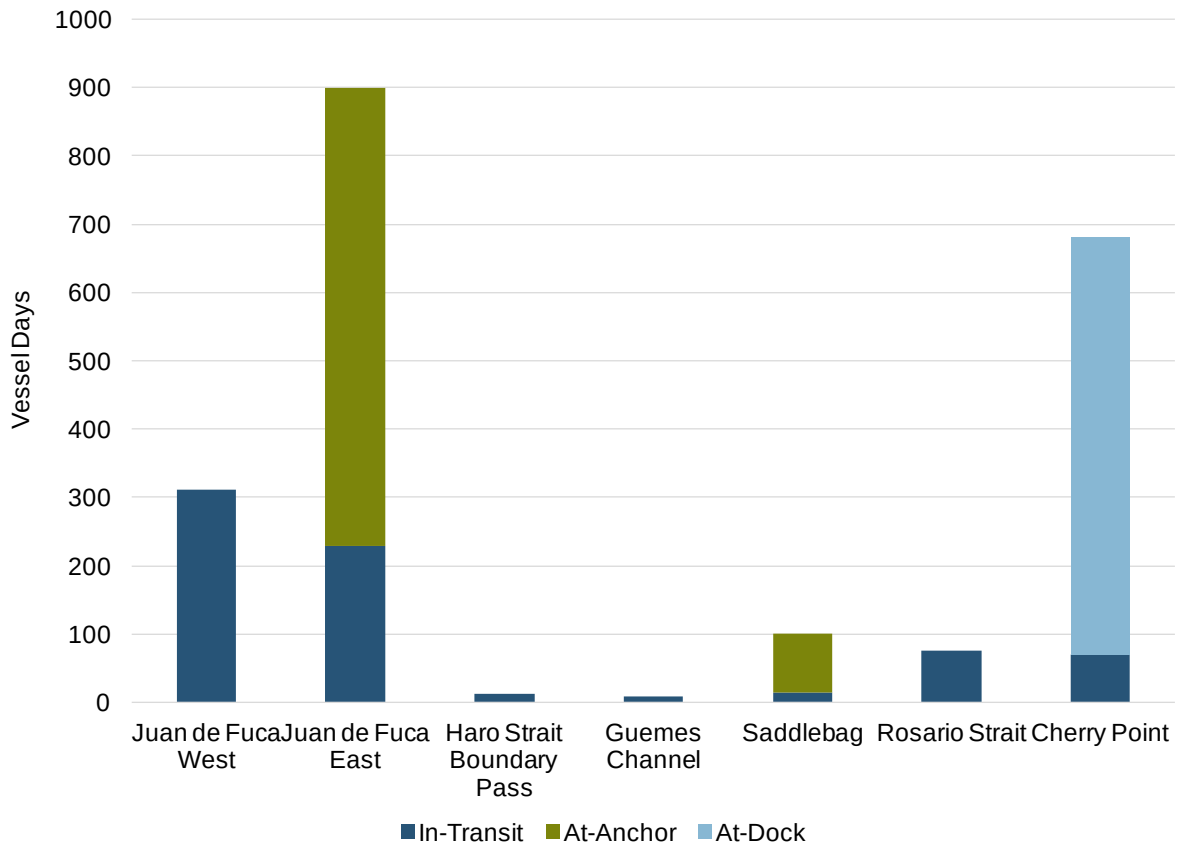
Table 19. GPT Bulker, Tug and Tank Barge Transit Time by Vessel Type and Subarea

Vessel	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Bulker	311.8	898.3	12.2	8.5	101.3	75.6	680.8	2,088.6
Tug	0.0	123.3	0.0	69.7	101.2	33.1	237.8	565.1
Tank Barge	0.0	82.9	0.0	61.8	0.0	6.8	0.0	151.5
Total	311.8	1,104.5	12.2	140.0	202.5	115.6	918.6	2,805.2

Note: Includes maneuvering time
Source: Northern Economics, 2014

In 2019, GPT bulkers are expected to spend about 2,100 vessel days within the study area. Tug and tank barges associated with GPT traffic will add another 700 vessel days, for a total of 2,800 GPT-related vessel traffic days in 2019. The queuing analysis[26] found that standard operational wait time would mean that the majority of bulker vessel time in the study area will be spent at anchor. GPT bulker days by activity type are summarized in Figure 48.

Figure 48. GPT Bulker Days by Activity Type and Subarea (2019)



[26] The queuing analysis is discussed in more detail in Section 2.4 of the main report.

Source: Northern Economics, 2014

4.3 Case C

Case C is the combination of Case B and the cumulative projects outlined in Table 20. Cumulative projects are defined as those which may be currently permitted, in the permitting process, or have been publicly announced.

Table 20. Case C Components

Case	Forecast Assumptions
C	Case B traffic plus the following cumulative projects:
	Tankers Expansion of Kinder Morgan (TransMountain Pipeline) export terminal adds 348 additional export tankers by 2019. Tug and tank barge movements to and from the study area (to support increased bunkering activity generated by these tankers) were also modeled. Planned expansion of crude by rail offloading facilities at Shell (60,000 bopd); adjusting for practical throughput capacity and assuming price spreads are attractive half of the year about 13 fewer fully laden tankers would be required

Note: bopd = barrels of oil per day
Source: Northern Economics, 2014

Case C assumptions both contribute to and lessen Case B vessel volumes. The Kinder Morgan pipeline expansion adds vessel traffic days to the subareas transited by tankers and escort tugs going to and from Canada (Strait of Juan de Fuca West, Strait of Juan de Fuca East, Haro Strait-Boundary Pass and Cherry Point). The expansion also adds tug and tank barge vessel traffic days to the Cherry Point subarea; refineries at Ferndale and Cherry Point, WA are expected to support increased bunker demand.

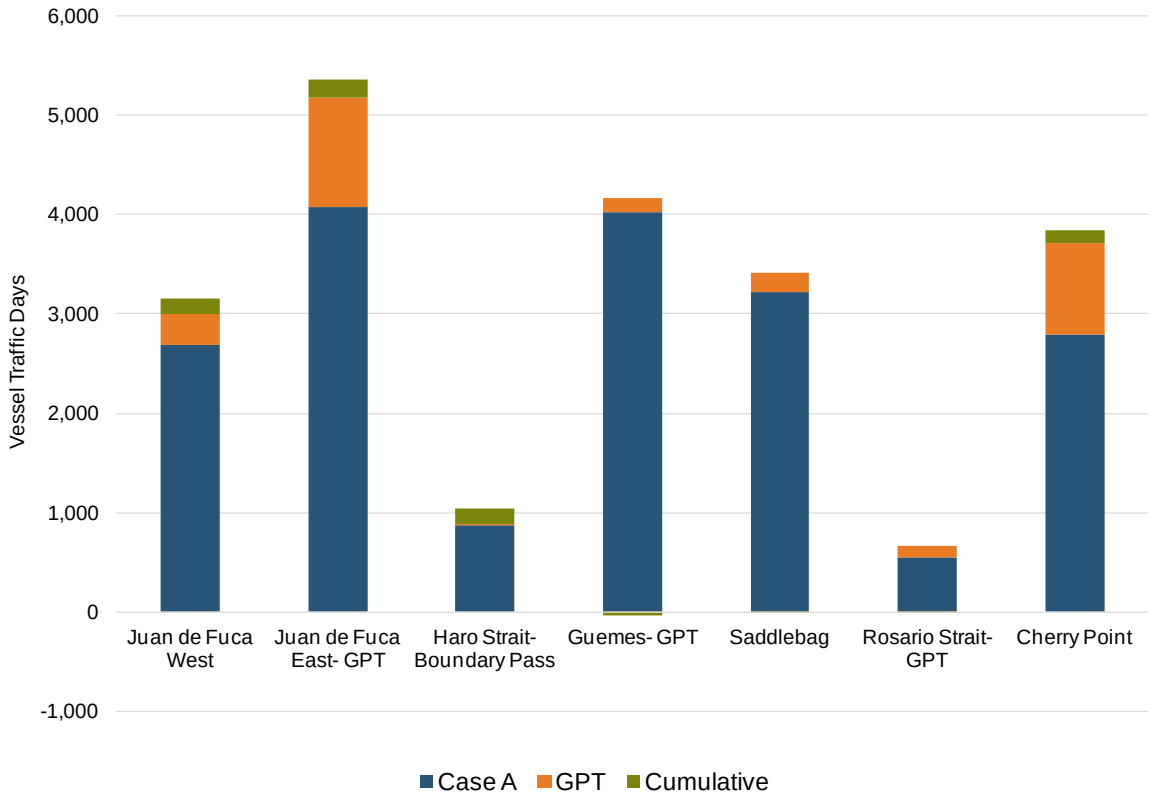
The planned rail terminal expansion at the Shell refinery will lower demand for tankers travelling to Anacortes, also reducing the number of escort and assist tug movements required. Consequently we see a negative change in vessel traffic numbers in Rosario Strait, Guemes Channel, and Saddlebag (Table 21 and Figure 49).

Table 21. Case C Vessel Traffic Days by Subarea and Component, for All Vessel and Activity Types (2019)

Component	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Guemes Channel	Saddlebag	Rosario Strait	Cherry Point	Total
Case B	3,003.9	5,183.5	889.0	4,165.0	3,420.4	666.0	3,714.9	21,042.6
Cumulative	150.2	176.4	148.7	-37.7	-7.5	-4.1	130.4	556.3
Case C	3,154.0	5,359.9	1,037.7	4,127.2	3,412.9	661.9	3,845.2	21,599.0

Note: Includes maneuvering time
Source: Northern Economics, 2014

Figure 49. Case C Vessel Traffic Days by Subarea and Component, for All Vessel and Activity Types (2019)



Note: Case A + GPT + Cumulative = Case C
Source: Northern Economics, 2014

4.3.1 Kinder Morgan

Kinder Morgan has applied for permits to expand its existing TransMountain Pipeline that originates in Edmonton, Alberta and terminates at the Burnaby Terminal in the Greater Vancouver area. There is a spur line from the Burnaby Terminal to the Westridge Marine Terminal that currently exports crude oil and also receives jet fuel for the Vancouver International Airport. On average, five vessels per month are currently loaded with crude oil at the Westridge Marine Terminal. The expanded system would be capable of serving 34 vessels per month, depending on market conditions, for an average increase of 29 tankers per month (Kinder Morgan 2013). The planned expansion of the pipeline and the marine terminal would occur in 2017 according to the current project schedule and result in an additional 348 (29 tankers for 12 months) export tankers calling annually at the Westridge Marine Terminal.

The additional tankers resulting from the Trans-Mountain Pipeline expansion will increase the demand for bunker at Port Metro Vancouver. If the current ratio of tank barge transits to vessel calls at the Vancouver, B.C. area remains constant, the 348 additional Kinder Morgan tankers are expected to generate 15 additional tug and tank barge transits from the study area. These additional calls have been incorporated into Case C.

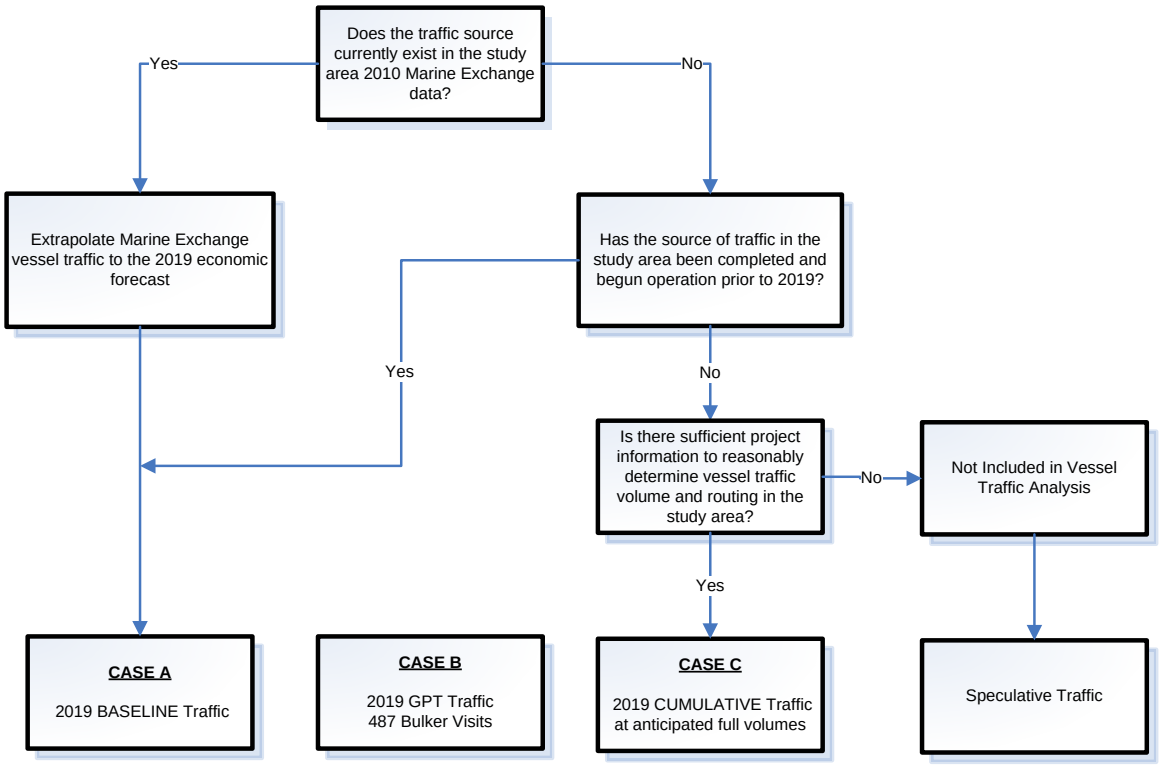
4.3.2 Shell Rail Terminal Construction

Shell has announced plans and filed for permits to build a 60,000 bopd rail unloading terminal at its Puget Sound refinery at Anacortes, Washington to bring in crude oil from North Dakota to replace declining Alaska North Slope production. The facility would have an initial capacity to unload one unit train (102 tank cars) per day and current plans call for about six trains per week. The 60,000 bopd rail terminal capacity would supply about 40 percent of the refinery's 145,000 bopd rated capacity.

4.4 Data Sources and Methodology

The forecasting cases were derived using the methodology described in Figure 50. The study team delineated the case components using years. Case A includes traffic expected in the study area by 2019; Case B expands on Case A by including GPT-related traffic. Case C includes projects that have been permitted or announced, but are not yet under construction and will not contribute traffic volumes till after 2019. Those projects which were excluded from the analysis have not been permitted and are considered speculative at this time.

Figure 50. Forecasting Case Methodology



CASE A Baseline traffic includes:

- **Historic traffic volumes extrapolated to to 2019 including legacy Alaska crude and foreign crude oil imports.**
- **Deltaport Expansion - 2010**
- **Westshore Expansion - 2012**
- **Second Westshore Expansion - 2017**
- **Neptune Expansion - 2015**
- **BP Rail - 2013**
- **Tesoro Rail - 2012**
- **Phillips Rail – Under Construction**

CASE B=CASE A plus GPT and includes:

- **318 Panamax vessels**
- **169 Capesize vessels**
- **GPT Assist Tugs**
- **GPT Bunkering vessels**

CASE C=CASE B plus Cumulative Traffic and includes:

- **Kinder Morgan Terminal Expansion**
- **Shell Rail Terminal**

Note: These projects may be currently permitted, in the permitting process, or have been publicly announced.

Speculative and is not inlcuded:

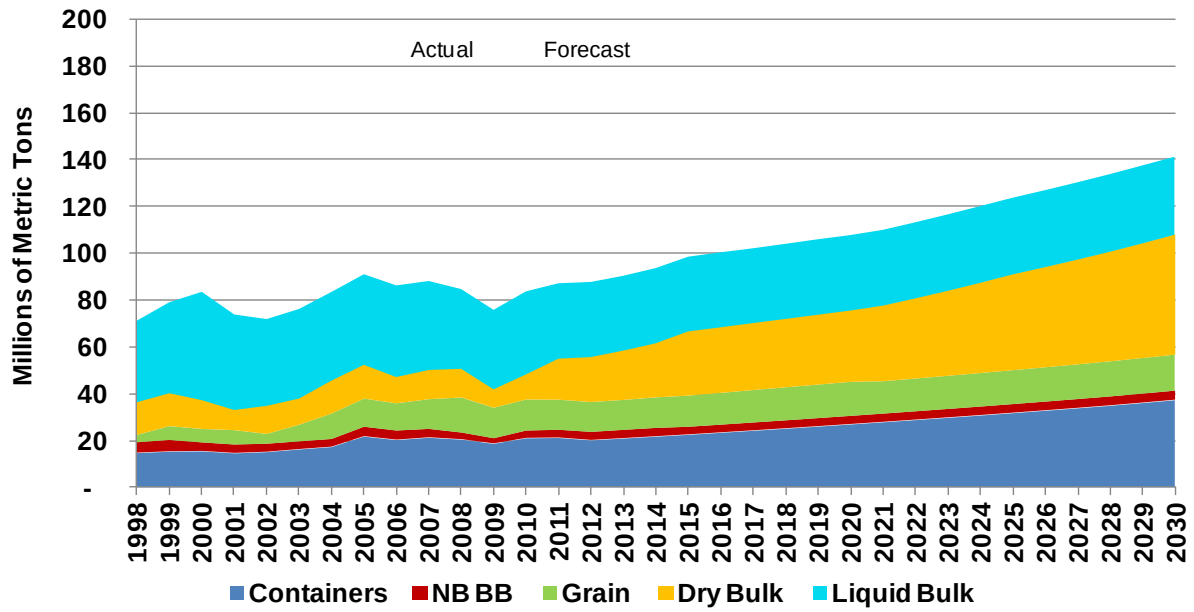
- **LNG / LPG**
- **Alaska Outer Continental Shelf Development – Post 2019 and lack of refinery volume capacity**
- **North Slope Shale Oil Development -– Post 2019 and lack of refinery volume capacity**

The study team's 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 GPT study team used both the 2009 Marine Cargo Forecast and the 2011 Update as the basis for our initial estimates of vessel traffic in the study area in 2019[27] (Figure 51).

Figure 51. Puget Sound and Washington Coast Moderate Commodity 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[28] with average annual vessel size, the number of unique vessel trips within the study area,[29] 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 DWT of these bulkers over that same period. The study then generalized the relationship between the three variables to derive a formula which would estimate the number of grain bulker trips into the study area using the total volume of BST forecasted grain exports.

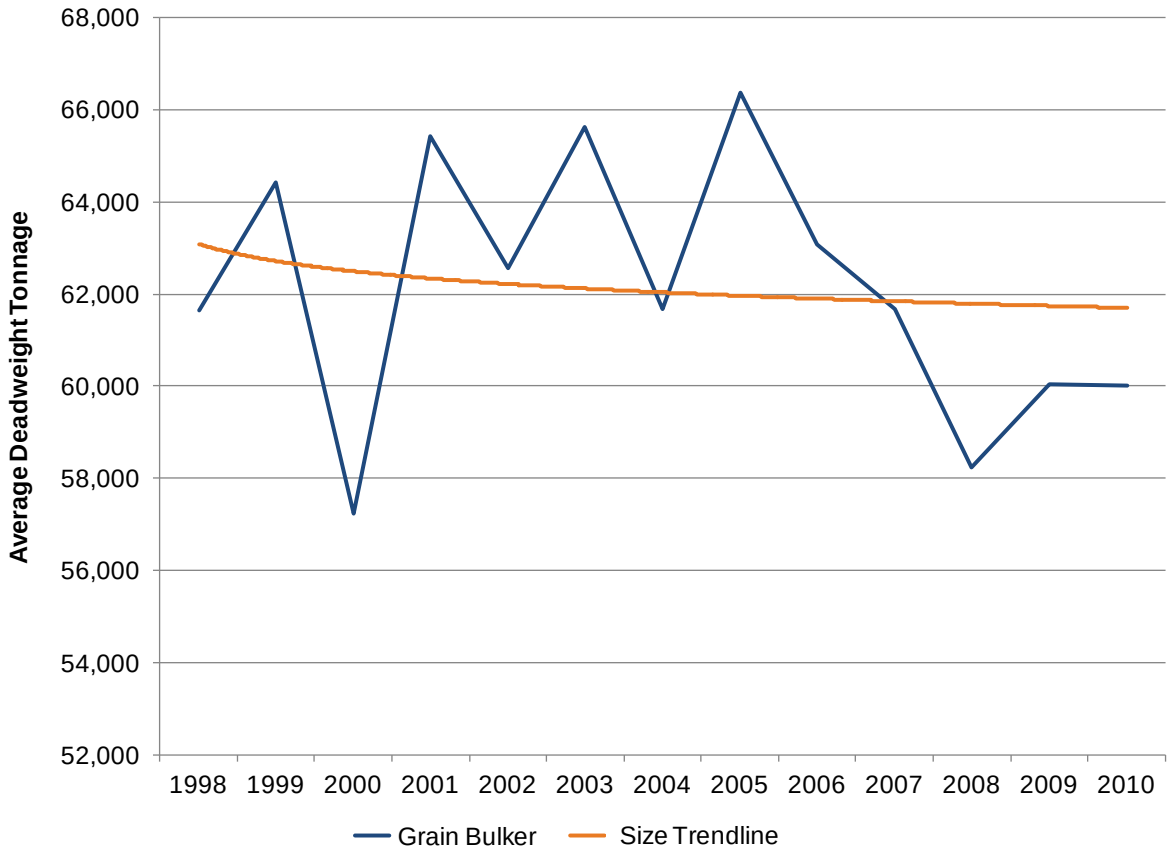
It should be noted that trends in vessel size were accounted for in this analysis. As shown in Figure 52, the study team accounted for overall trends in average vessel size. As vessel size increases, the trips necessary to transport equivalent commodity volumes decreases. The opposite is true for vessel types which may be decreasing in size.

[27] BST's 2011 report was both the most recent forecast and the most recent compilation of actual cargo volume data available at the time this report was written.

[28] Actual commodity volumes from 1998–2008 were published in the 2009 Marine Cargo Forecast.

[29] Both available from the MX data.

Figure 52. Grain Bulker Average DWT, 1998-2010



Source: Northern Economics, 2014 using MX 2012

The study team compared its estimates to the actual data available from the Marine Exchange of Puget Sound to check the accuracy of this approach. Table 22 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 the study's results is 8 percent.

Table 22. 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, 2014 using MX 2012

The only vessel types for which neither the MX data nor the BST forecast were used to forecast are non-oil tugs, ferries and fishing vessels. Each of these is discussed in more detail in the following sections.

Non-Oil 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 non-oil tug transits proportional to total growth in study area vessel activity.

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 the study's data, ferry vessel traffic days ranged from a high of 2,600 to a low of 2,570. The study team held ferry traffic days constant at 2010 levels for 2019.

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 the analysis. It should be noted that incremental increases in vessel traffic by type were forecasted separately from specific terminal expansions.

4.5 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 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 incorporate such uncertainty, the study team built variation into the model using Palisade Corporation's @RISK software. @RISK allows the study team to model 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 ship trips and tug maneuvering and at-berth time.

This report uses the most-likely vessel traffic days as a basis for presentation; however, it is worth noting that the values used for the downstream risk analysis are actually ranges of values. The variables for which ranges were used are those that present the most uncertainty, and are described in detail below.

Economic Forecast

Each of the commodity forecasts developed by BST Associates and used in the model included annual commodity volumes for 2011 through 2026, 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.[30] 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 Ship Trips

The base analysis modeled trends in cruise ship traffic to develop a forecast.[31] 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. In other words, the study incorporates a high and a low value, with the average of the two being most likely.

Tug Maneuvering and At-Berth Time

Tug maneuvering time was expected to range from 0.25 to 1.5 hours per call to port. For the purpose of modeling, the study team used a uniform distribution to represent this uncertainty, with 0.25 hours and 1.5 hours 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.

GPT Tug Loitering, Maneuvering, and Underway Time

GPT tug loitering time was expected to be 2 hours for Cherry Point tug assists. Maneuvering time for GPT assist tugs was expected to range from 1 to 2 hours per call to port, with a triangular distribution used to represent this uncertainty, with 1 hour as the lower bound, 1.5 hours the most-likely time, and 2 hours as the upper limit.

Underway time for GPT anchoring tug assists was expected to range from 0.5 hours to 1 hour, with a most likely time of 0.75 hours. This was modeled with a triangular distribution. GPT anchoring

[30] The years for which the MX data were available.

[31] Cruise ships are the only passenger vessel type for which an @RISK forecast distribution was developed as ferry vessel days are held constant at 2010 levels.

tug assist maneuvering time was expected to range from 1 to 2 hours per call to port, with a triangular distribution used to represent this uncertainty, with 1 hour as the lower bound, 1.5 hours the most-likely time, and 2 hours as the upper limit.

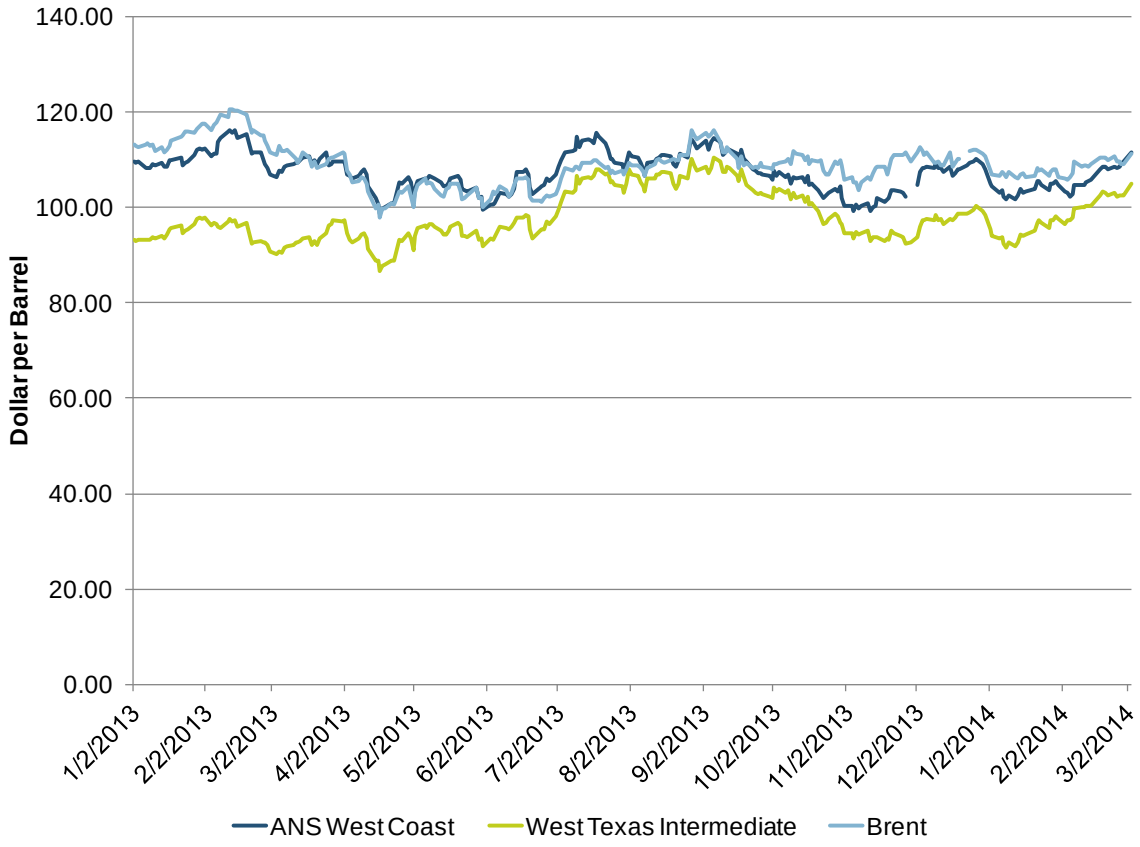
GPT-Fuel Demand

Between half and all (50–100 percent) of the 487 bulker vessels calling at GPT are expected to bunker in Port Angeles. The study team ranged the fuel demand estimate between these points; assist tug, tug, and tank barge movements related to bunkering operations in Port Angeles vary with bunker demand.

Crude Prices

The cost differential between North Dakota crude and ANS crude oil may not cover the cost of rail transportation, which is estimated at about $10 per barrel (RBN Energy LLC, 2013). Figure 53 shows the historical crude oil price spreads between Brent crude (a global benchmark that is representative of crude oil imported into West Coast ports from foreign nations, ANS, and West Texas Intermediate (WTI), which is a benchmark for Mid-Continent crude oil prices.

Figure 53. Historic Crude Oil Prices, ANS, Brent, and WTI



Source: Alaska Department of Revenue, 2014

As can be seen, the spread between Brent and WTI has varied considerably over the past 16 months, and at times ANS crude prices have exceeded Brent pricing. Public databases with historic North Dakota crude pricing were not identified, but on April 2, 2014 crude oil prices for North Dakota crude oil traded at just under $96 per barrel at the Clearbrook Minnesota hub, which is a major delivery point for Bakken crude (Reuters 2014). On the same date ANS prices were estimated at $104.93, WTI at $99.62, and Brent at $104.79 (Alaska Department of Revenue, 2014).

It is generally known that North Dakota crude has been trading at large discounts to WTI and Brent due to the lack of sufficient "take-away" capacity via pipelines and rail transport. However, additional pipelines have come online or been re-purposed and a number of rail terminals have been built in the Bakken field to move crude to other markets that are not served by pipeline routes. As a result, the price differential has narrowed in recent months.

However, as Figure 53 shows, the volatility in prices can change over time and forecasting future prices is very difficult. The analysis presented here assumes that in 2019 half (50 percent) of the time Bakken crude will enjoy a price advantage over ANS crude with Bakken crude selling for at least $10 lower than ANS crude. Thus, about half of the time North Dakota crude would displace ANS crude. Subsequently, on a daily basis averaged over the year and adjusting for practical throughput capacity of 90 percent of nameplate capacity, in Case A about 63,000 bopd would be transported to study area refineries by rail displacing ANS crude by tanker.

Since there is a great deal of uncertainty regarding the volume of crude that may be transported by rail, the model uses 50 percent as the mid-point, 25 percent as a high case (results in more tanker calls), and 75 percent as a low case (reduces the number of tanker calls).

5 References

Alaska Department of Revenue, 2014. Crude Oil and Natural Gas Prices. Available at http://www.tax.alaska.gov/programs/oil/dailyoil/dailyoil.aspx. Accessed on April 8, 2014.

Alyeska Pipeline. 2013. Valdez Marine Terminal: Tankers. Available at http://www.alyeska-pipe.com/TAPS/ValdezTerminalAndTankers/Tanker. Accessed on January 29, 2013.

British Columbia (B.C.) Ferries. 2012. Map of ferry routes. Available at https://www.bcferries.com/bcftravelcentre. Accessed on December 18, 2012.

BST. 2009. 2009 Marine Cargo Forecast: Technical Report. Prepared for the Washington Public Ports Association and Washington State Department of Transportation. March 23, 2009.

BST. 2012. Washington Public Ports Association 2011 Study: Puget Sound Projection. Provided at the request of Northern Economics, Inc. October 16, 2012.

Code of Federal Regulations. Title 33 CFR 110.230 (b)(1)

Commercial Fishing Entry Commission (CFEC). 2012. Permit and Fishing Activity by Year, State, Census Area or Alaskan City. Juneau, AK. Available at http://www.cfec.state.ak.us/fishery_statistics/earnings.htm. Accessed December 10, 2012.

Hiatt, Terry, et al. 2012. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries off Alaska, 2010. November 18, 2011. Alaska Fisheries Science Center, National Marine Fisheries Service. Seattle, WA. Available at http://www.afsc.noaa.gov/refm/docs/2011/economic.pdf.

Kinder Morgan. 2013. Trans Mountain Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act. Accessed on April 7, 2014 on the Internet at http://transmountain.s3.amazonaws.com/application/Application-Summary-Volume-8---Marine-Transportation_FINAL.pdf. December 2013.

Marine Exchange of Puget Sound. 2012. Vessel traffic data (1995–2010) prepared at the request of Northern Economics, Inc. July 31, 2012 and August 13, 2012.

National Marine Fisheries Service Northwest Regional Office. 2012. History of L.E. Permits (P.19). Sustainable Fisheries Division, Permits Branch, Northwest Regional Office, National Marine Fisheries Service. Seattle, WA. Accessed on November 23, 2012 on the Internet at https://nwr2.nmfs.noaa.gov/nwp_public_ss/home/index_pub_permits_ss.cfm.

National Oceanic and Atmospheric Administration (NOAA). 2013. Image of Cherry Point, WA. Available at http://www.noaanews.noaa.gov/stories2009/20091120_cherrypoint.html. Accessed on January 29, 2013.

National Oceanic and Atmospheric Administration (NOAA). 2012a. "Strait of Juan De Fuca and Georgia, Washington," United States Coast Pilot 7, US Department of Commerce, National Oceanic and Atmospheric Administration, 44th Edition, Chapter 12, 2012.

National Oceanic and Atmospheric Administration (NOAA), National Data Buoy Center. 2012b. Station CHYW1 – 9449424 – Cherry Point, WA. Available at http://www.ndbc.noaa.gov/station_page.php?station=chyw1. Accessed November 2012.

National Oceanic and Atmospheric Administration (NOAA). Undated. Port Angeles, US Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC Chart No. 18468, Appendix l.

Neptune Terminals, 2012. Community Update Summer 2012. Available at http://www.neptuneterminals.com/wp-content/uploads/2012/04/Neptune_Information-Summer_2012.pdf. Accessed on April 16, 2014.

Northern Economics, Inc. 2001. Sector and Regional Profiles of the North Pacific Groundfish Fisheries – 2001. North Pacific Fishery Management Council. Anchorage, AK. November 2001. http://www.fakr.noaa.gov/npfmc/PDFdocuments/resources/SectorProfiles/NorthernEconomics1.htm.

Pacific International Terminals, Inc. (PIT). 2011. Project Information Document: Gateway Pacific Terminal. February 28, 2011.

Port Metro Vancouver Finance Department, Decision Support Services. 2012. Historic vessel data prepared at request of Northern Economics, Inc. August 31, 2012.

Port of Port Angeles. Website. Available at http://www.portofpa.com/marine-facilities/index.html. Accessed on November 4, 2012.

Puget Sound Harbor Safety Committee (PSHSC). 2013. Harbor Safety Plan: Tanker Size Limitations for Puget Sound. Available at http://cdn.assets.sites.launchrocketship.com/3ce74667-d320-4623-8287-04eee9a9f4f8/files/22ec52a9-24f1-448a-9877-0ac99814b3e1/harbor_safety_plan_2013_final_4-3-2013.pdf

RBN Energy LLC. 2013. "Crude Loves Rock'n'Rail – West Coast Destinations." Available at http://www.rbnenergy.com. Accessed on July 26, 2013.

Reuters, 2014. "Bakken crude breakeven prices as low as $58/bbl in 2014." Available at http://www.reuters.com/article/2014/04/02/energy-crude-bakken-idUSL1N0MU21Z20140402. Accessed on April 11, 2014.

United States Coast Guard (USCG) Sector Puget Sound. 2012. Anchorage use data prepared at the request of Northern Economics, Inc. August 13, 2012.

Washington State Department of Ecology (WDOE), Spill Prevention, Preparedness and Response Program. 2011. Vessel Entries and Transits for Washington Waters (VEAT) 1995–2010. WDOE Publication 11-08-11. March 2011.

Washington State Department of Ecology (WDOE). 2013a. BP Cherry Point Refinery. Available at http://www.ecy.wa.gov/programs/swfa/industrial/oil_bp.html. Accessed on January 29, 2013.

Washington State Department of Ecology (WDOE). 2013b. Phillips 66 Ferndale Refinery (formerly ConocoPhillips). Available at http://www.ecy.wa.gov/programs/swfa/industrial/oil_phillips.html. Accessed on January 29, 2013.

Washington State Department of Transportation. 2012. Washington State Ferries, San Juan Islands Route Map. Available at http://www.wsdot.wa.gov/ferries/info_desk/route-maps/. Accessed on December 18, 2012.

Westshore Terminals Limited Partnership. 2013. Vessel Lineup. Available at http://www.westshore.com/pdf/misc/vessellineup.pdf. Accessed in various months throughout 2013.

Westshore Terminals Limited Partnership. 2014. Westshore Terminals Reinvestment Project. Available at http://www.westshore.com/p2s5/index.html#advantage. Accessed on April 16, 2014.

Winningham, Brian. BST Associates. Written communication with the Glosten Associates. November 2, 2012.

Appendix B Small Vessel Memo

Small Vessel Memo

Non-oil Tugs, Fishing Vessels (<60 feet), and Recreational Vessels

Prepared for

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November 2014

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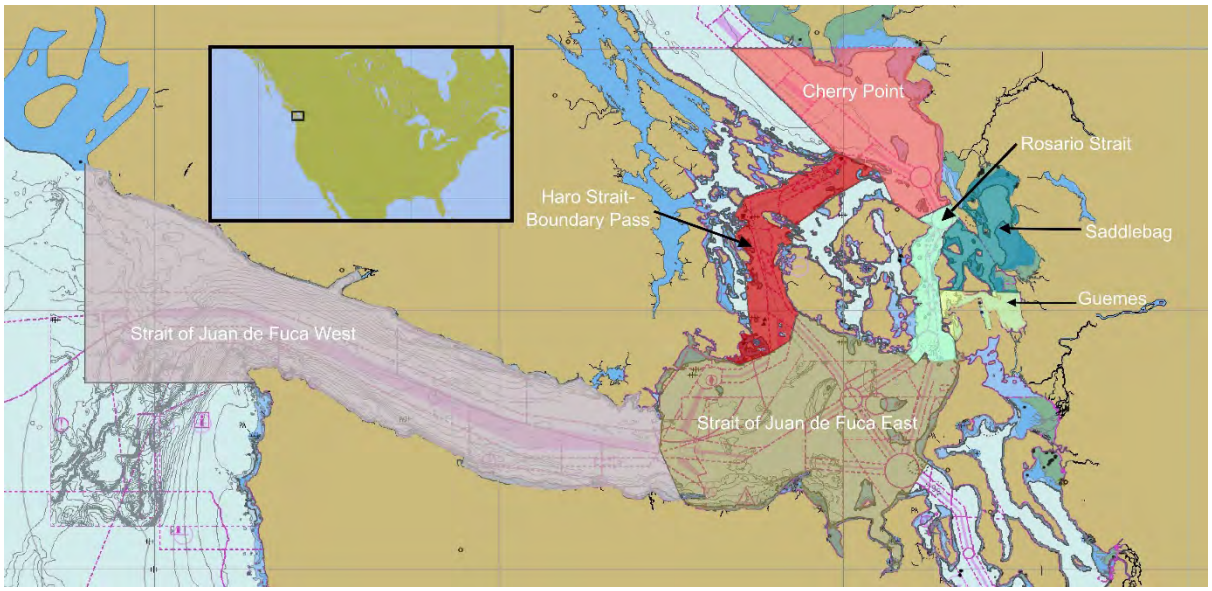
Abbreviations

AIS	Automatic Identification System
CCG	Canadian Coast Guard
USCG	U.S. Coast Guard
CFEC	Commercial Fisheries Entry Commission
GPT	Gateway Pacific Terminal
MX	Marine Exchange
NEI	Northern Economics, Inc.
NRT	Near-Real Time
PacFIN	Pacific Fisheries Information Network
WADFW	Washington Department of Fish and Wildlife
WADOL	Washington State Department of Licensing Records and Public Disclosure
WARCO	Washington State Recreation and Conservation Office

Executive Summary

This memo addresses the movement of small vessels within the Gateway Pacific Terminal (GPT) study area (Figure ES-1). Small vessel types include non-oil tugs, commercial fishing vessels less than 60 feet in length, and recreational vessels. The analysis of each of the three vessel types is unique as limited tracking data exist and no single database was sufficient for analysis of all three vessel types.

Figure ES-1. Map of the seven GPT Study Subareas



Source: The Glosten Associates 2012

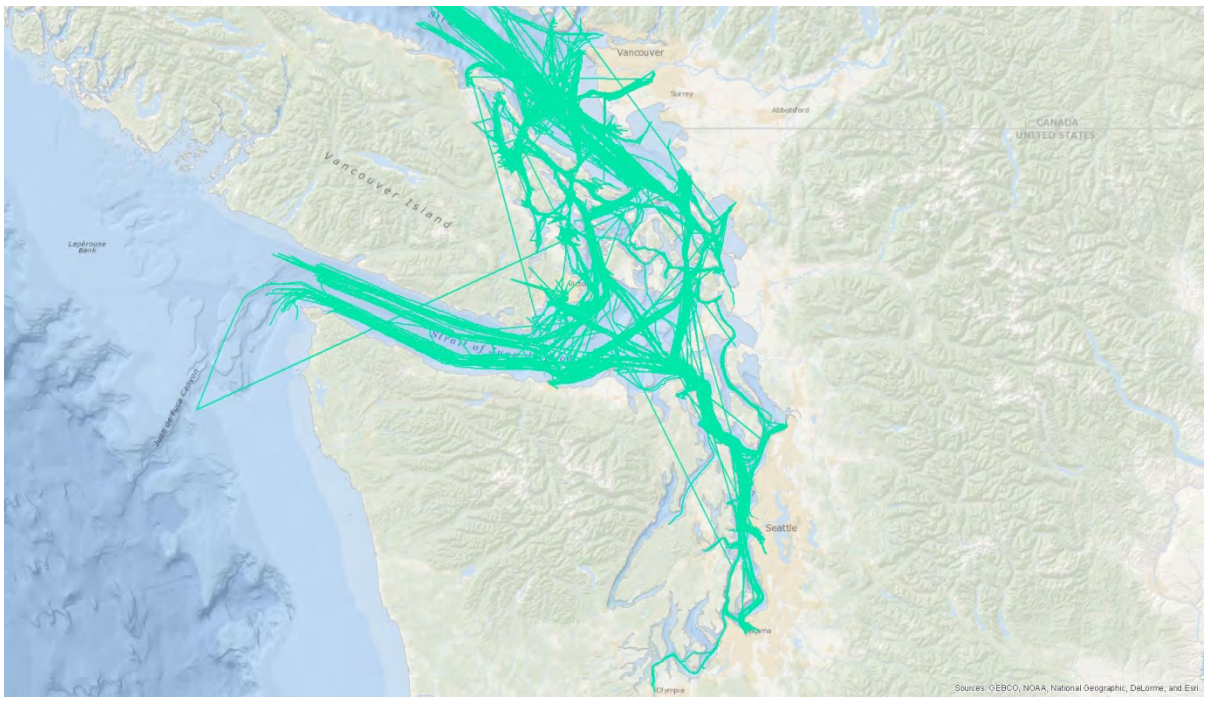
Non-oil Tugs and Barges

Tugs that tow barges loaded with crude oil or petroleum products are referred to as oil tugs with tank barges, and are analyzed independently due to a unique risk profile. Tugs included in the small vessel category are those which typically do not move oil or petroleum barges. These vessels are referred to as "non-oil tugs" and include assist tugs, escort tugs, and tugs towing barges other than tank barges.

Vessel transit information for tugs in the study area is sourced from the Near-Real Time (NRT) data made available through the U.S. and Canadian Coast Guards. Using these data, the study team is able to estimate vessel traffic days[1] by activity type and subarea, which allows non-oil tugs to be incorporated into the quantitative modeling effort. A portion of the NRT data is graphed below to show patterns of non-oil tug movement (Figure ES-2).

[1] A vessel traffic day is 24 hours of time in the study area. Traffic days may be further defined with respect to the type of vessel, one of the four activity types, and one of the seven subareas. The four activity types are: underway, maneuvering, at-anchor, and at-dock.

Figure ES-2. 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.

To obtain the number of non-oil tugs in the study area, the study team sampled the available NRT data (2007–2010).[2] Of the nearly 77,000 tug transits sampled over the four years, non-oil tugs represented 70 percent of total tug movements. Using average speed and distance travelled, the study team estimated total vessel traffic days underway by subarea. The resulting distribution by subarea is shown in Table ES-1.

Table ES-1. Non-oil Tug Vessel Traffic Day Distribution for Time Underway by Subarea, 2007–2010

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddle Bag	Rosario Strait	Cherry Point
Percent of Total	16	27	4	2	3	18	27

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

CCG and USCG NRT data are not available prior to 2007. To estimate non-oil tug historic vessel traffic days, the study team adjusted the available NRT data backward using the trend of total vessel traffic volumes under the conclusion that tug traffic varies in proportion to total traffic.

Table ES-2 summarizes the estimated traffic days spent by tugs in each of the study subareas. According to our analysis, most non-oil tug vessel traffic days are spent in the Juan de Fuca East (27 percent) and Cherry Point (27 percent) subareas. To estimate non-oil tug historic vessel traffic

[2] Data for tug movements previous to 2007 were unavailable.

days, the study team backcast the available NRT data to 1995 using the trend of total vessel traffic volumes under the conclusion that tug traffic varies in proportion to total traffic.[3]

Table ES-2. Non-oil Tug Vessel Traffic Days Underway by Subarea

Year	Total	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	1,377.7	223.2	375.2	67.6	47.8	47.9	250.3	365.8
1996	1,338.8	216.9	364.5	65.7	46.5	46.6	243.2	355.4
1997	1,342.8	217.5	365.6	65.9	46.6	46.7	243.9	356.5
1998	1,224.3	198.3	333.4	60.1	42.5	42.6	222.4	325.1
1999	1,312.4	212.6	357.4	64.4	45.6	45.7	238.4	348.4
2000	1,239.8	200.8	337.6	60.8	43.0	43.1	225.2	329.2
2001	1,298.2	210.3	353.5	63.7	45.1	45.2	235.8	344.7
2002	1,239.8	200.8	337.6	60.8	43.0	43.1	225.2	329.2
2003	1,262.5	204.5	343.8	61.9	43.8	43.9	229.3	335.2
2004	1,222.7	198.1	332.9	60.0	42.4	42.5	222.1	324.6
2005	1,281.3	207.6	348.9	62.9	44.5	44.6	232.8	340.2
2006	1,248.5	202.2	340.0	61.3	43.3	43.4	226.8	331.5
2007	1,597.8	259.8	436.2	78.8	53.5	55.5	291.3	422.7
2008	1,349.7	218.1	366.4	66.0	48.2	47.4	244.8	358.7
2009	1,204.1	195.3	327.6	59.2	41.7	41.2	218.8	320.2
2010	1,196.4	193.1	326.0	58.4	42.2	41.9	216.5	318.3

Source: Northern Economics, 2014 using NRT data (USCG and CCG) 2010.

Fishing Vessels < 60 feet in Length

The data available regarding small commercial fishing vessels were insufficient to generate an estimate of vessel traffic days by subarea by activity type for all small fishing vessels. The information contained in this report summarizes the small commercial fishing vessel data that is available, including estimated transits through each portion of the study area for Alaska-bound vessels (Table ES-3 and Figure ES-3). However, the same estimates could not be produced for vessels fishing locally (in study area waters), as harvest, landing and moorage data exist independently. That is to say, we may derive where vessels are fishing, where the fish are being delivered, and where the vessels moor—but we are unable to track which vessels are responsible for which harvests or deliveries.

Of the small commercial fishing vessels transiting to Alaska, our research indicates that the vast majority travel north using the Inside Passage, coming from the areas shown in Figure ES-3. Consequently, Cherry Point subarea sees the largest number of vessel transits each year. Since 1995, approximately 40 percent fewer small vessels are transiting between Alaska and the study area.

[3] Please refer to *Analysis Format and Vessel Traffic Data* for further information regarding methodology behind estimating historic traffic days.

Figure ES-3. Origin Areas of Alaska-bound fishing Vessels destined for Inside Passage

Note: Vessels routed through Admiralty Inlet will travel north vial Haro or Rosario Strait. Fishing vessels entering the study area near Whidbey Island or Saddlebag are likely to travel north via Rosario Strait.

Source: Northern Economics, Inc. using Google Maps 2012

Table ES-3. Small Fishing Vessels Transits to or from Alaska, 1995–2011

Year	Admiralty Inlet then north	Whidbey Island then north	Saddlebag then north	Strait of Juan de Fuca then North	Combined transits through Cherry Point Subarea
1995	397	145	232	233	1,008
1996	376	135	217	215	944
1997	364	133	212	212	922
1998	371	132	213	214	930
1999	347	124	198	208	877
2000	327	118	187	209	840
2001	300	106	167	190	764
2002	247	91	145	168	650
2003	225	86	135	154	600
2004	208	81	130	153	572
2005	226	87	140	156	610
2006	211	80	131	148	571
2007	218	81	132	150	581
2008	197	76	122	152	548
2009	231	85	137	159	612
2010	210	78	123	150	561
2011	229	85	135	142	591

Note: Vessels routed through Admiralty Inlet will pass through Juan de Fuca East subarea and will travel north vial Haro or Rosario Strait. Fishing vessels entering the study area near Whidbey Island or Saddlebag are likely to travel north via Rosario Strait. See Figure ES-1 for subareas.

Source: Estimates developed by Northern Economics based on interviews with vessel owners associations and permit and harvest data from the Alaska Commercial Fishing Entry Commission (CFEC, 2011a, 2011b).

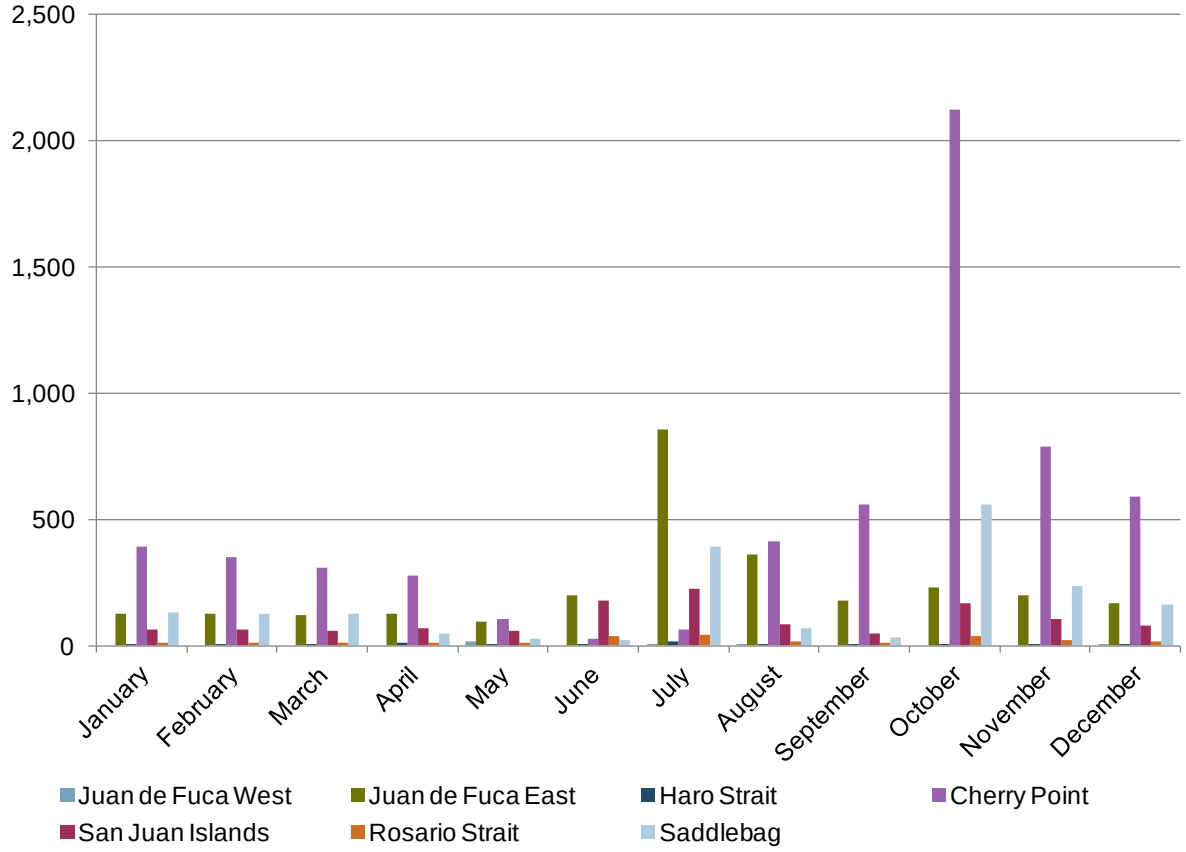
With regard to commercial vessels fishing locally, exact transit routes are unknown. However, the study team is able to estimate trips to harvest areas using fish ticket data. Fish tickets record the catch areas, species, weight, gear, etc. of landings by fishing permit holders. One fishing trip is assumed per recorded landing. While the data entered in each ticket are considered confidential by the Washington Department of Fish and Game, information can be requested in aggregate as long as it meets confidentiality constraints (Carroll 2006). The following tables and figures highlight the study subareas which have the highest levels of commercial harvest activity. Crab and shrimp harvesting activity takes place throughout the year, though activity peaks in Juan de Fuca East in July (855) and in Cherry Point (2,214) in October. These two subareas are highlighted in Table ES- 4.

Table ES- 4. Annual Average Number of Commercial and Tribal Crab and Shrimp Trips by Study Subarea, 2002–2011

Subarea	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Juan de Fuca West	-	-	-	-	15	-	8	8	-	-	-	5	35
Juan de Fuca East	125	125	119	128	96	198	855	359	179	231	199	167	2,780
Haro Strait	2	4	5	14	7	8	17	9	1	3	3	2	76
Cherry Point	391	350	308	277	104	25	66	413	559	2,124	787	589	5,995
San Juan Islands	66	62	61	67	61	181	228	84	47	170	105	79	1,212
Rosario Strait	14	12	12	11	12	37	45	16	10	36	22	16	243
Saddlebag	133	129	128	51	28	22	391	67	34	557	234	165	1,938

Note: Assume one round trip per recorded landing.
Source: Northern Economics, Inc. using PacFin 2012.

Figure ES- 4. Annual Average Number of Commercial and Tribal Crab and Shrimp Trips, by Month and Study Subarea, 2002–2011



Note: Assume one round trip per recorded landing.
Source: Northern Economics, Inc. using PacFin 2012.

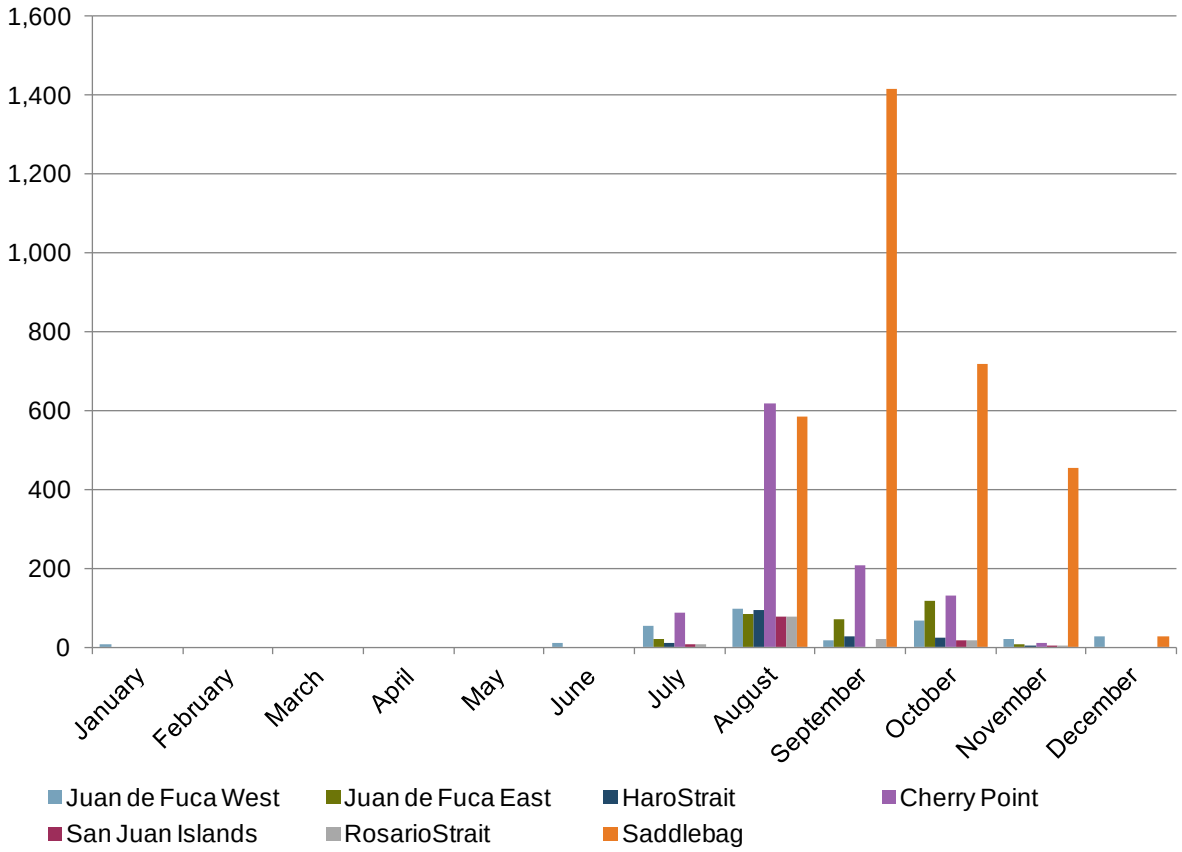
In contrast, commercial salmon harvests take place in only the latter half of the year. According to Washington Department of Fish and Wildlife harvest records, the majority of landings take place in the Saddlebag subarea; the second most take place in the Cherry Point subarea (see Table ES-5.

Table ES-5. Annual Average Number of Commercial and Tribal Salmon Trips by Month and Study Subarea, 2002–2011

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
	Average Landings by Month (2002–2011)												
Juan de Fuca West	9	-	-	-	-	12	54	99	18	69	21	26	308
Juan de Fuca East	-	-	-	-	-	-	21	86	71	117	8	-	302
Haro Strait	-	-	-	-	-	-	10	96	27	23	4	-	160
Cherry Point	-	-	-	-	-	-	88	618	208	132	12	-	1,058
San Juan Islands	-	-	-	-	-	-	8	77	-	19	3	-	106
Rosario Strait	-	-	-	-	-	-	8	77	22	19	3	-	128
Saddlebag	-	-	-	-	-	-	-	585	1,413	717	454	26	3,195

Note: Assume one round trip per recorded landing.
Source: Northern Economics, Inc. using PacFin 2012.

Figure ES-5. Annual Average Number of Commercial and Tribal Salmon Harvest Trips by Month and Study Subarea, 2002–2011



Note: Assume one round trip per recorded landing; commercial and tribal trips are included.
Source: Northern Economics, Inc. using PacFin 2012.

The study team cannot present information regarding transits to and from the fishing grounds due to lack of data for making reliable estimates. Confidentiality rules prohibit the release of any data point unless it includes information from no fewer than three harvesters and no fewer than three processors or buyers. Because there are a relatively small number of processors and buyers, the confidentiality hurdles are difficult to overcome.

Recreational Vessels

Recreational vessel movement data, like small fishing vessel data, are insufficient to generate vessel traffic days by subarea and activity type, and are therefore not incorporated into the quantitative modeling effort. However, the large volume of pleasure craft registered to addresses bordering the study area confirms that recreational vessel traffic should be at least qualitatively incorporated into the vessel traffic analysis.

Recreational vessels within the project area are, generally speaking, smaller than most other vessel types; five pleasure craft registered within the study area are more than 100 feet in length. When analyzed as a group, the total number of vessels moored in the counties surrounding the study area (Clallam, Island, Jefferson, San Juan, Skagit and Whatcom) represents fourteen percent of all vessels registered in Washington State, from coastal to inland waterways. Table ES-6 summarizes small vessel counts within the study area as well as state-wide figures.

Table ES-6. Small Vessel Count by Type

Primary Use	Study Area	Study Area (% of State)	WA State
Commercial Fishing	293	31	931
Commercial Passenger	52	19	272
Dealer	13	12	112
Livery/Rental	132	19	686
Manufacture	10	10	97
Other	322	21	1,562
Pleasure	30,911	14	227,527
Grand Total	**31,733**	**14**	**231,187**

Note: Study area includes all small vessels registered to or moored in counties bordering the study area.
Source: WDOL 2014

Statewide vessel-based recreation generally peaks in July, with another small jump in October, attributable to sport fishing.

With regard to vessel collision and risk profiles, it is worth noting the characteristics of local recreational vessels, which make up the majority of the small vessels in the study area. Of the 30,911 pleasure craft in the study area, most are made of fiberglass (or plastic), followed by aluminum and wood. Approximately half of the vessels use outboard motors only, while another 40 percent use either inboard or a combination of inboard/outboard engines. More than eighty percent of the pleasure vessels registered to counties bordering the study area are fueled by gasoline.

1 Data Constraints

All three small vessel types are similar in that data available on the activities and movements of each are limited. Per the Gateway Pacific Terminal (GPT) Vessel Traffic Study and Risk Assessment project scope, "To the degree that accurate statistics exist for the movement of smaller vessels, they will be incorporated in the traffic study." While a quantitative analysis was possible for tugs and some fishing vessels, recreational vessel traffic is analyzed qualitatively due to data constraints. More specifically:

- The Marine Exchange (MX) data include only piloted, deep-draft vessels. In the case of these vessels, only a few large fishing vessel movements are captured.
- The U.S. and Canadian Coast Guards' Near-Real Time (NRT) data capture more fishing vessel movements; however, they omit all small fishing vessels that are not equipped with AIS transponders.
- The NRT data do track all tugs; however, only the NRT data captured by Canadian stations record tow data. Tow data are necessary to distinguish between tugs with tank barges and non-oil tugs.
- Neither small fishing vessels nor most recreational vessels are required to have AIS on board. While some moves are captured, many are missed; consequently, transiting patterns must be inferred.

2 Non-oil Tugs and Barges

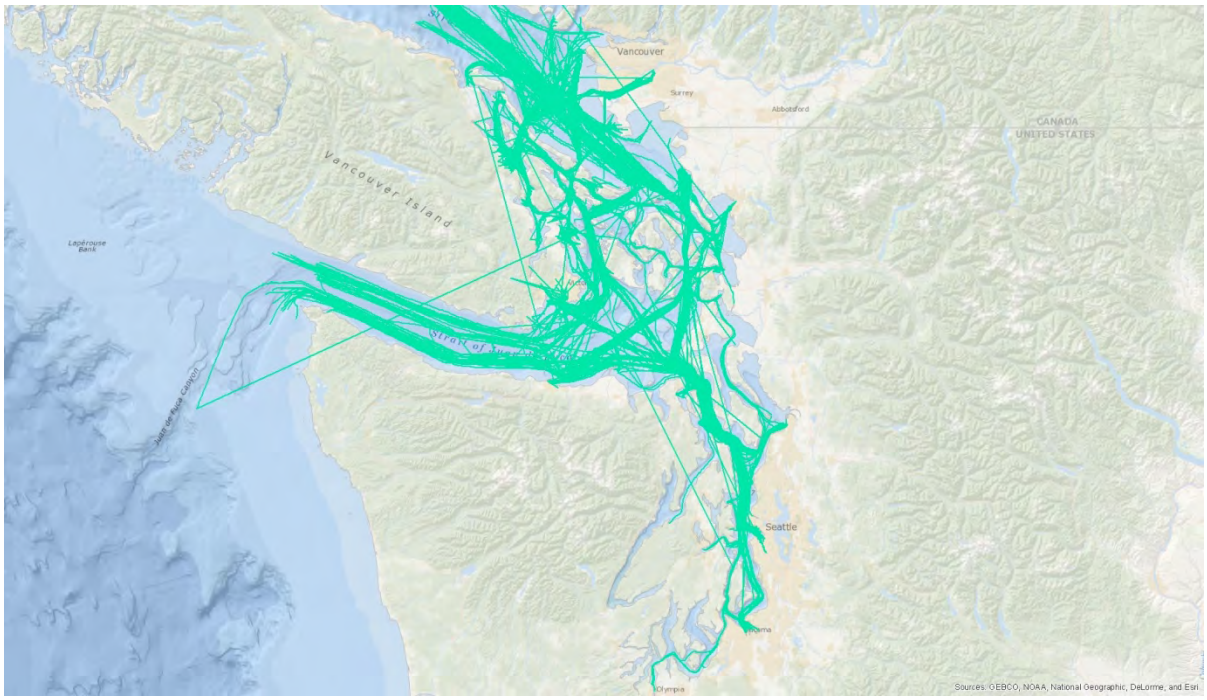
Tugs that tow barges loaded with crude oil or petroleum products are referred to as oil tugs with tank barges, and are analyzed independently due to a unique risk profile. Tugs included in the small vessel category are those which typically do not move oil or petroleum barges. These vessels are referred to as "non-oil tugs" and include assist tugs, escort tugs, and tugs towing barges other than tank barges.

Non-oil tugs move various commodities in the study area, including (but not limited to) equipment, general cargo, wood chips and logs. Non-oil tugs may be chartered for unique moves or travel on set routes.

Escort tugs are also considered non-oil tugs. Washington's Administrative Code requires escort tugs for all oil tankers 40,000 deadweight tonnes or greater when not in ballast (The Glosten Associates 2004). These tugs do not have tows, and instead travel with larger vessels through the study area as a safety precaution, providing assistance for docking and maneuvering when necessary.

To analyze non-oil tug movements, the study team relied on NRT data made available through the U.S. and Canadian Coast Guards. Tugs operating in the study area are required to have Automatic Identification Systems (AIS) on board. A vessel's AIS systems emits an electronic signal to broadcast information that has been entered on board, such as vessel name, origin, destination, size, routing, etc. The U.S. and Canadian Coast Guard capture these data in a tracking system; these data captures are referred to as NRT data and can be graphed to show patterns of vessel movement (Figure 1).

Figure 1. 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.

The following was noted regarding non-oil tug transits:

- They travel to a larger number of locations than other vessel types; these locations include small harbors and navigational buoys[4].
- They are more likely to use Rosario Strait than Haro Strait when travelling north and south within the study area.
- They travel to and from Alaska using the Inside Passage[5].
- A non-oil tug can be towing a full load, an empty load, or not towing anything.
- Non-oil tugs destined for Saddlebag are assumed to go to Bellingham;

To obtain the number of non-oil tugs in the study area, the study team sampled the available NRT data (2007–2010)[6] . Of the nearly 77,000 tug transits sampled over the four years, non-oil tugs represented 70 percent of total tug movements. Within this 70 percent of moves, the most common subarea reported as an origin or destination was south Puget Sound; approximately 34 percent of non-oil tugs trips are reported as beginning or ending at a location mapped to the south Puget Sound (Seattle, Tacoma, etc.). Using average speed, Table 1, and distance[7] travelled in each of the subareas, the study team estimated total vessel traffic days underway by subarea. The resulting distribution of travel time spent by subarea is shown in Table 2.

Table 1. Tug Average Speed by Subarea

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddle Bag	Rosario Strait	Cherry Point
Speed (nm/hr=kt)	8.65	8.51	7.71	6.37	8.93	8.20	8.20

Table 2. Non-oil Tug Vessel Traffic Days Underway, Distribution by Subarea, 2007–2010

	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddle Bag	Rosario Strait	Cherry Point
Percent of Total	16%	27%	4%	2%	3%	20%	26%

[4] Escort tugs frequently note their origin or destination as a navigational buoy at which they are awaiting a tanker for escort.

[5] The Inside Passage is the protected coastal waterway linking the Pacific Northwest to Southeast Alaska. While not within the study area, transits to and from the Inside Passage indicate that vessel traffic is transiting through the study area via Cherry Point subarea.

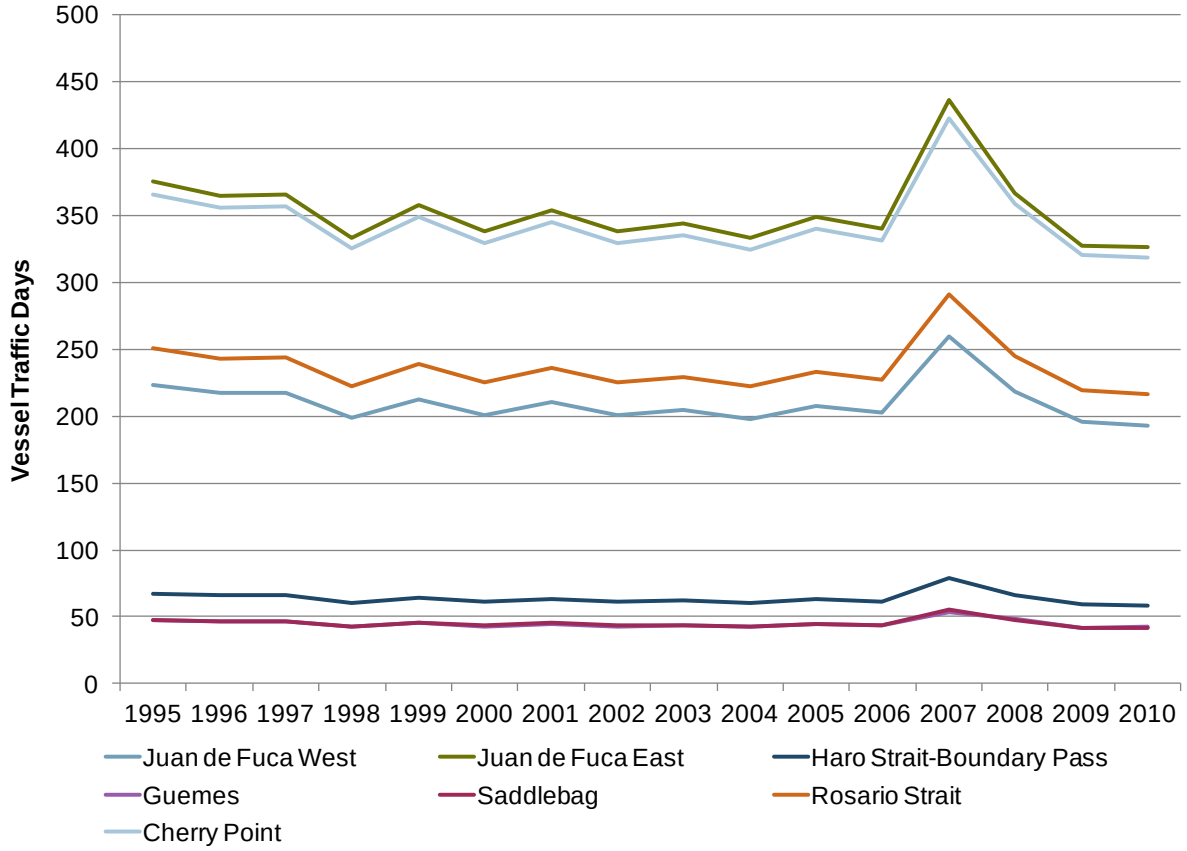
[6] Data for tug movements previous to 2007 were unavailable.

[7] Average distances are by commonly travelled route; more than 170 origin-destination pairs were used in the analysis.

CCG and USCG NRT data are not available prior to 2007. To estimate non-oil tug historic vessel traffic days, the study team backcast the available NRT data back to 1995 using the trend of total vessel traffic volumes under the conclusion that tug traffic varies in proportion to total traffic[8].

Figure 2 and Table 3 summarize the estimated non-oil tug vessel traffic days underway by study subarea.

Figure 2. Non-oil Tug Vessel Traffic Days Underway by Subarea, 1995–2010



Source: Northern Economics, 2014.

[8] Please refer to *Analysis Format and Vessel Traffic Data* for further information regarding methodology behind estimating historic traffic days.

Table 3. Non-oil Tug Vessel Traffic Days Underway by Subarea, 1995–2010

Year	Total	Juan de Fuca West	Juan de Fuca East	Haro Strait-Boundary Pass	Guemes	Saddlebag	Rosario Strait	Cherry Point
1995	1,377.7	223.2	375.2	67.6	47.8	47.9	250.3	365.8
1996	1,338.8	216.9	364.5	65.7	46.5	46.6	243.2	355.4
1997	1,342.8	217.5	365.6	65.9	46.6	46.7	243.9	356.5
1998	1,224.3	198.3	333.4	60.1	42.5	42.6	222.4	325.1
1999	1,312.4	212.6	357.4	64.4	45.6	45.7	238.4	348.4
2000	1,239.8	200.8	337.6	60.8	43.0	43.1	225.2	329.2
2001	1,298.2	210.3	353.5	63.7	45.1	45.2	235.8	344.7
2002	1,239.8	200.8	337.6	60.8	43.0	43.1	225.2	329.2
2003	1,262.5	204.5	343.8	61.9	43.8	43.9	229.3	335.2
2004	1,222.7	198.1	332.9	60.0	42.4	42.5	222.1	324.6
2005	1,281.3	207.6	348.9	62.9	44.5	44.6	232.8	340.2
2006	1,248.5	202.2	340.0	61.3	43.3	43.4	226.8	331.5
2007	1,597.8	259.8	436.2	78.8	53.5	55.5	291.3	422.7
2008	1,349.7	218.1	366.4	66.0	48.2	47.4	244.8	358.7
2009	1,204.1	195.3	327.6	59.2	41.7	41.2	218.8	320.2
2010	1,196.4	193.1	326.0	58.4	42.2	41.9	216.5	318.3

Source: Northern Economics, 2014.

3 Fishing Vessels

Small commercial fishing vessel traffic (defined as fishing vessels less 60 feet in length) within the Gateway Pacific Terminal study area is divided into two components: 1) vessels transiting through the study area on their way to or from Alaska; and 2) vessels that are actively fishing within the study area.

3.1 Summary of Vessels Transiting to/from Alaska

A large number of small fishing vessels based in Washington and Oregon make regular transits to and from Alaska. These small commercial vessels are primarily salmon boats, but also include some longline and pot vessels engaged in halibut, sablefish and crab fisheries. To generate the estimates presented below, the study team mapped all small fishing vessels travelling to and from Alaska to the Inside Passage. Based on industry contacts, this route is the most likely as it affords greater safety for the relatively small boats.

To make these estimates we first interviewed representatives from fishing vessel owner associations that are linked to the salmon fisheries in Alaska. The representative were able generalize how often vessels whose owners residing outside of Alaska transited between their home port and the fishing grounds. The representatives also indicated that operators in Southeast Alaska salmon fisheries made the transit more often than operators of salmon fisheries that were farther north and farther west.

Using data from Alaska's Commercial Fishing Entry Commission (CFEC), we obtained the number of active permit holders by state in each of Alaska's limited entry salmon fishery from 1995–2011 (CFEC, 2012a), and for permit holders from Washington state we obtained the distribution by county of permit holders in each fishery (CFEC, 2012b). Permit holders from Washington's Coastal, Columbia River and Clallam Counties, as well as permit holders from Oregon, were assumed to transit up the coast and then through the Strait of Juan de Fuca and up the inside passage[9]. Permit holders from counties adjacent to Puget Sound were assumed to transit north from South Puget Sound, Whidbey (Island and Snohomish counties) or Saddlebag (residents of Skagit and Whatcom counties). We then combined all of these data proportionally to generate estimates of transits to Alaska.

The estimated number of annual transits are shown in Table 4 and Figure 3. In the table and figure the combined transits through Cherry point equals the sum of the four component regions. Figure 4 shows the estimated breakdown of transits by month—salmon and longline vessels generally transit north in the spring and south in the fall, while crabbers go north in the fall and south in spring.

Since 1995, approximately 40 percent fewer small vessels are transiting between Alaska and the study area.

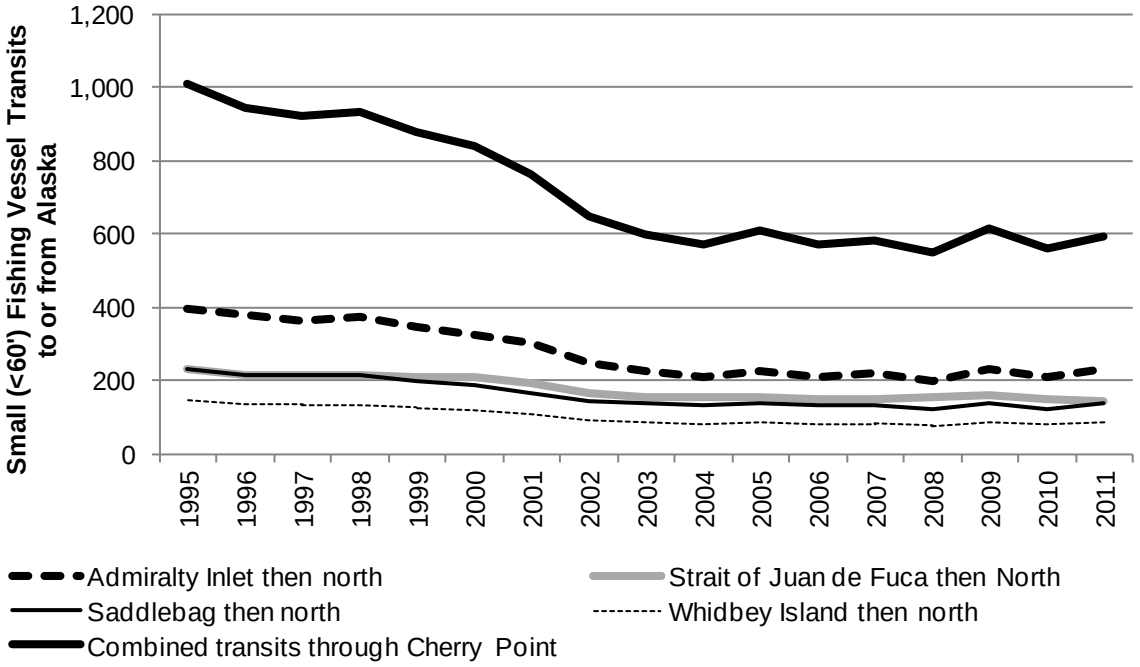
[9] Routing based on industry interviews. Fishing vessels may use Haro Strait, Rosario Strait, or transit through the San Juan Islands to reach the Inside Passage. Transit pattern by proportion could not be determined with available data.

Table 4. Small Fishing Vessels Transits to or from Alaska, 1995–2011

Year	Admiralty Inlet then north	Whidbey Island then north	Saddlebag then north	Strait of Juan de Fuca then North	Combined transits through Cherry Point Subarea
1995	397	145	232	233	1,008
1996	376	135	217	215	944
1997	364	133	212	212	922
1998	371	132	213	214	930
1999	347	124	198	208	877
2000	327	118	187	209	840
2001	300	106	167	190	764
2002	247	91	145	168	650
2003	225	86	135	154	600
2004	208	81	130	153	572
2005	226	87	140	156	610
2006	211	80	131	148	571
2007	218	81	132	150	581
2008	197	76	122	152	548
2009	231	85	137	159	612
2010	210	78	123	150	561
2011	229	85	135	142	591

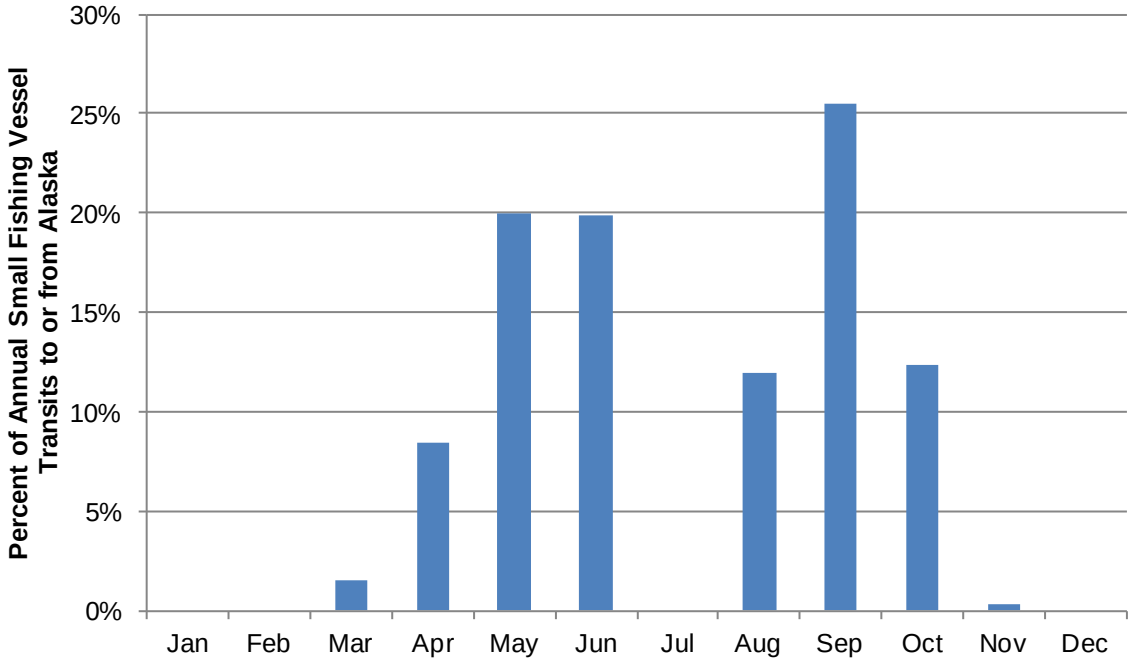
Source: Estimates developed by Northern Economics based on interviews with vessel owners associations and permit and harvest data from the Alaska Commercial Fishing Entry Commission (CFEC, 2011a, 2011b).

Figure 3. Small Fishing Vessels Transits to or from Alaska, 1995–2011



Source: Estimates developed by Northern Economics based on interviews with vessel owners associations and permit and harvest data from the Alaska Commercial Fishing Entry Commission (CFEC, 2011a, 2011b).

Figure 4. Estimated Percent of Small FV Transits to or from Alaska by Month



Source: Estimates developed by Northern Economics based on interviews with vessel owners associations.

3.2 Summary of Small Vessels Actively Fishing within the Study Area

Unlike the summary of vessels transiting to/from Alaska, small vessels actively fishing in the study area cannot be mapped to specific origin and destination pairs with available data. While the study team is able to determine where harvests in the study area are taking place, and the most likely homeports of the vessels involved in local fisheries, the available data do not let us link the two sources. In other words, while the study team can identify where fishing is taking place, and where vessels are likely docking, we cannot conclude which vessels made which landings.

In the following sections we present the small fishing data that are available, and highlight areas of the most activity. Three types of data are presented: number of fishing trips by fishery and by area (harvest data), number of commercial fishing permits by gear type and by area of residence, and value of delivered catch by area of the delivery port.

3.2.1 Harvest Data

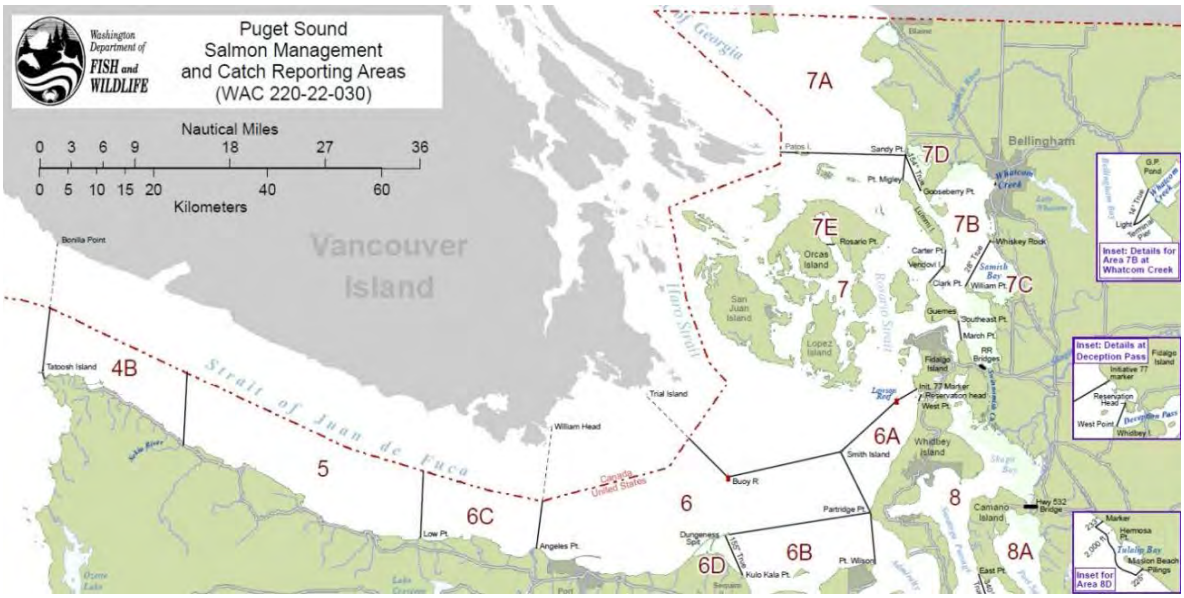
Estimates of the numbers of small fishing vessels that are actively harvesting and delivering fish and shellfish in the GPT study area are based on fish ticket[10] information provided from the

[10] Landings for each fishing trip are reported in a "fish ticket" issued by the buyer of the fish to the vessel operator. A copy of the fish ticket is submitted by the buyer to the appropriate management agency, in this case to WDFW. In most cases, vessels fish for a single type of species within a given trip—they fish for salmon or they fish for crab, but not both on the same trip. It is possible that a vessel will fish in multiple management areas during the same trip. When they do so, the fish ticket will report the harvest amount from each area in a separate line item. As used in this analysis, a "landing" is counted if an area is reported on a fish ticket.

Pacific Fisheries Information Network (PacFIN) database—a collection of commercial fishery data of all species from Washington, Oregon and California. Data provided show the average number of active vessels and number of landings of crab, shrimp and salmon from specific harvest areas by month for the years 2002–2011. Figure 5 shows the salmon management areas, while Figure 6 shows the crab, shrimp and groundfish management areas.

With the exception of Salmon Area 7 and Crab Areas 20B and 22A, which fall across several GPT study subareas, the Washington Department of Fish and Wildlife (WADFW) harvest areas are easily translated into the GPT study subareas.

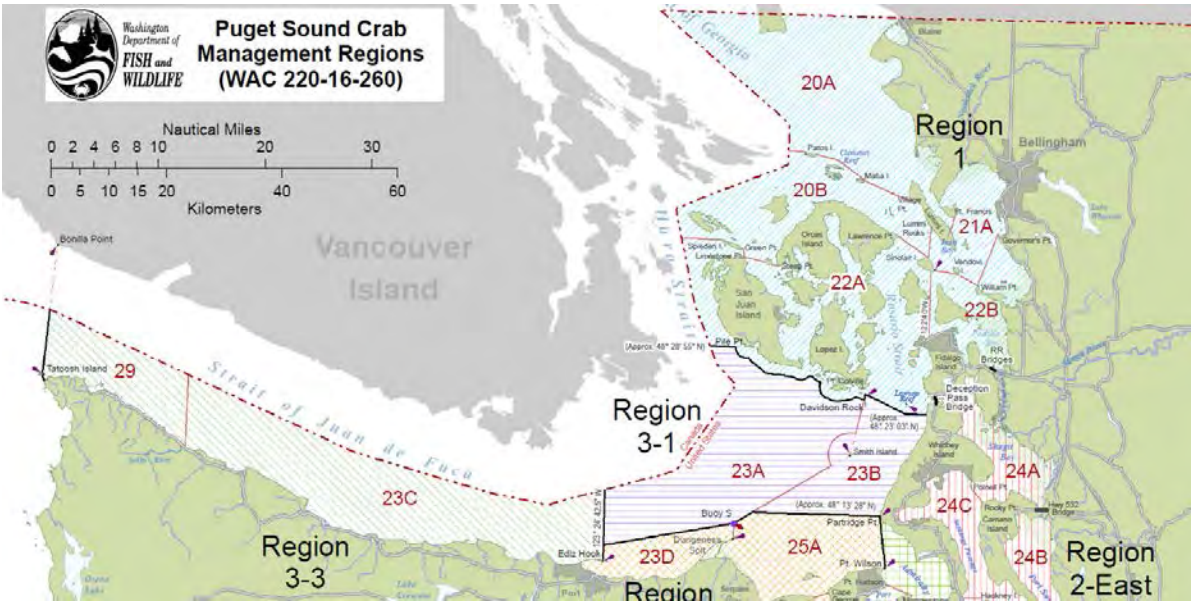
Figure 5. Washington Department of Fish and Wildlife Salmon Management Areas



Source: Maps provided by Kendall Henry of Washington Department of Fish and Wildlife, 2012.

Because multiple management areas can be reported on a single fish ticket, there is the possibility that the number of actual transits through an area may be slightly overstated. We did not obtain information from PacFIN that estimates the number fish tickets in which multiple management areas were reported. While the information provided in a fish ticket includes the location of the buyer, it is often not possible to report that information due to confidentiality restrictions. In exchange for these data, management agencies assure buyers that confidential business information will not be released to the public—WDFW and PacFIN will not release buyer location information unless more than three buyers of a given species are reporting from the same location. While it would be very useful for this study to know the precise locations from which fish tickets were issued, confidentiality restrictions preclude the release of that information. Confidentiality restrictions also preclude us from knowing the "homeport" of the individuals that have harvested the fish. While this information is knowable by fishery managers, it cannot be released to the public, or to analysts that have not been granted access to confidential information.

Figure 6. Washington Department of Fish and Wildlife Crab, Shrimp & Groundfish Management Areas



Source: Maps provided by Kendall Henry of Washington Department of Fish and Wildlife, 2012.

Table 5 summarizes the translation of WADFW harvest areas into GPT study subareas for the three WADFW harvest areas that overlap multiple GPT study areas.[11] For example, if the total harvest of crab and shrimp in 22A produced 100 fish tickets, the study team assumes that each ticket is equivalent to a single round-trip, and that total trips are distributed in the percentages shown. Fifteen percent of trips would have taken place in Strait of Juan de Fuca East, 70 percent would have taken place inside the San Juan Islands, and another 15 percent would have taken place in Rosario Strait.

Table 5. Translation of WADFW Harvest Areas to GPT Study Areas

Area	Crab & Shrimp Area 22A	Crab & Shrimp Area 20B	Salmon Area 7
Strait of Juan de Fuca East	15%	-	20%
Haro Strait	-	20%	25%
Inside San Juan Islands	70%	20%	20%
Rosario Strait	15%	-	20%
Cherry Point	-	60%	15%
Total	**100%**	**100%**	**100%**

Source: Developed by Northern Economics based on personal communications. (Velaquez, Rantz, Lummi Tribe)

While the translation of WADFW harvest areas into appropriate GPT subareas does add uncertainty to the estimated numbers of trips, it should be noted that the WADFW areas in question are less important in terms of overall landings than other WADFW areas which do not overlap study subareas.[12]

Under the assumption that each landing constitutes a single trip, Figure 7, Table 6, Figure 8 and Table 7 show estimates of the average number of commercial and tribal landings by month for WADFW management areas for crab, shrimp, and salmon between 2002–2011, along with the associated GPT subareas.[13] The subarea with the most landings is highlighted in Table 6 and Table 7.

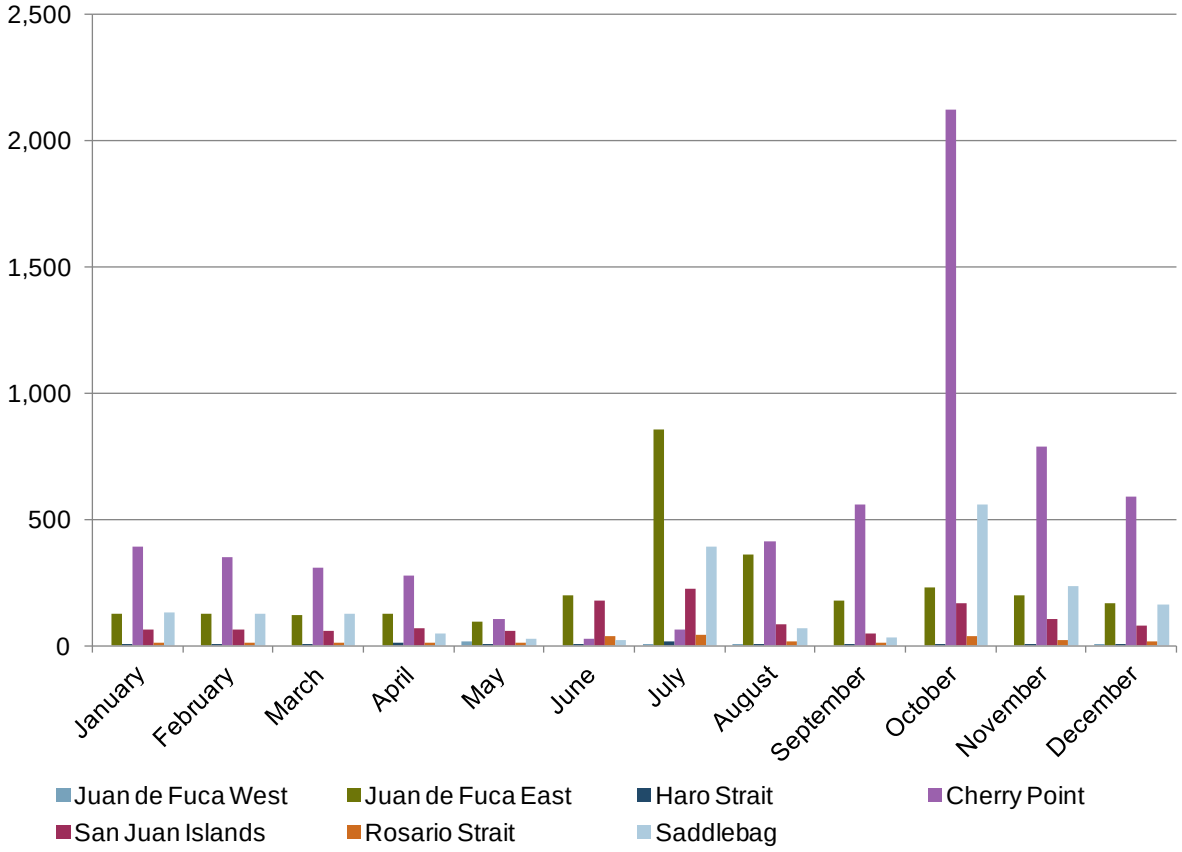
Cherry Point is the most important area for crab and shrimp harvests, while salmon harvests are highest in Saddlebag. While a closer examination of fishing effort by location is outside the scope of this study, these tables and graphics reflect official data from WADFW. We can conclude that fishing concentration takes place in locations where the catch per unit of effort is the highest, and the costs and risk are relatively low.

[11] Translation of crab and shrimp areas was based on conversations with a WDFW crab biologist (Velasquez, 2012) and later corroborated in an interview with a board member of the Puget Sound Crab Association (Rantz, 2012). Translation of WDFS salmon harvest areas was made with significantly less information, and was based primarily on information from a discussion with Lummi tribal members who indicated that there were significant harvests on the west and southwest sides of San Juan Island.

[12] Crab and shrimp areas 20B and 22a account for only about 20 per of all landings in Region 1 (Areas 20A, 20B, 21A, 22A, 22B). Similarly Salmon Area 7 accounts for 13 percent of all salmon landings north of the Strait of Juan de Fuca (i.e., Areas 7, 7A, 7B, 7C, 7D and 7E).

[13] Landings of crab and shrimp are combined into a single table since they share the same management area definitions.

Figure 7. Annual Average Number of Commercial and Tribal Crab and Shrimp Trips by Month and Study Subarea 2002–2011



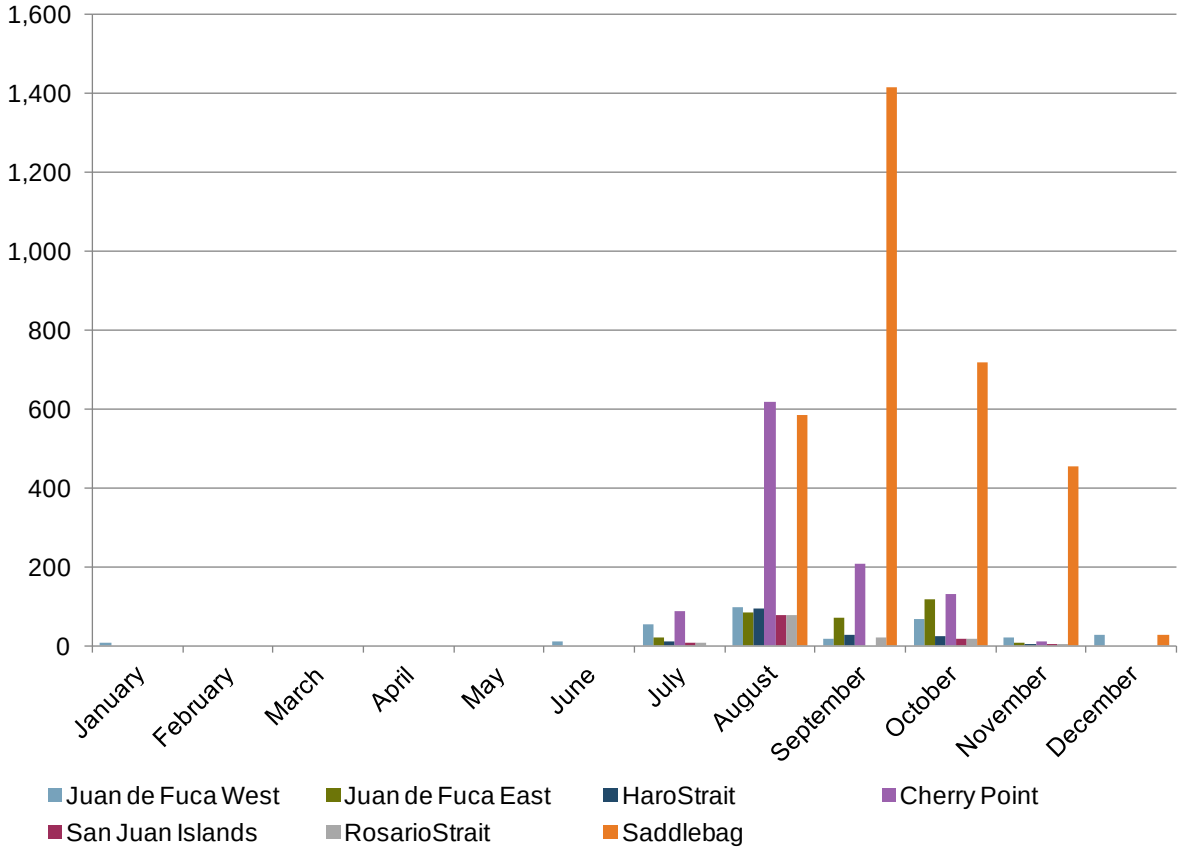
Note: Assume one round trip per recorded landing.
Source: Northern Economics, Inc. using PacFin 2012.

Table 6. Annual Average Number of Commercial and Tribal Crab and Shrimp Trips by Month and by Study Subarea and Management Area, 2002–2011

GPT Study Subarea	WADFW Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Juan de Fuca West	23C	-	-	-	-	15	-	8	8	-	-	-	-	30
	29	-	-	-	-	-	-	-	-	-	-	-	5	5
Juan de Fuca West Total		-	-	-	-	15	-	8	8	-	-	-	5	35
Juan de Fuca East	22A	14	12	12	11	12	37	45	16	10	36	22	16	243
	23A	-	-	-	24	21	17	30	39	11	-	-	-	141
	23B	22	18	19	30	14	-	220	80	83	63	53	36	638
	23D	-	-	-	-	23	12	20	17	-	-	-	-	72
	25A	89	95	88	63	27	132	541	207	75	132	124	115	1,686
Juan de Fuca East Total		125	125	119	128	96	198	855	359	179	231	199	167	2,780
Haro Strait	20B	2	4	5	14	7	8	17	9	1	3	3	2	76
Cherry Point	20A	385	340	294	234	82	-	14	386	556	2,115	780	582	5,767
	20B	7	11	15	43	22	25	52	27	3	9	8	7	228
Cherry Point Total		391	350	308	277	104	25	66	413	559	2,124	787	589	5,995
San Juan Islands	20B	2	4	5	14	7	8	17	9	1	3	3	2	76
	22A	64	58	56	53	54	172	211	76	46	167	102	77	1,136
San Juan Islands Total		66	62	61	67	61	181	228	84	47	170	105	79	1,212
Rosario	22A	14	12	12	11	12	37	45	16	10	36	22	16	243
Saddlebag	21A	67	58	64	27	-	12	299	35	19	310	123	85	1,097
	22B	66	71	64	24	28	9	92	32	15	247	111	81	841
Saddlebag Total		133	129	128	51	28	22	391	67	34	557	234	165	1,938

Note: Assume one round trip per recorded landing.
Source: Northern Economics, Inc. based on PacFin Fish Ticket Data, 2012.

Figure 8. Annual Average Number of Commercial and Tribal Salmon Trips by Month and Study Subarea, 2002–2011



Note: Assume one round trip per recorded landing
Source: Northern Economics, Inc. using PacFin 2012.

Table 7. Annual Average Number of Commercial and Tribal Salmon Trips by Month and by Study Subarea and Management Area, 2002–2011

GPT Study Subarea	WADFW Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Juan de Fuca West	6C	9	-	-	-	-	-	-	-	7	31	-	11	57
	5	-	-	-	-	-	12	54	99	11	38	21	16	250
Juan de Fuca West Total		9	-	-	-	-	12	54	99	18	69	21	26	308
Juan de Fuca East	7	-	-	-	-	-	-	8	77	22	19	3	-	128
	6	-	-	-	-	-	-	13	9	-	5	-	-	27
	6D	-	-	-	-	-	-	-	-	49	93	5	-	147
Juan de Fuca East Total		-	-	-	-	-	-	21	86	71	117	8	-	302
Haro Strait	7	-	-	-	-	-	-	10	96	27	23	4	-	160
Cherry Point	7	-	-	-	-	-	-	6	58	16	14	2	-	96
	7A	-	-	-	-	-	-	83	561	143	98	10	-	894
	7D	-	-	-	-	-	-	-	-	50	19	-	-	69
Cherry Point Total		-	-	-	-	-	-	88	618	208	132	12	-	1,058
San Juan Islands	7	-	-	-	-	-	-	8	77	-	19	3	-	106
Rosario	7	-	-	-	-	-	-	8	77	22	19	3	-	128
Saddlebag	7B	-	-	-	-	-	-	-	369	1,300	709	454	26	2,858
	7C	-	-	-	-	-	-	-	216	112	9	-	-	337
Saddlebag Total		-	-	-	-	-	-	-	585	1,413	717	454	26	3,195

Source: Northern Economics, Inc. based on PacFin Fish Ticket Data, 2012

Data for harvest are typically reported by management area; more specific data on harvesting locations are not publically available.[14] However, it is worth noting the following:

- Crab harvesting generally takes place in water less than 300 feet—very little harvesting takes place in deeper waters (Velasquez, 2012).
- We have also heard anecdotally (Rantz, 2012) that relatively little crab harvesting occurs in the southwest corner of the San Juan Islands because of significant tides coming in through the Strait of Juan de Fuca.
- As seen in Table 6, the largest share of crab harvesting activity occurs in the Cherry Point subarea. Anecdotal information (Rantz, 2012) indicates that a significant amount of crab harvesting activity takes place between the shoreline and the east side of Alden Bank, which lies approximately half way between Lummi Bay and Birch Bay just east of main shipping lanes up the inside passage.

3.2.2 Commercial Permit Holder Data

The study team obtained information regarding the commercial (non-Treaty) permit holders for Puget Sound fisheries by gear type (salmon drift gillnet, salmon purse seine, crab pots). These data are summarized in Table 8. The table shows the area of residence of all non-Indian

[14] More specific data are not regularly collected by the management agencies, and even if they have been collected they could not be released to the public due to confidentiality concerns.

commercial permit holders that are allowed to fish in Puget Sound salmon, crab and shrimp fisheries. The table lists residents by areas of interest to the GPT study.

The areas in Table 8 are specified in a way that can provide some insights into the likely transit routes:

1) **Juan de Fuca East permit holders** includes residents of Port Angeles and Sequim.
2) **Saddlebag permit holders** include residents of Skagit County and residents of the southern portion of Whatcom County adjacent to Bellingham Bay (Bellingham, Lummi Island, Demming). If these permit holders fish in salmon and crab areas within Saddlebag they will not pass through other traffic areas. If these permit holders are moving to areas to the southwest, it is assumed they would likely use Guemes Channel. If these permit holders fish in Cherry Point, it is assumed they would transit through Hale Passage.
3) **Cherry Point permit holders** include residents of the northern portion of Whatcom County (north of Bellingham Bay). These permit holders are assumed to moor their vessels north of Bellingham Bay. If they fish in waters in the Cherry Point area, they will not transit through any other of the GPT study areas. If these permit holder fish in Saddlebag, they are assumed to use Hale Passage.
4) **San Juan Islands permit holders** are residents of San Juan County.
5) **Whidbey permit holders** includes residents of Island and Snohomish Counties. These permit holders are listed separately because it appears likely they would access fishing areas to the north of the Strait of Juan de Fuca by traveling through the Swinomish Channel into the Guemes or Saddlebag study areas. If they are fishing in the Strait of Juan de Fuca, it is assumed they will transit on the west side of Whidbey Island through Admiralty Inlet.
6) **S. Puget Sound permit holders** include residents of Jefferson County and other counties adjacent to the southern portions of Puget Sound. If these permit holders fish in any of the GPT study areas, we assume they pass through Admiralty Inlet and then move north or west.
7) **Permit Holders from Outside the Study Area** reside in Pacific Coast/Lower Columbia River counties of Washington State (45 percent) or other states (55 percent). It is assumed that residents of other states moor their boats in Puget Sound, while residents of non-adjacent areas of Washington State transit up the coast and through the Strait of Juan de Fuca.

Table 8. Commercial (non-Treaty) Limit Entry Permits Holders in 2012 by Area of Residence

	Juan de Fuca East	Saddlebag	Cherry Point	San Juan Islands	Whidbey	South Puget Sound	Outside Study Area	Total
Dungeness Crab Pots	10	126	53	2	36	17	5	249
Percent of Crab Permits	4%	51%	21%	1%	14%	7%	2%	100%
Salmon Seine/Gillnet	-	98	30	10	31	85	16	270
Percent of Salmon Permits	0%	36%	11%	4%	11%	31%	6%	100%

Shrimp Pots/Trawl	1	13	3	-	1	4	1	23
Percent of Shrimp Permits	4%	57%	13%	0%	4%	17%	4%	100%

Source: Table developed by Northern Economics based on data provided by WADFW.

While the information in Table 8 is useful in that it shows where permit holders reside, there is no way to link these residency data with the areas in which harvests were made. For example, there is no way to determine if harvests in salmon area 7 are made by residents of the Saddlebag area or by residents of other states.

3.2.3 Deliveries

A summary of commercial (Non-Treaty) landing values by county for 2006 is reproduced in Table 9 from a report summarizing the economic impact of Washington commercial fisheries (TCW Economics, 2008). The data in the table could be used, if necessary, for the assignment of delivery ports for harvests in the GPT study area. The primary difficultly in doing so is that harvests from outside of the delivery region are likely to be included. For example, deliveries into South Puget Sound are likely to include harvests from the GPT study area (Strait of Juan de Fuca and North Puget Sound) and from harvests taken within the South Puget Sound region.

Table 9. Ex-vessel Value of Commercial Landings in 2006 by the Area of the Delivery Port

	Strait of Juan de Fuca East	Saddlebag/ Cherry Point	San Juan Islands	Whidbey	South Puget Sound	Total
Salmon ($ 1,000)	604	3,998	28	696	1,776	7,101
Percent of Salmon	8%	56%	0%	10%	25%	100%
Shellfish ($ 1,000)	1,036	9,158	107	684	9,153	20,139
Percent of Shellfish	5%	45%	1%	3%	45%	100%
Total ($ 1,000)	1,640	13,156	136	1,380	10,929	27,240
Percent of Total	6%	48%	0%	5%	40%	100%

Notes: 1) Values may include harvests taken from outside of the port area. 2) Shellfish includes harvest of crab, shrimp and other non-farm shellfish.

The study team has not presented information regarding transits to and from the fishing grounds because we do not have the data to make reliable estimates. Specifically, the confidentiality rules prohibit the release of any data point unless it includes information from no fewer than three harvesters and no fewer than three processors or buyers. Because there are a relatively small number of processors and buyers, the confidentiality hurdles are difficult to overcome.

4 Recreational Vessels

Recreational vessels operating within the study area are numerous; however, these vessels are not generally tracked, making their transits and activities difficult to quantify. In this section we present the data available regarding these vessels, including characteristics, counts and use patterns as these data have a bearing on vessel collision and risk profiles.

4.1 Recreational Vessel Characteristics

Recreational vessels within the project area are numerous and varied in type and size. Generally speaking they are smaller (all pleasure craft registered to the study area are under 100 feet in length), and operate on an unscheduled basis. They may be motorized or hand-powered, and include sail boats and personal watercraft.

The State of Washington, Department of Licensing (DOL) provided the project team with electronic data extracted from the Department's database of registered vessels, as displayed in Table 10.

According to Washington State Recreation and Conservation Office (2012), registration is required

> …to navigate, operate, employ, or moor your vessel in Washington, you must have a Washington title, registration card, and registration decals, except:
>
> - If your vessel is a canoe, kayak, or a vessel not propelled by a motor or sail.
> - If your vessel is less than 16 feet in length **and** has a motor of 10 horsepower or less **and** is used on non-federal waters only.
> - If your vessel is properly registered by a resident of another state or country who uses Washington waters for 60 days or fewer.

Table 10. Registered Vessels in the State of Washington by Hull Material and Type of Power

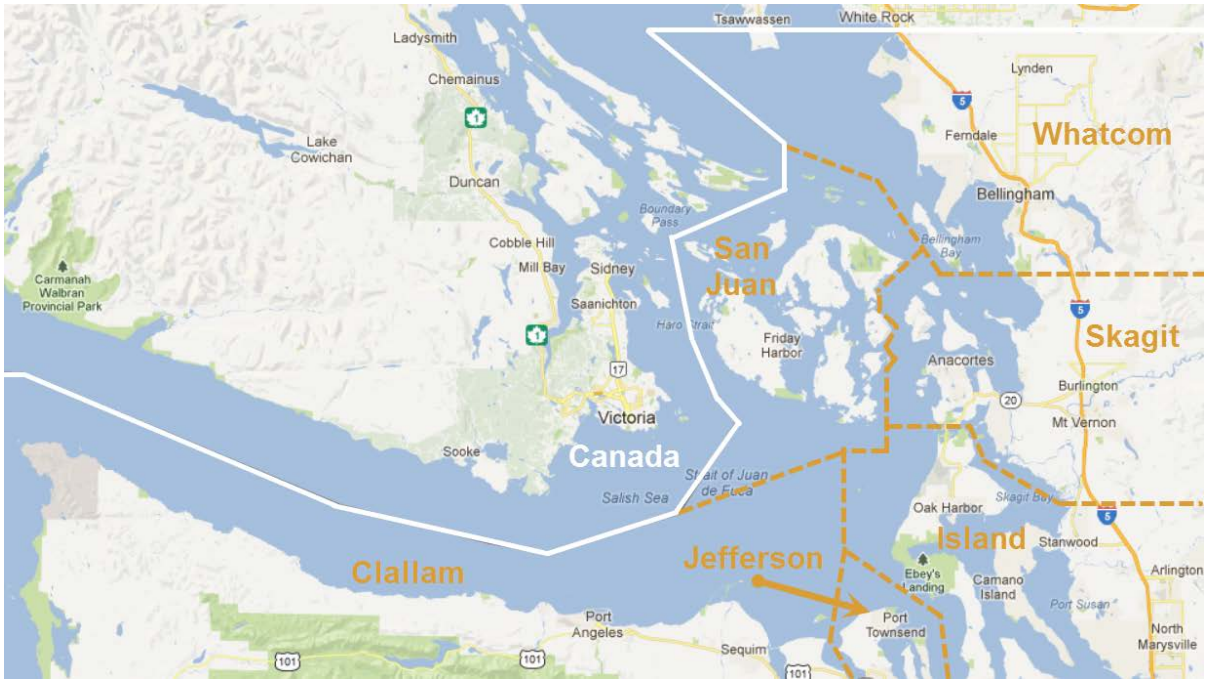
Hull Material	Outboard	Inboard/ Outboard	Inboard	Jet	Sail	Other	Total
Fiberglass/Plastic	48,900	49,105	33,640	19,722	6,463	768	158,598
Aluminum	57,413	1,479	2,204	2,186	29	1,068	64,379
Wood	1,218	96	2,027	6	572	78	3,997
Rubber	2,994	9	18	4	1	120	3,146
Other	486	14	23	21	11	41	596
Steel	131	20	209	4	28	18	410
Concrete	7	0	26	0	26	2	61
Total	**111,149**	**50,723**	**38,147**	**21,943**	**7,130**	**2,095**	**231,187**

Source: WADOL 2014
Note: Registration for these vessels expires on June 30, 2014 or 2015.

These registered vessels include all types of primary uses, such as pleasure craft (by far the largest category), commercial passenger transport, and commercial fishing.

Vessel registration data received from the state were filtered to include just those vessels that are actively registered and moored in a county bordering the study area. These six counties are Clallam, Island, Jefferson, San Juan, Skagit and Whatcom. Figure 9 displays the counties bordering the study area. While recreational traffic likely comes into the study area from other areas such as Canada or South Puget Sound, the volume of traffic from these areas could not be determined with available data.

Figure 9. Study Area and Bordering Counties



Source: Google Maps 2012. Northern Economics, Inc.

In aggregate, the vessels moored in the counties shown in Figure 9 represent 14 percent of all vessels registered in Washington State, from coastal to inland waterways. Table 11 summarizes small vessel counts within the study area as well as statewide figures.

Table 11. Small Vessel Count by Type

Primary Use	Study Area (#)	Study Area (% of State)	WA State (#)
Comm. Fishing	293	31	931
Comm. Passenger	52	19	272
Dealer	13	12	112
Livery/Rental	132	19	686
Manufacture	10	10	97
Other	322	21	1,562
Pleasure	30,911	14	227,527

Grand Total	**31,733**	**14**	**231,187**

Source: WDOL 2014.

Pleasure Vessels

A total of 30,911 vessels registered within the project area are pleasure craft, representing 14 percent of the state's total pleasure craft fleet. Most are made of fiberglass (or plastic), followed by aluminum and wood. Approximately half of the vessels use outboard motors only, while inboard or a combination of inboard/outboard engines account for nearly another 40 percent.

A breakout of pleasure vessels by counties bordering the project is provided in Table 12. Whatcom, Skagit and Island counties report the largest number of pleasure vessels, and they average between 17.7 and 20.9 feet in length.

Table 12. Pleasure Vessels by County

County	Vessel Count	Average Vessel Length (ft.)
Clallam	3,544	18.0
Island	5,362	17.7
Jefferson	2,507	21.2
San Juan	2,803	23.7
Skagit	8,712	20.9
Whatcom	7,983	20.1
Total	**30,911**	**20.1**

Source: WDOL 2014.

The distribution of pleasure vessel length can be seen in Table 13. There are five vessels over 100 ft. registered and moored in those counties bordering the study area.

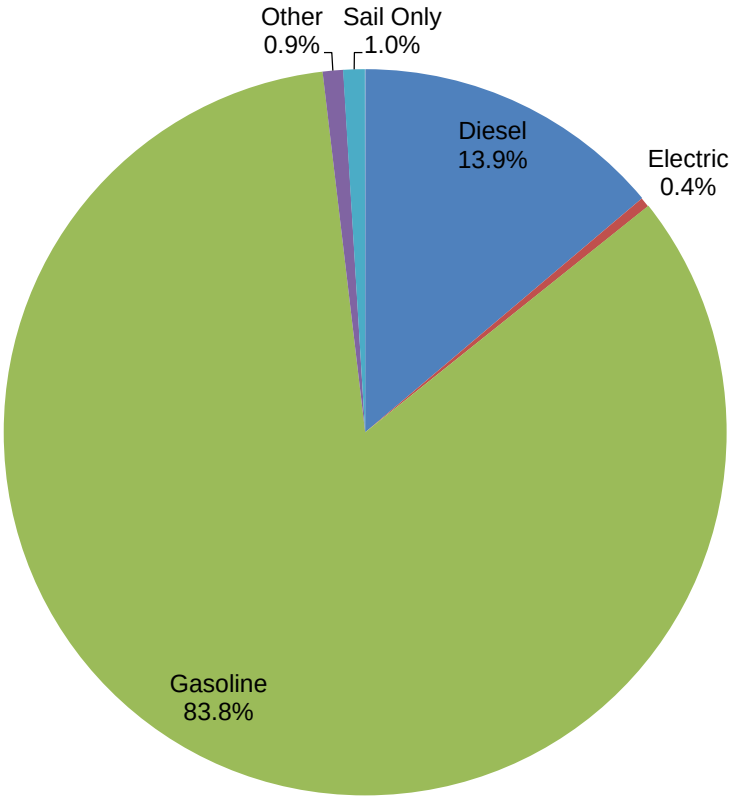
Table 13. Pleasure Vessel Length Distribution

		Pleasure Vessel Size						Weighted Average Length	Min/Max
Location		0-15	16-30	31-50	51-100	>100	Total	ft.	
Study Area	#	10,222	16,863	3,578	243	5	30,911	20.1	5/310
	%	33.1	54.6	11.6	0.8	0.0	100		
Washington State	#	73,190	140,723	12,496	1,063	55	227,527	18.4	5/907
	%	32.2	61.8	5.5	0.5	0.0	100		

Source: WDOL 2014.

The types of fuel being used by pleasure vessels can be seen in Figure 10, excluding hand-powered vessels (i.e., kayaks, canoes, rowboats). Sail boats generally have a small inboard or outboard motor for occasional use, even though primary vessel power is from winds.

Figure 10. Pleasure Vessel Fuel Type



Source: WDOL 2014.

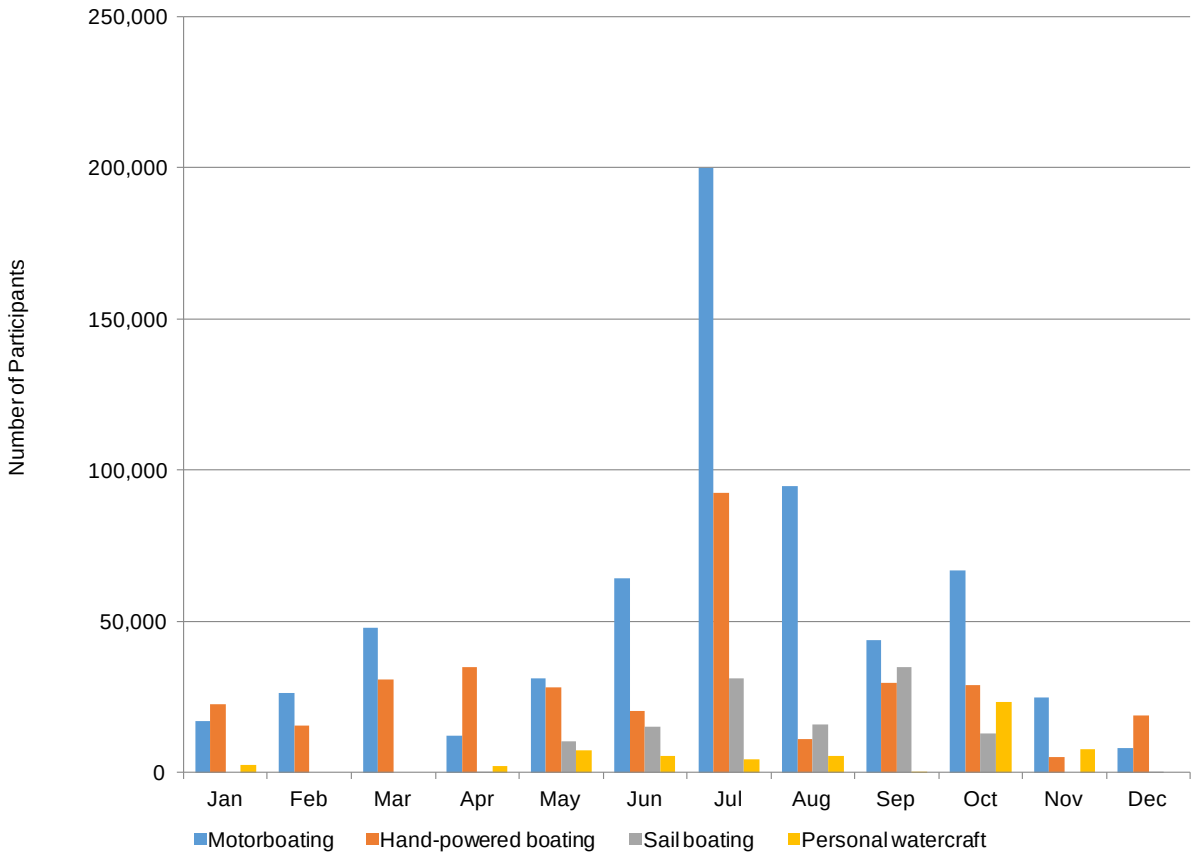
4.2 Recreational Vessel Use

Washington's State Recreation and Conservation Office (WARCO) noted, in a 2007 survey of the state's population, four vessel-based recreational water activities:

- Motor boating
- Canoeing, kayaking, other hand-powered boating
- Sail boating
- Personal watercraft (such as Jet Skis)

Figure 11 summarizes the estimated number of participants in each of the four water-vessel related activities, based on survey data collected (WARCO, 2007). As a statistically based survey, the estimated number of participants shown is subject to a certain level of variability due to sample size, location, etc. For this figure, the study team used saltwater based activities only, as these most closely matched conditions and related activities in the project area.

Figure 11. Estimated Number of Washington Participants, Water Vessel Activities



Source: Northern Economics, Inc. using cross-tabulations from WAROC's 2006 Outdoor Recreation Survey collected by Clearwater Research, Inc., Boise, Idaho, 2007.

Motorized vessel use predominates over all other small vessel activities, with 27 percent of Washington's population participating. Human or hand-powered vessel use, such as kayaking, was the next most frequent type of activity at 18 percent.

Statewide vessel-based recreation generally peaks in July, with another small jump in October, attributable to sport fishing. Activities such as fishing for salmon and bottomfish[15] are popular among anglers, with a recorded salmon catch in 2008 of just over 32,000 fish and approximately 69,000 bottomfish (WADFW, 2012).

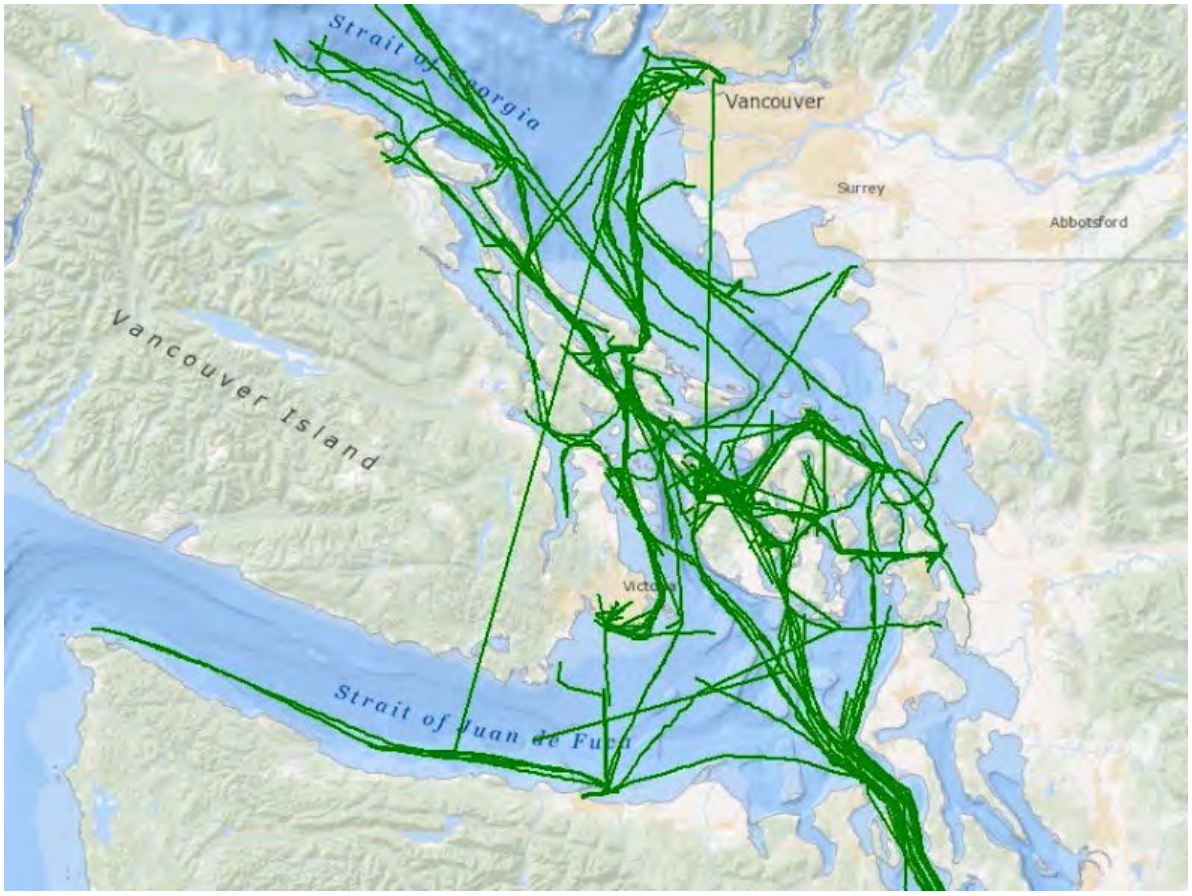
Sight-seeing was highest among sailboaters and paddlers, with relaxation cited as a key motivation. Motor boat users showed the highest fishing participation, while sailboaters had the lowest number of fishing participants.

[15] Bottomfish are defined as halibut, flounder, soles, sanddabs, sablefish, lingcod, greenlings, rockfish, Pacific cod, Pollock, surfperches, cabezon, sculpins, spiny dogfish and other miscellaneous bottomfish species.

4.3 Recreational Vessel Traffic Patterns

Most small vessels are not required to carry AIS transponders; however, several do possess these electronic tracking devices, and Figure 12 illustrates (limited) pleasure craft vessel tracks for July, 2010. While this figure illustrates some recreational traffic patterns, the study team is unable to conclude what portion of total traffic these lines represent.

Figure 12. Small Vessel Tracking, 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.

These vessel tracks are consistent with prior surveys suggesting summer boat use is high, and that the San Juan Islands attract a significant portion of boaters, especially sailboats.

Recreational traffic is tied to mooring location. Most small vessels moor at harbors or marinas, such as the one displayed in Figure 13, at Bellingham.

Figure 13. Small-boat Harbor, Bellingham

Source: Northern Economics, Inc., 2005

The number of masts shown suggests sail boats are common in this area. This is consistent with a survey of Washington boaters that reported boats near the coastal portions of the project area were generally longer than 26 feet, and were more likely to be sailboats than in other parts of the state (Responsive Management, 2007). Counties with high boat use included King, San Juan, and Thurston, with sailboat owners expressing a strong preference for the San Juan area.

5 References

Carroll, Amy. 2006. Fish Tickets Fishery Database is the Envy of the Industry. Available at http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=246

Commercial Fisheries Entry Commission (CFEC) 2012a "Permit & Fishing Activity by Year, State, Census Area or Alaskan City" http://www.cfec.state.ak.us/fishery_statistics/earnings.htm

Commercial Fisheries Entry Commission (CFEC) 2012b "CFEC Public Lookup Database." http://www.cfec.state.ak.us/plook/

The Glosten Associates. 2004. Study of Tug Escorts in Puget Sound. Prepared for State of Washington, Department of Ecology. December 2004.

Puget Sound, WA. 2012. Google Maps. Google. Available at https://www.google.com/mapmaker

Rantz, 2012. Rantz, John. Board member of the Puget Sound Crab Association. Personal Communication with Marcus Hartley of Northern Economics, Inc. on December 27, 2012Responsive Management National Office, Washington Boater Needs Assessment, Data Summary, 2007. Harrisonburg, Virginia.

Responsive Management National Office, Washington Boater Needs Assessment, Executive Summary, 2007b. Harrisonburg, Virginia.

TCW Economics, 2008. Economic Analysis of the Non Treaty Commercial and Recreational Fisheries in Washington State. December 2008. Sacramento, CA. With technical assistance from The Research Group, Corvallis, OR. Prepared for Washington Department of Fish and Wildlife. Available on the internet at http://wdfw.wa.gov/publications/00464/wdfw00464.pdf.

Velasquez, 2012. Velasquez, Don. Puget Sound Crab Biologist; Washing Department of Fish and Wildlife. Personal Communication with Marcus Hartley of Northern Economics, Inc. on December 14, 2012.

Washington State Department of Licensing Records and Public Disclosure (WADOL). 2014. Vessel registration data prepared at the request of Northern Economics, Inc. February 11, 2014.

Washington State Department of Fish and Wildlife (WADFW). 2012. Log Tow Routes. Available at http://wdfw.wa.gov/fishing/commercial/crab/pugetsound/towroutes.html. Accessed on December 30, 2012.

Washington State Recreation and Conservation Office (WARCO). 2007. 2006 Outdoor Recreation Survey, Final Report.
Available at http://www.rco.wa.gov/documents/rec_trends/2006RecSurveyFull.pdf

Washington State Recreation and Conservation Office (WARCO). 2012. Boater registration guidelines. Available at http://boat.wa.gov/register.asp.

Washington Department of Fish and Wildlife, Sport Catch Report 2008, published 2012.

Appendix C Characterization of Historical Vessel Incidents

Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study

Characterization of Historical Vessel Incidents

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ENVIRONMENTAL RESEARCH CONSULTING

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Gateway Pacific Terminal Vessel Traffic Study Characterization of Historical Vessel Incidents

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 no traffic data exists 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) and other vessels (238 large fishing vessels, cruise ships, ferries, and tugs). Vessels other than those in the miscellaneous category were called VTS (for Vessel Traffic Study) vessels for the purposes of these analyses.

Five groups of incident causes were analyzed: allisions, collisions, groundings, transfer errors (including bunkering errors), and other, non-impact incidents. The activity at the time of the incident – anchored, docked, underway, or maneuvering – was 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 were 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 include 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 and 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 other 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 tug and 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. They were 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 three quarter years with an equal number occurring in Juan de Fuca West, Juan de Fuca East, and Cherry Point.
- Groundings occur about once 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 transfer errors where 84% of reported incidents with the potential for spillage did result in a spill. 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 would be for tankers, which 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 an 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 GPT Vessel Traffic and Risk Assessment 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 was 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 GPT VTS 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 1were included.

Table 1: Data Collected on Historical Vessel Incidents

Data Field	Categories		
GPT Subarea	• Juan de Fuca West • Juan de Fuca East • Guemes • Saddlebag • Haro Strait-Boundary Pass • Rosario Strait • Cherry Point		
Vessel Type	• Bulk • General Cargo • Tanker • Tug and Tank Barge • Other	**Vessels in Vessel Traffic Study (VTS Vessels)**	**All Vessels**
	• Miscellaneous		
Incident Cause	• Allision • Collision • Grounding • Other, Non-Impact • Transfer Error		
Activity Type	• Anchored • Docked • Maneuvering • Underway		

Notes on Vessel Types

The numbers of incidents by vessel type are show in Table 2. The incidents are further detailed by vessel type in Table 3.

- 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," which are part of the "Other Vessel" and "Small Other Vessel" categories, 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.
- "Other Vessels" includes fishing vessels over 60 feet, cruise ships, and regularly-scheduled ferries regardless of size, and all tugs regardless of size.
- "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.

Table 2: Number 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
Other	238	238	238
Miscellaneous	687	687	-
Total	**1,116**	**1,116**	**429**

Table 3: Number 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	**Other 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
Pleasure Craft	406	**Miscellaneous**	0
Fishing Vessel – Factory	7	**Other Vessel**	7
Fishing Vessel – Reefer	1	**Other Vessel**	1
Fishing Vessel – Trawler	27	**Other Vessel**	27
Passenger Vessel – Cruise	2	**Other Vessel**	2
Passenger Vessel – Ferry	70	**Other Vessel**	70
Towboat/Tugboat	89	**Other Vessel**	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: Number 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	36	**Transfer Error**	36
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
Transfer Error	47	40	**Transfer Error**	40
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: Number 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: Number 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**

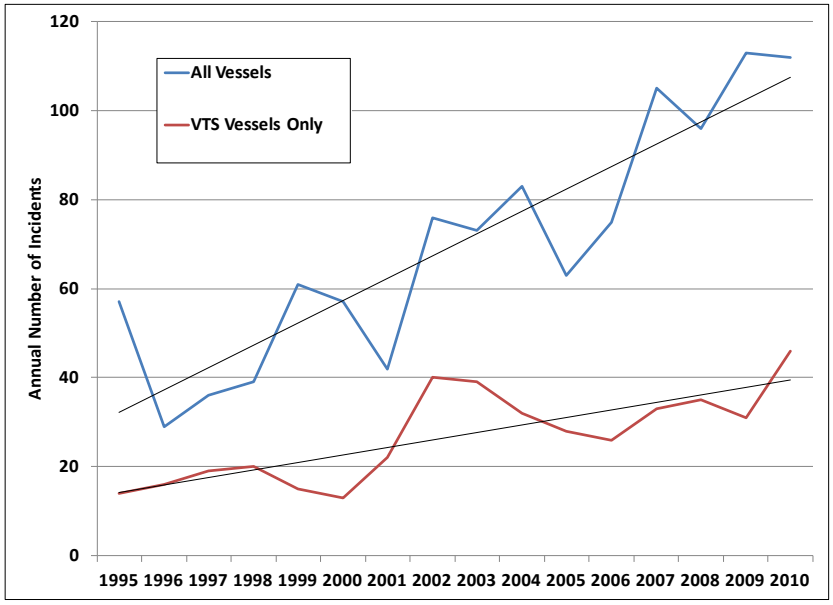

Figure 2: Annual Number of Incidents for All Vessels

Breakdown of Incidents by Subarea

The incidents are broken down by subarea and year for all vessels in Table 7, Figure 3, and Figure 4. VTS vessels only are shown in Table 8, Figure 5, and Figure 6. The breakdowns by individual vessel types are shown in Table 10 through Table 17. Figure 7 through Figure 12 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**

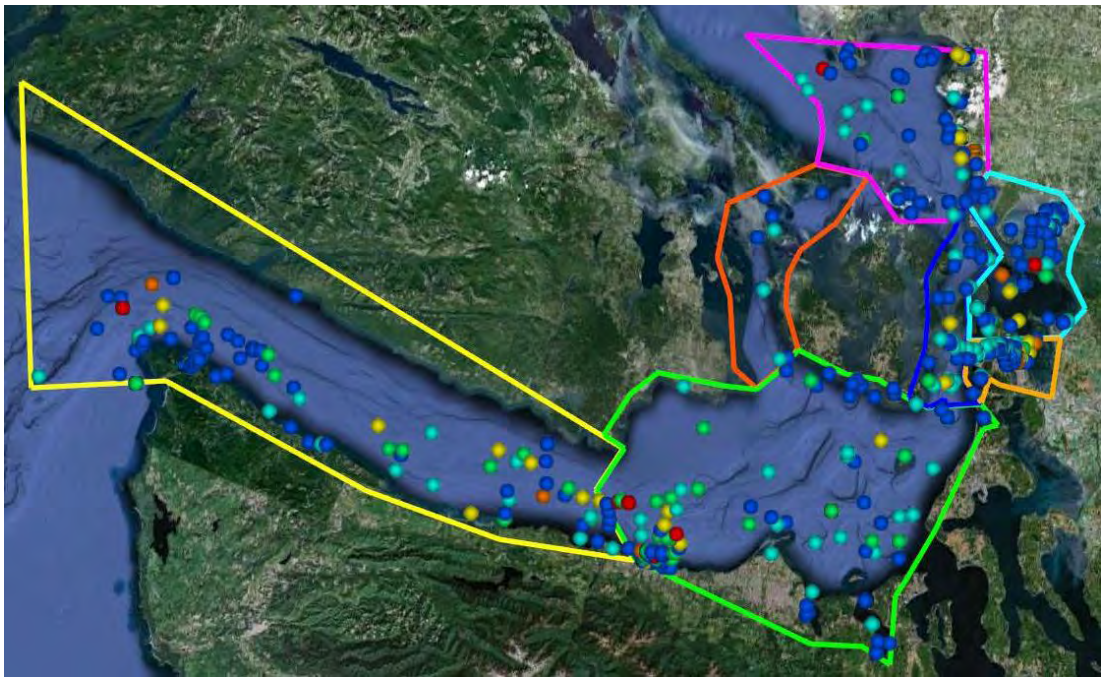

Figure 3: Map of All Vessel Incidents by Subarea

Red represents Bulkers, orange is for tug and tank barges, yellow is for tankers, green is for general cargo vessels, aqua is for other vessels and blue is for 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.

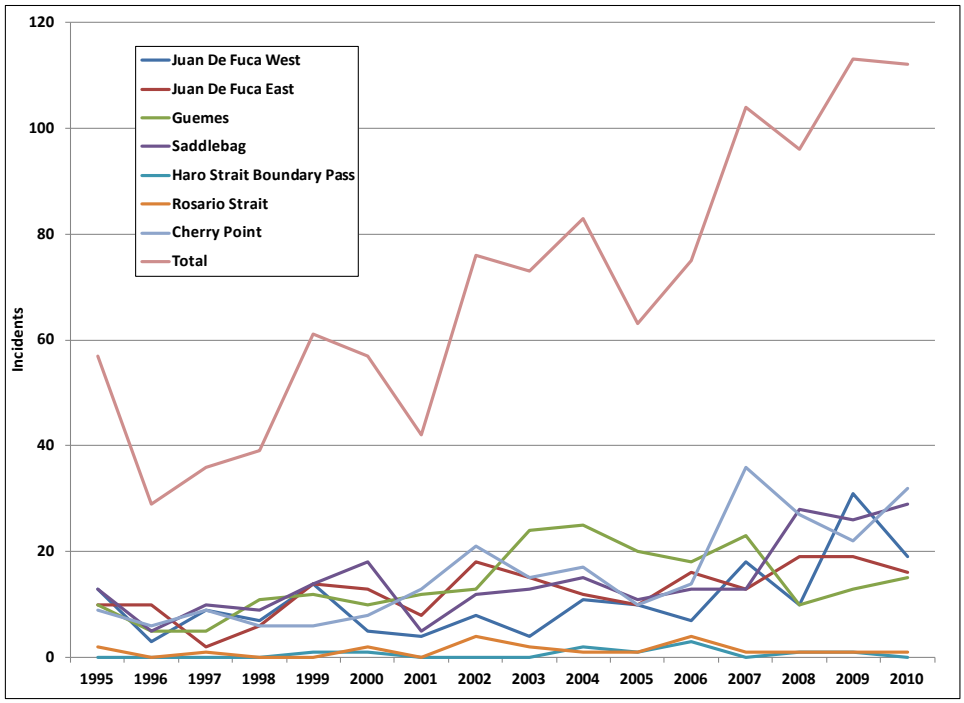

Figure 4: Annual Incidents Involving All Vessels by Geographic Subarea

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**

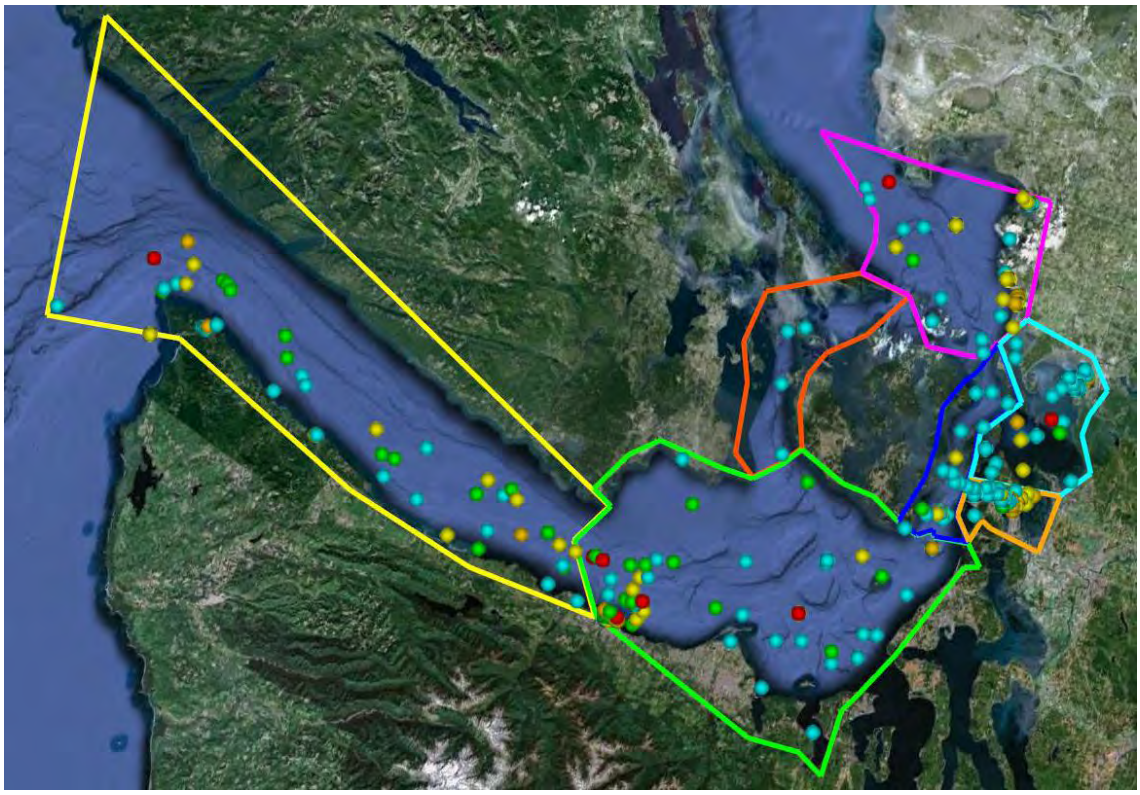

Figure 5: Map of All VTS Vessel Incidents by Subarea

Red represents Bulkers, orange is for tug and tank barges, yellow is for tankers, green is for general cargo vessels, and aqua is for other 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.

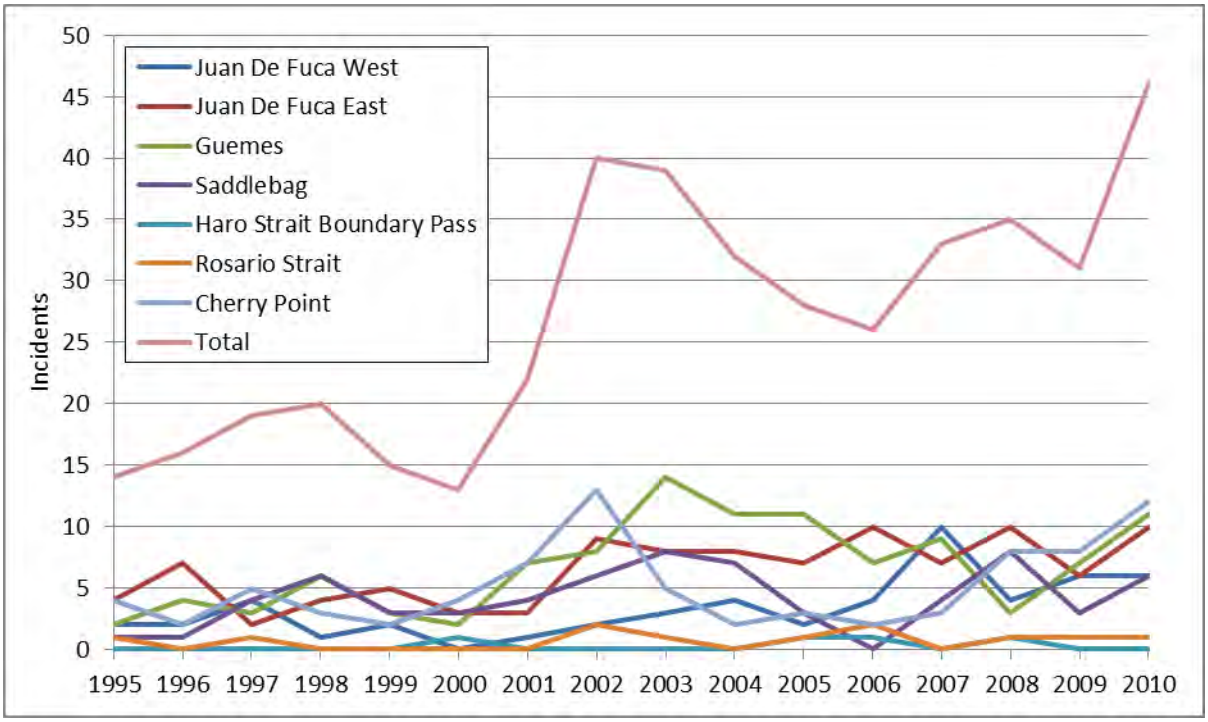

Figure 6: Annual Incidents Involving VTS Vessels by Geographic Subarea

Table 9: Subarea Totals 1995 – 2010 for VTS Vessel Incidents				
Geographic Zone	**Total Incidents**	**% Total**	**Average Incidents/Year**	**Return Years**
Juan De Fuca West	53	12%	3.3	0.30
Juan De Fuca East	103	24%	6.4	0.16
Guemes	108	25%	6.8	0.15
Saddlebag	67	16%	4.2	0.24
Haro Strait Boundary Pass	4	1%	0.3	4.00
Rosario Strait	11	3%	0.7	1.45
Cherry Point	83	19%	5.2	0.19
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**

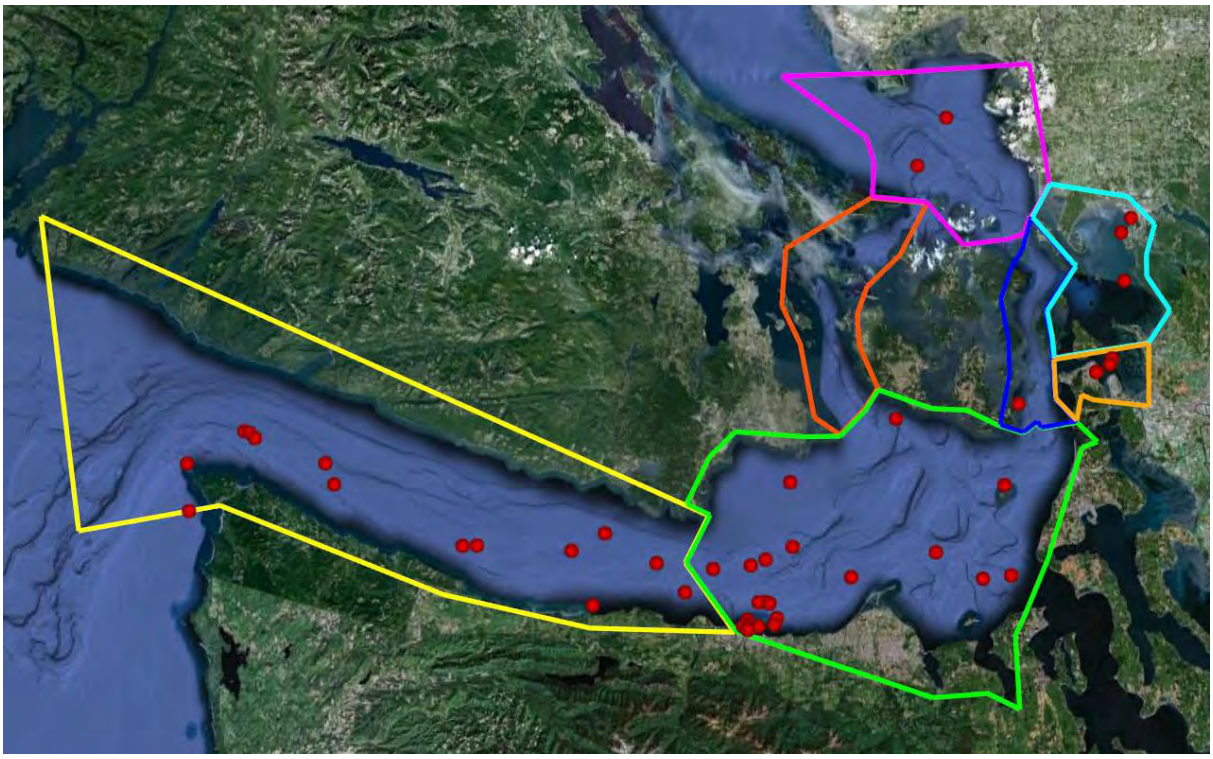

Figure 8: Map of General Cargo Vessel Incidents 1995 – 2010

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**
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**
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**

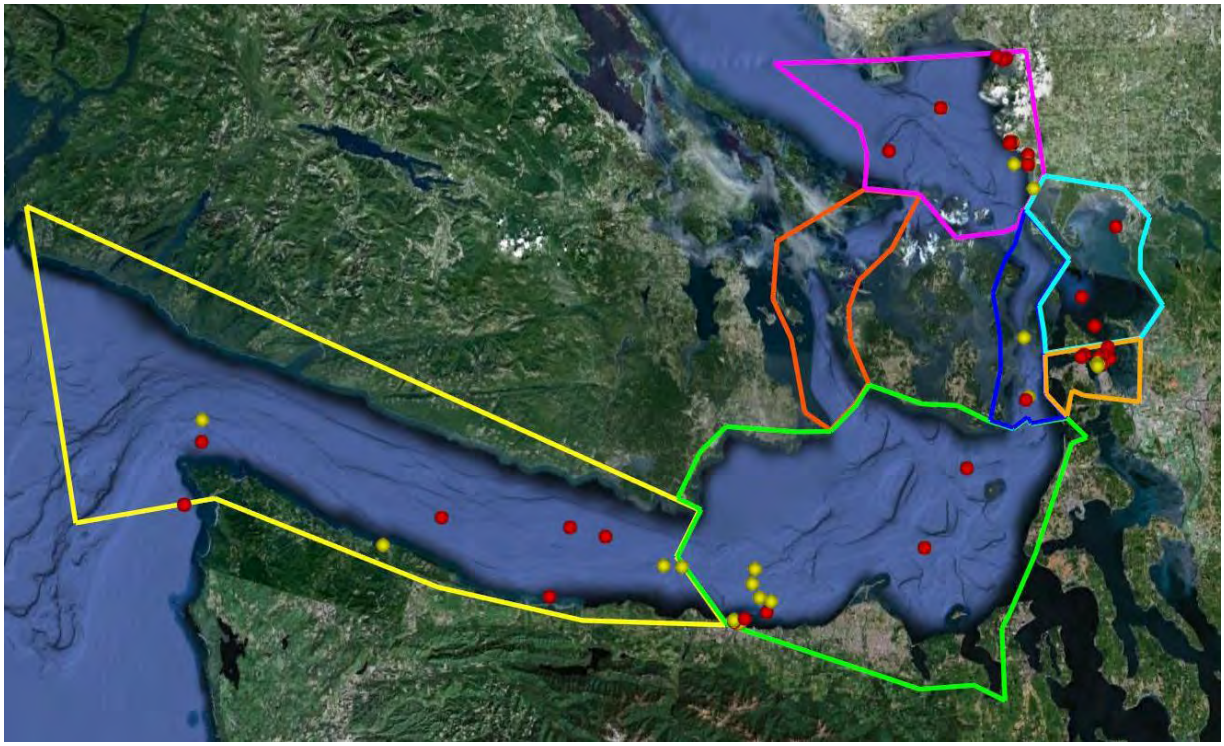

Figure 9: Map of Tanker Incident Locations 1995 – 2010
Red indicates product tankers and yellow indicates crude tankers.

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**
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**

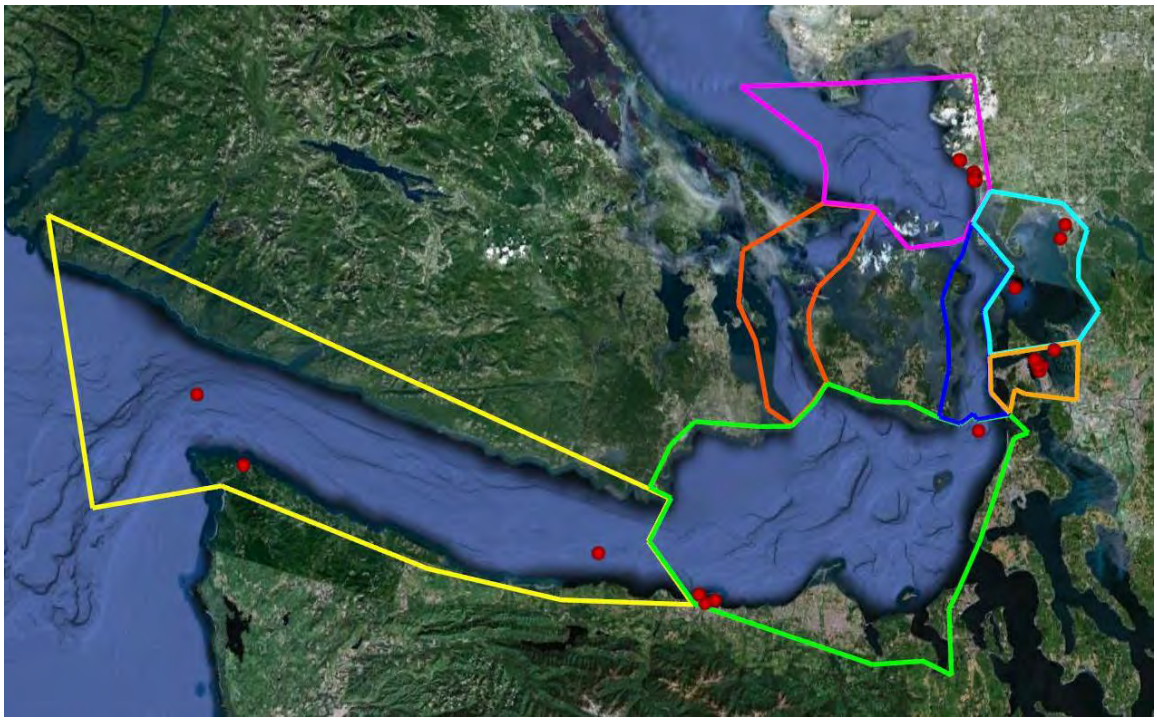

Figure 10: Map of "Tug and Tank Barge" Incident Locations 1995 – 2010

Table 16: Incidents Involving Other 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	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**
Total	**25**	**44**	**69**	**57**	**4**	**10**	**29**	**238**

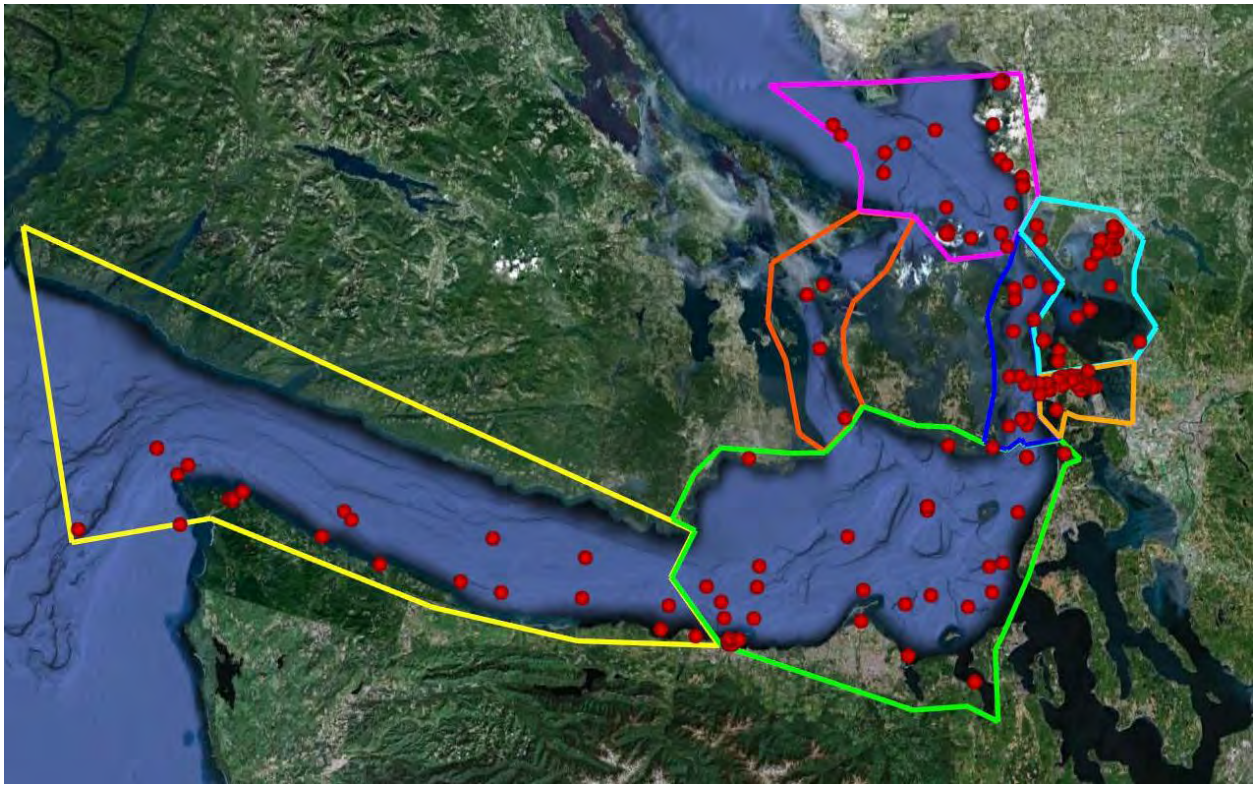

Figure 11: Map of Other Vessel Incident Locations 1995 – 2010

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**
Total	**120**	**98**	**118**	**167**	**6**	**10**	**168**	**687**

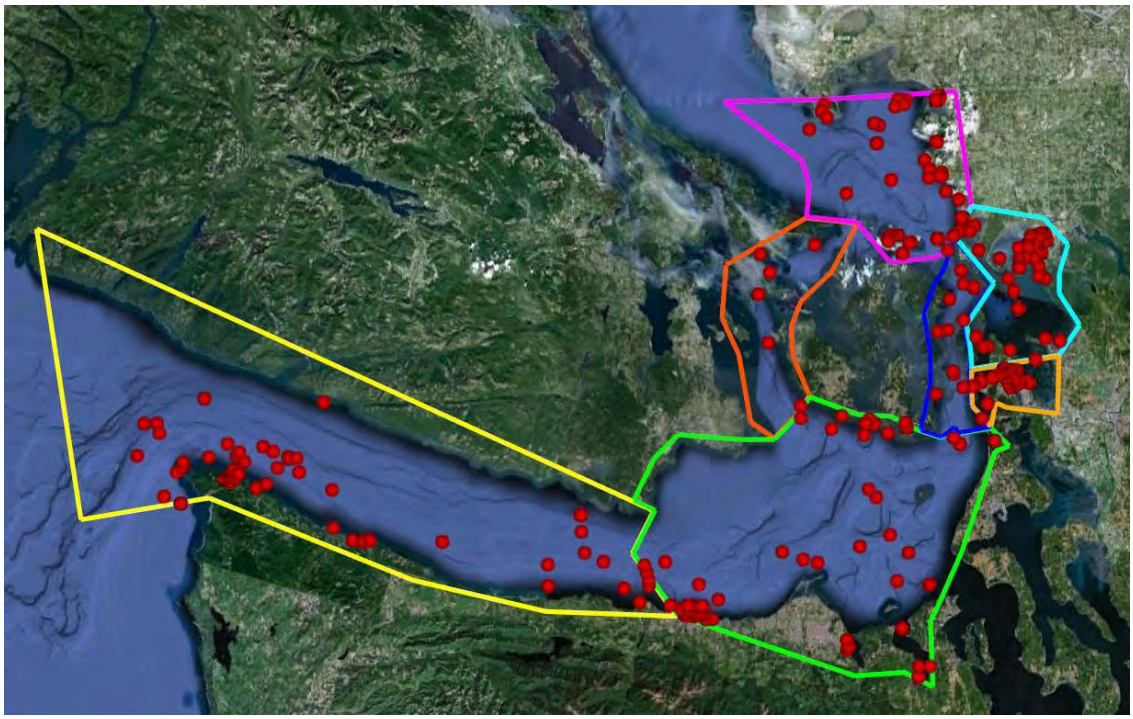

Figure 12: Map of Miscellaneous Vessel Incident Locations 1995 – 2010

Further Analysis for VTS Vessel Incidents Only

Breakdown of VTS Vessel Incidents by Cause and Activity

Table 18 shows a breakdown of VTS vessel incidents by vessel type and incident cause. Table 19 shows the percentages of total incidents involving VTS vessels.

Table 18: VTS Vessel Incidents by Vessel Type and Incident Cause 1995 – 2010

Cause	Bulk	General Cargo	Tanker	Tug and Tank Barge	Other	Total	Avg. Per Year	Return Years
Allision	1	1	2	1	13	**18**	1.13	0.88
Collision	1	0	1	4	1	**7**	0.44	2.27
Grounding	0	0	2	0	13	**15**	0.94	1.06
Other, Non-Impact	11	46	58	19	179	**313**	19.56	0.05
Transfer Error	2	3	27	12	32	**76**	4.75	0.21
Total	**15**	**50**	**90**	**36**	**238**	**429**	**26.81**	0.04

Table 19: VTS Vessel Incidents by Vessel Type and Incident Cause 1995 – 2010 (% All VTS Incidents)						
Cause	**Percentage of All VTS Vessel Incidents**					
	Bulk	**General Cargo**	**Tanker**	**Tug and Tank Barge**	**Other**	**Total**
Allision	0.2%	0.2%	0.5%	0.2%	3.0%	**4.2%**
Collision	0.2%	0.0%	0.2%	0.9%	0.2%	**1.6%**
Grounding	0.0%	0.0%	0.5%	0.0%	3.0%	**3.5%**
Other, Non-Impact	2.6%	10.7%	13.5%	4.4%	41.7%	**73.0%**
Transfer Error	0.5%	0.7%	6.3%	2.8%	7.5%	**17.7%**
Total	**3.5%**	**11.7%**	**21.0%**	**8.4%**	**55.5%**	**100.0%**

The percentages of incidents by cause for each incident cause are shown in Table 20. For example, 5.6% of the allisions of VTS vessels involve bulkers. Table 21 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.

Table 20: VTS Vessel Incidents Vessel Type and by Cause 1995 – 2010 (% VTS Incidents within Cause)						
Cause	**Percentage of Incidents Within Cause**					
	Bulk	**General Cargo**	**Tanker**	**Tug and Tank Barge**	**Other**	**Total**
Allision	5.6%	5.6%	11.1%	5.6%	72.2%	**100.0%**
Collision	14.3%	0.0%	14.3%	57.1%	14.3%	**100.0%**
Grounding	0.0%	0.0%	13.3%	0.0%	86.7%	**100.0%**
Other, Non-Impact	3.5%	14.7%	18.5%	6.1%	57.2%	**100.0%**
Transfer Error	2.6%	3.9%	35.5%	15.8%	42.1%	**100.0%**
Total	**3.5%**	**11.7%**	**21.0%**	**8.4%**	**55.5%**	**100.0%**

Table 21: VTS Vessel Incidents by Vessel Type and Cause 1995 – 2010 (% VTS Incidents within Vessel Type)						
Cause	**Percentage of Incidents Within Vessel Type**					
	Bulk	**General Cargo**	**Tanker**	**Tug and Tank Barge**	**Other**	**Total**
Allision	6.7%	2.0%	2.2%	2.8%	5.5%	**4.2%**
Collision	6.7%	0.0%	1.1%	11.1%	0.4%	**1.6%**
Grounding	0.0%	0.0%	2.2%	0.0%	5.5%	**3.5%**
Other, Non-Impact	73.3%	92.0%	64.4%	52.8%	75.2%	**73.0%**
Transfer Error	13.3%	6.0%	30.0%	33.3%	13.4%	**17.7%**
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 22 and Table 23 show the percentages of incidents that occur with VTS vessels by activity (anchored, docked, underway, or maneuvering).

Table 22: VTS Vessel Incidents by Vessel Type and Activity 1995 – 2010

Activity	Bulk	General Cargo	Tanker	Tug and Tank Barge	Other	Total	Avg. Per Year	Return Years
Anchored	1	3	6	2	5	**17**	1.06	0.94
Docked	6	8	44	23	98	**179**	11.19	0.09
Underway	8	33	31	7	110	**189**	11.81	0.08
Maneuvering	0	6	9	4	25	**44**	2.75	0.36
Total	**15**	**50**	**90**	**36**	**238**	**429**	**26.81**	**0.04**

Table 23: VTS Vessel Incidents by Vessel Type and Activity 1995 – 2010 (% All VTS Incidents)

Activity	Percentage of All VTS Vessel Incidents					
	Bulk	General Cargo	Tanker	Tug and Tank Barge	Other	Total
Anchored	0.2%	0.7%	1.4%	0.5%	1.2%	**4.0%**
Docked	1.4%	1.9%	10.3%	5.4%	22.8%	**41.7%**
Underway	1.9%	7.7%	7.2%	1.6%	25.6%	**44.1%**
Maneuvering	0.0%	1.4%	2.1%	0.9%	5.8%	**10.3%**
Total	**3.5%**	**11.7%**	**21.0%**	**8.4%**	**55.5%**	**100.0%**

The percentages of incidents by activity for each vessel type are shown in Table 24. For example, 4.5% of the incidents while at dock involve general cargo vessels. Table 25 shows the percentages of incidents within each vessel type. For example, nearly 49% of tanker incidents occur while docked.

Table 24: VTS Vessel Incidents by Vessel Type and Activity 1995 – 2010 (% VTS Incidents within Activity)

Activity	Percentage of Incidents within Activity					
	Bulk	General Cargo	Tanker	Tug and Tank Barge	Other	Total
Anchored	5.9%	17.6%	35.3%	11.8%	29.4%	**100.0%**
Docked	3.4%	4.5%	24.6%	12.8%	54.7%	**100.0%**
Underway	4.2%	17.5%	16.4%	3.7%	58.2%	**100.0%**
Maneuvering	0.0%	13.6%	20.5%	9.1%	56.8%	**100.0%**
Total	**3.5%**	**11.7%**	**21.0%**	**8.4%**	**55.5%**	**100.0%**

Table 25: VTS Vessel Incidents by Vessel Type and Activity 1995 – 2010 (% VTS Incidents within Vessel Type)						
Activity	**Percentage of Incidents within Vessel Type**					
	Bulk	**General Cargo**	**Tanker**	**Tug and Tank Barge**	**Other**	**Total**
Anchored	6.7%	6.0%	6.7%	5.6%	2.1%	**4.0%**
Docked	40.0%	16.0%	48.9%	63.9%	41.2%	**41.7%**
Underway	53.3%	66.0%	34.4%	19.4%	46.2%	**44.1%**
Maneuvering	0.0%	12.0%	10.0%	11.1%	10.5%	**10.3%**
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

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 Table 26 through Table 30. The percentages are percentages of all incidents *within that vessel type* that occurred during 1995 – 2010. The averages are average incidents per year.

Table 26 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
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 27 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
Transfer	1	2%	0.06	2	4%	0.13	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 28: 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
Transfer	3	3%	0.19	24	27%	1.50	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 29: 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
Transfer	0	0%	0.00	12	33%	0.75	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 30: VTS Vessel Incidents by Activity and Cause 1995 – 2010 – Other Vessels												
Cause	Activity											
	Anchored			Docked			Underway			Maneuvering		
	Total	%	Avg	Total	%	Avg	Total	%	Avg	Total	%	Avg
Allision	**0**	0%	0.00	0	0%	0.00	2	1%	0.13	11	5%	0.69
Collision	**0**	0%	0.00	0	0%	0.00	1	0%	0.06	0	0%	0.00
Grounding	**0**	0%	0.00	0	0%	0.00	13	5%	0.81	0	0%	0.00
Other	**3**	1%	0.19	68	29%	4.25	94	39%	5.88	14	6%	0.88
Transfer	**2**	1%	0.13	30	13%	1.88	0	0%	0.00	0	0%	0.00
Total	**5**	**2%**	**0.31**	**98**	**41%**	**6.13**	**110**	**46%**	**6.88**	**25**	**11%**	**1.56**

Table 31 summarizes vessel incidents by vessel type, cause, and activity.

Table 31: 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**	**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**	**Transfer**	0.13	7.7
Bulker	**Docked**	**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**	**Transfer**	0.00	n/a
Bulker	**Underway**	**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**	**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**	**Transfer**	0.06	16.7
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**	**Transfer**	0.13	7.7
General Cargo	**Docked**	**Total**	**0.50**	**2.0**

Table 31: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity				
Vessel Type	**Activity**	**Cause**	**Avg. Per Year**	**Return Years**
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**	**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**	**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**	**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**	**Transfer**	1.50	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**	**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**	**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**	**Transfer**	0.00	n/a
Tug and Tank Barge	**Anchored**	**Total**	**0.13**	**7.7**

Table 31: 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**	**Allision**	0.00	n/a
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**	**Transfer**	0.75	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**	**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**	**Transfer**	0.00	n/a
Tug and Tank Barge	**Maneuvering**	**Total**	**0.25**	**4.0**
Other Vessel	**Anchored**	**Allision**	0.00	n/a
Other Vessel	**Anchored**	**Collision**	0.00	n/a
Other Vessel	**Anchored**	**Grounding**	0.00	n/a
Other Vessel	**Anchored**	**Other**	0.19	5.3
Other Vessel	**Anchored**	**Transfer**	0.13	7.7
Other Vessel	**Anchored**	**Total**	**0.31**	**3.2**
Other Vessel	**Docked**	**Allision**	0.00	n/a
Other Vessel	**Docked**	**Collision**	0.00	n/a
Other Vessel	**Docked**	**Grounding**	0.00	n/a
Other Vessel	**Docked**	**Other**	4.25	0.2
Other Vessel	**Docked**	**Transfer**	1.88	0.5
Other Vessel	**Docked**	**Total**	**6.13**	**0.2**
Other Vessel	**Underway**	**Allision**	0.13	7.7
Other Vessel	**Underway**	**Collision**	0.06	16.7
Other Vessel	**Underway**	**Grounding**	0.81	1.2
Other Vessel	**Underway**	**Other**	5.88	0.2
Other Vessel	**Underway**	**Transfer**	0.00	n/a
Other Vessel	**Underway**	**Total**	**6.88**	**0.1**
Other Vessel	**Maneuvering**	**Allision**	0.69	1.4
Other Vessel	**Maneuvering**	**Collision**	0.00	n/a
Other Vessel	**Maneuvering**	**Grounding**	0.00	n/a
Other Vessel	**Maneuvering**	**Other**	0.88	1.1
Other Vessel	**Maneuvering**	**Transfer**	0.00	n/a
Other Vessel	**Maneuvering**	**Total**	**1.56**	**0.6**

Table 31: Summary of VTS Vessel Incidents by Vessel Type, Cause, and Activity				
Vessel Type	**Activity**	**Cause**	**Avg. Per Year**	**Return Years**
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**	**Transfer**	0.38	2.6
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**	**Transfer**	4.39	0.2
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**	**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**	**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 32. Percentages of VTS vessel incidents by subarea are shown in Table 33. Annual incident rates are shown in Table 34.

Table 32: 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
Transfer	1	8	23	17	0	0	27	76
Total	**53**	**103**	**108**	**67**	**4**	**11**	**83**	**429**

Table 33: 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%
Transfer	0.2%	1.9%	5.4%	4.0%	0.0%	0.0%	6.3%	17.7%
Total	**12.4%**	**24.0%**	**25.2%**	**15.6%**	**0.9%**	**2.6%**	**19.3%**	**100.0%**

Table 34: 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
Transfer	0.06	0.50	1.44	1.06	0.00	0.00	1.69	4.75
Total	**3.31**	**6.44**	**6.75**	**4.19**	**0.25**	**0.69**	**5.19**	**26.81**

Figure 13 through Figure 17 show the locations of incidents within the subareas by incident cause for VTS vessel incidents.

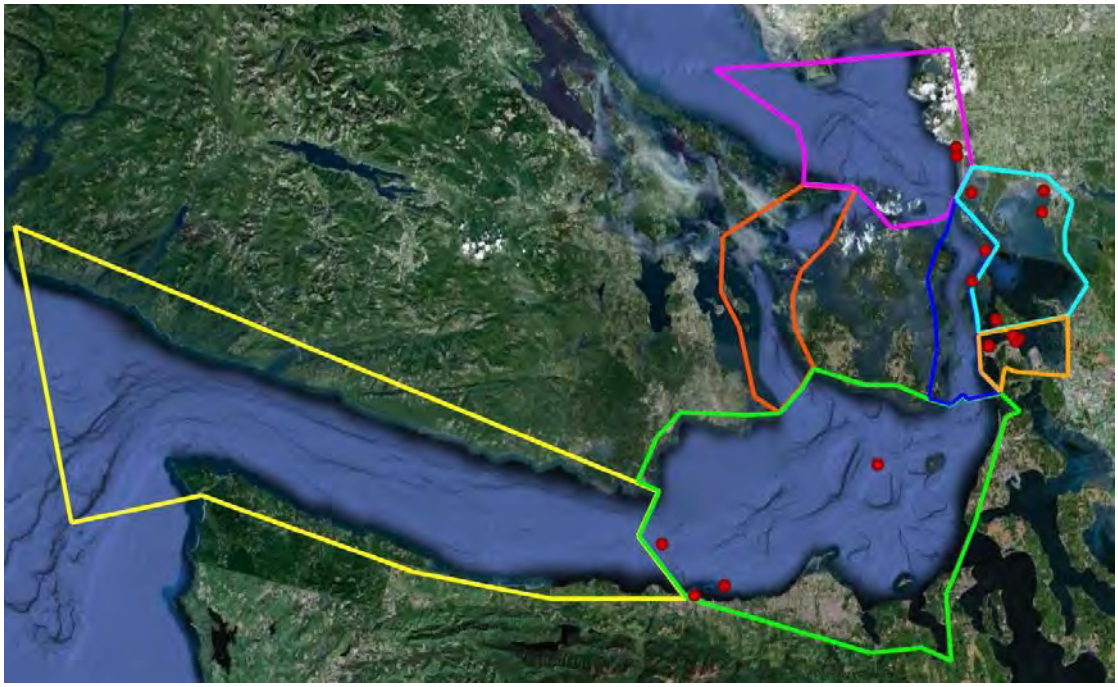

Figure 13: Map of Locations of Allisions for VTS Vessels 1995 – 2010

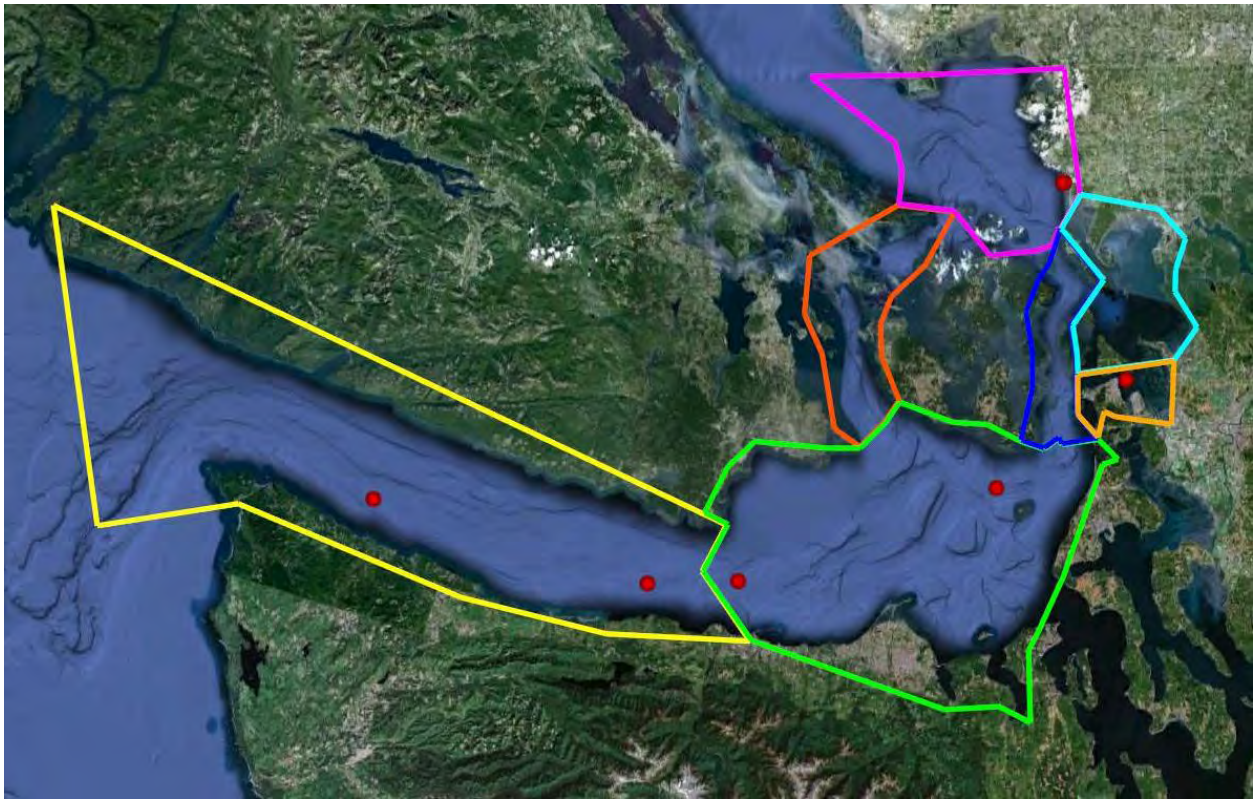

Figure 14: Map of Locations of Collisions for VTS Vessels 1995 – 2010

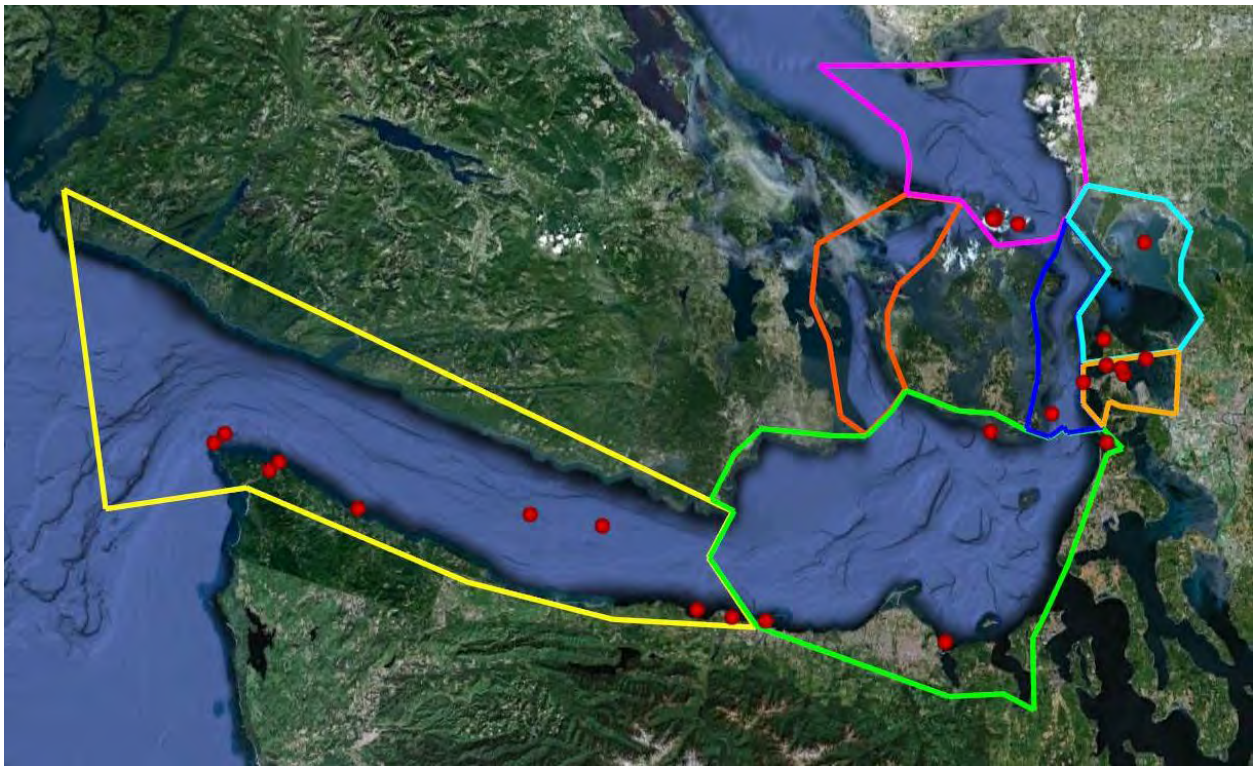

Figure 15: Map of Locations of Groundings for VTS Vessels 1995 – 2010

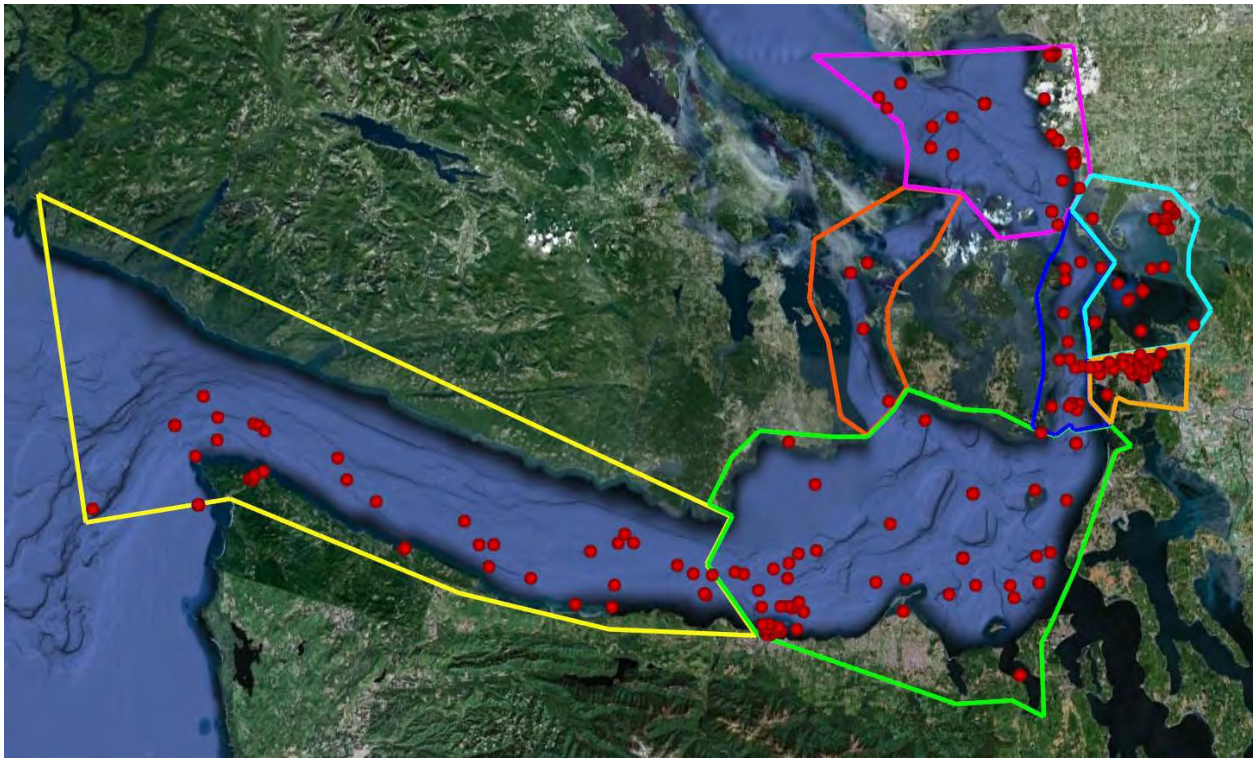

Figure 16: Map of Locations of Other, Non-Impact Incidents for VTS Vessels 1995 – 2010

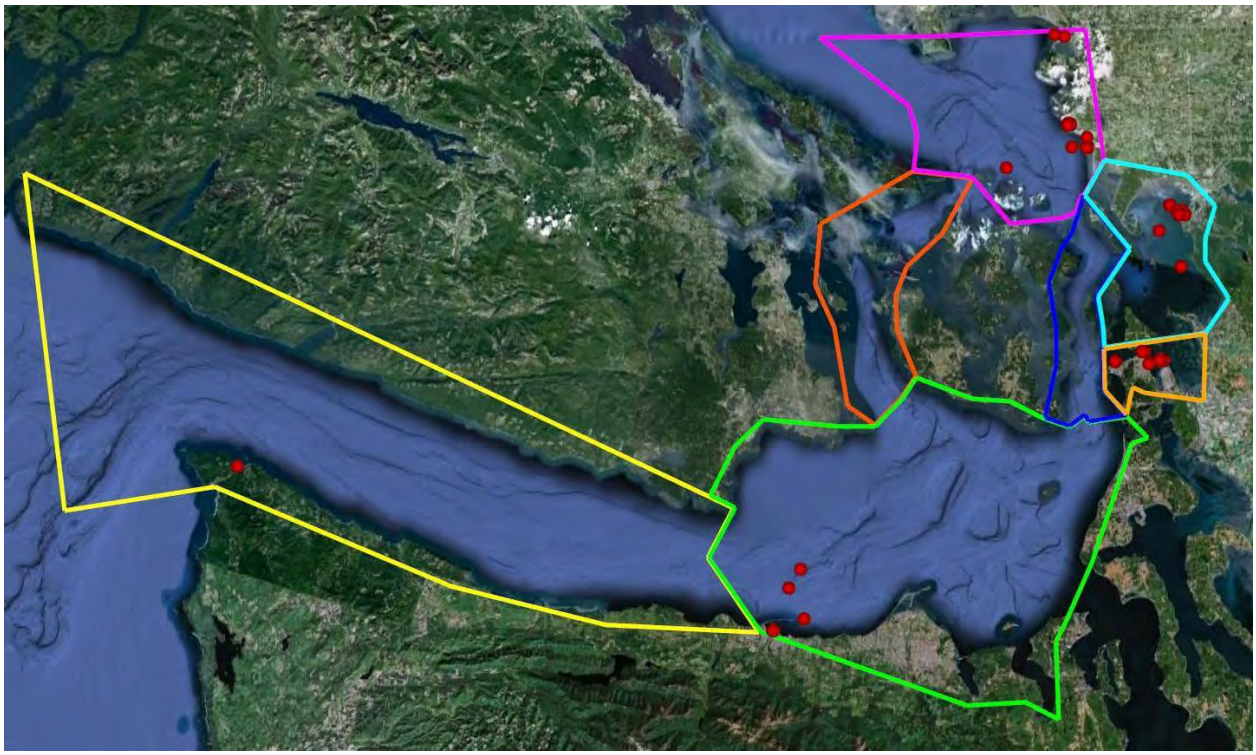

Figure 17: Map of Locations of Transfer Errors for VTS Vessels 1995 – 2010

Figure 18 through Figure 22 show locations of VTS vessel incidents by vessel type and cause.

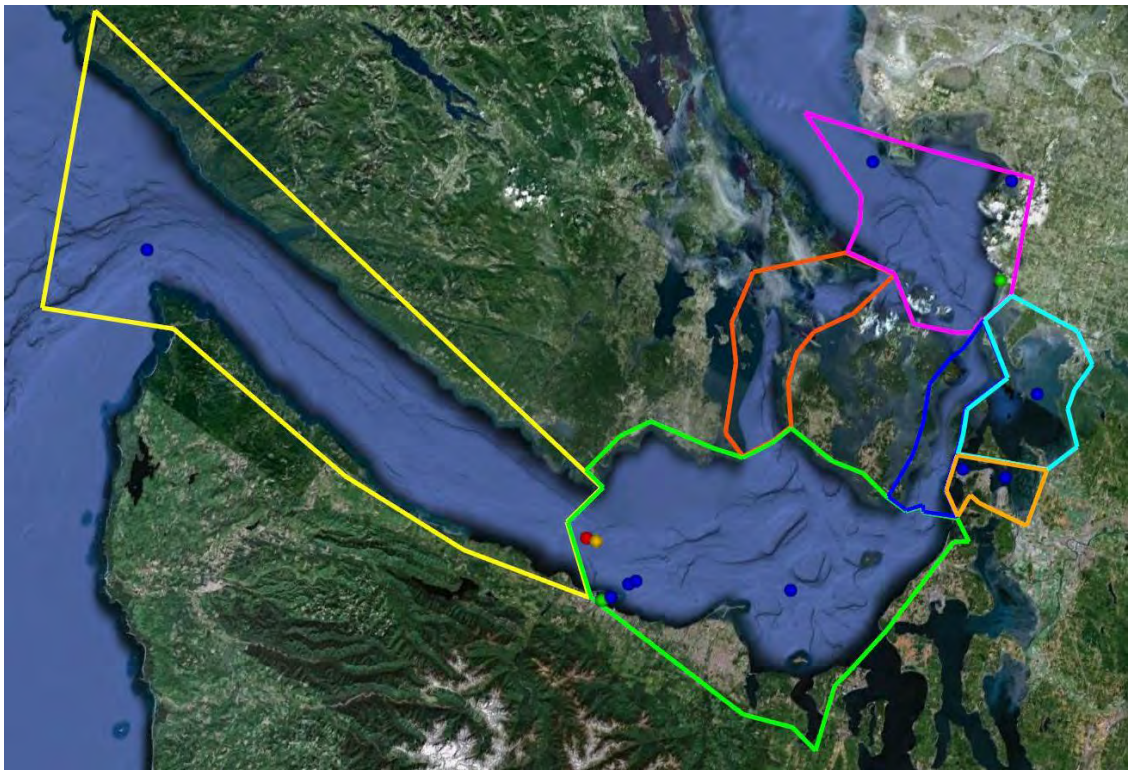

Figure 18: Map of Bulker Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Allisions are in red; collisions in orange; groundings in yellow; transfer errors in green; and other, non-impact incidents in blue.

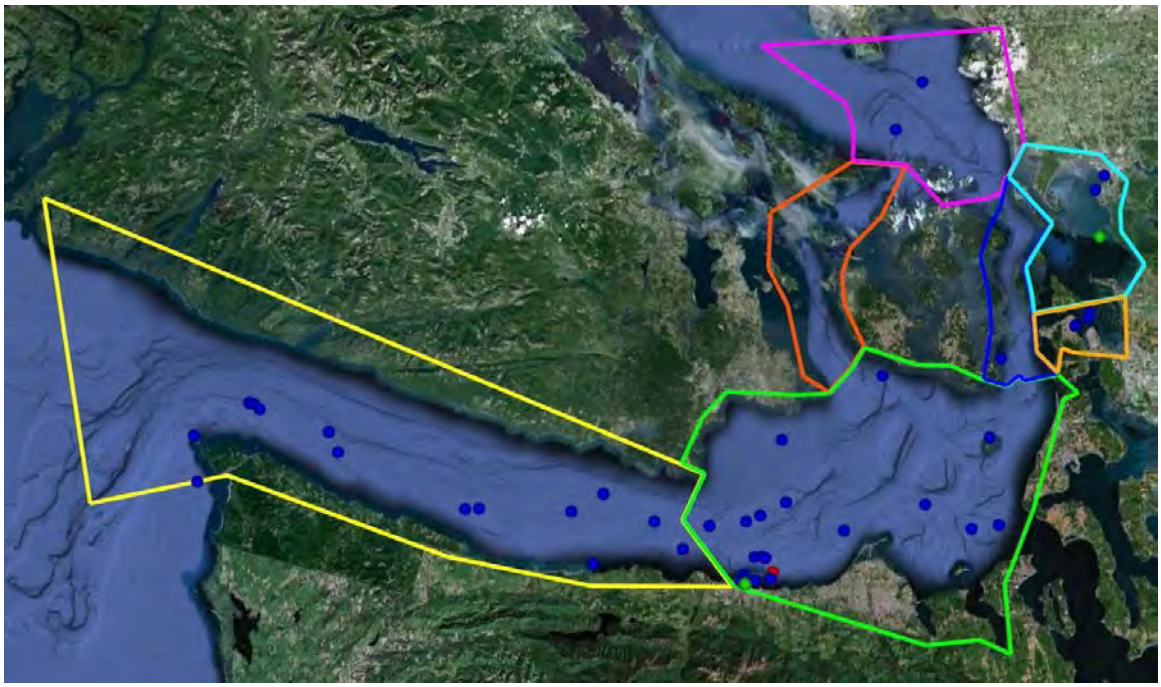

Figure 19: Map of General Cargo Vessel Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Allisions are in red; collisions in orange; groundings in yellow; transfer errors in green; and other, non-impact incidents in blue.

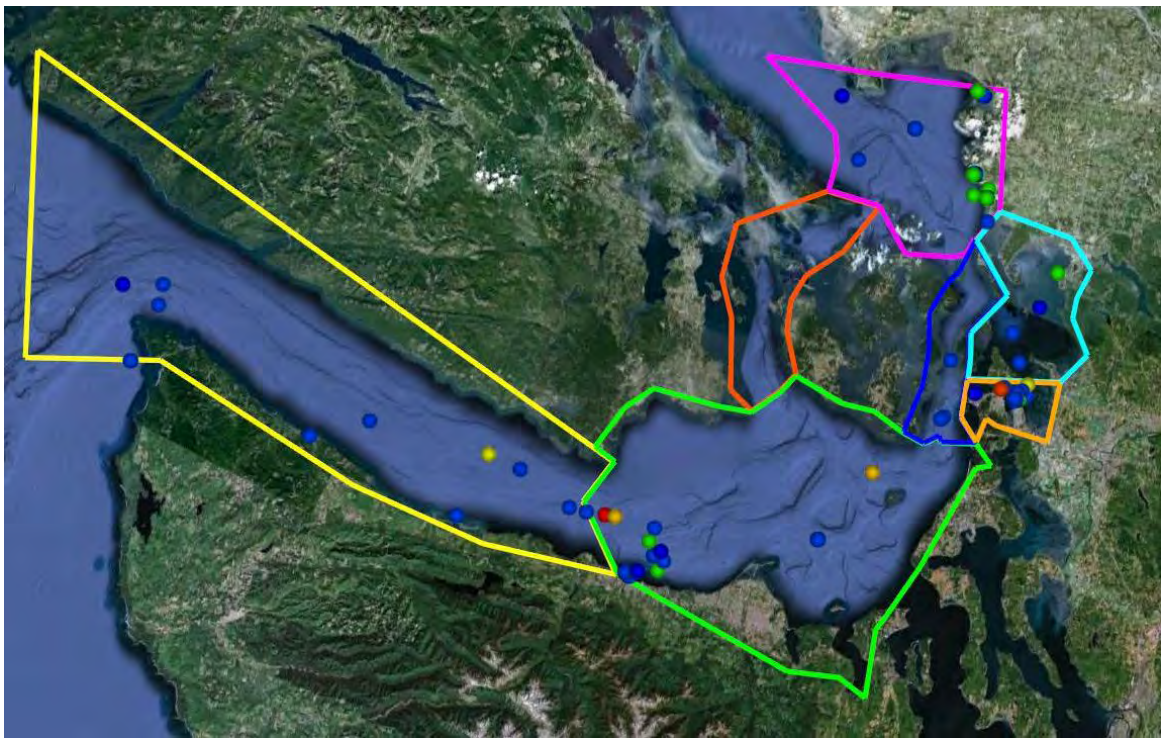

Figure 20: Map of Tanker Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Allisions are in red; collisions in orange; groundings in yellow; transfer errors in green; and other, non-impact incidents in blue.

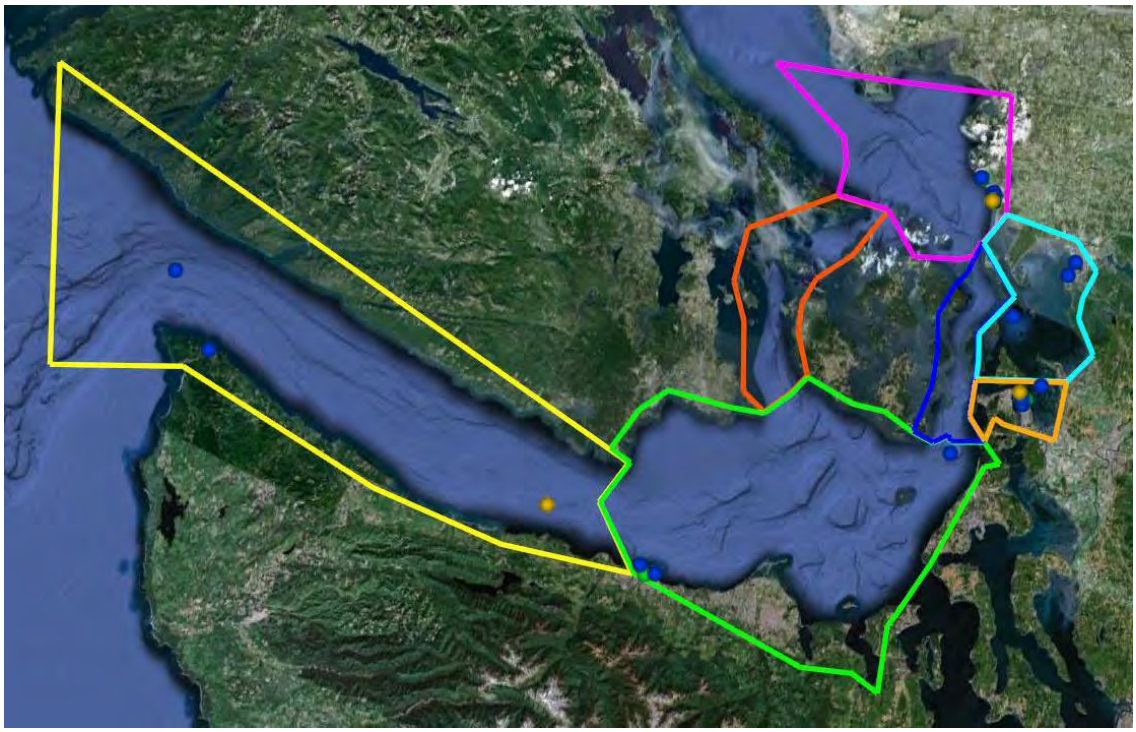

Figure 21: Map of Tug and Tank Barge Incidents 1995 – 2010 by Cause

Dots on map represent locations of incidents. Allisions are in red; collisions in orange; groundings in yellow; transfer errors in green; and other, non-impact incidents in blue.

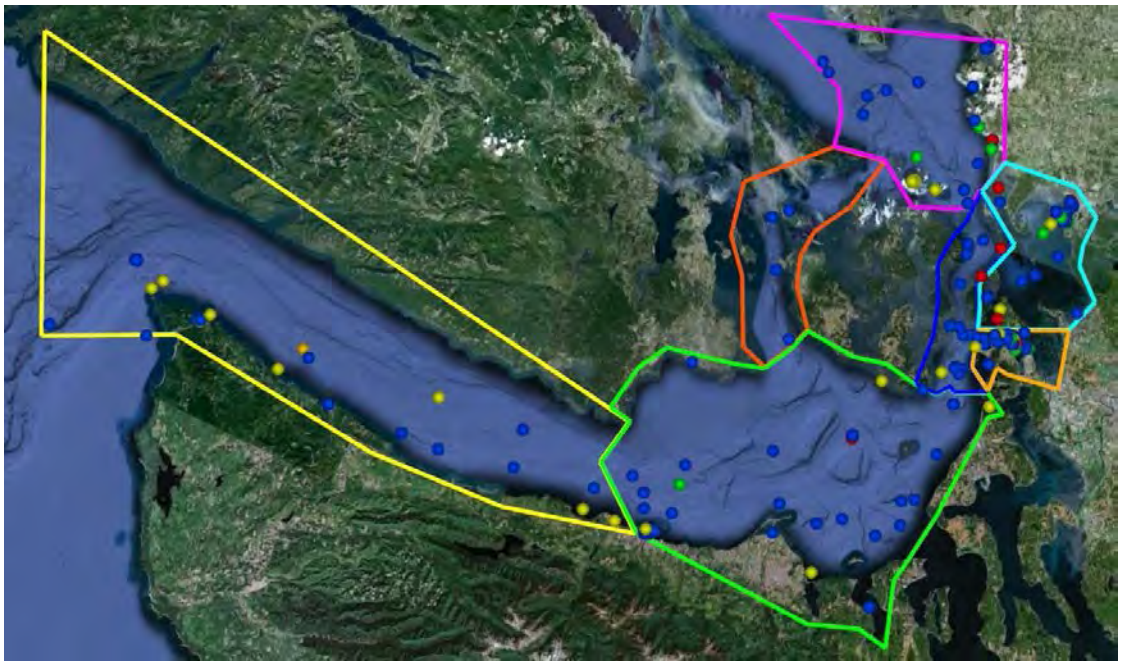

Figure 22: Map of Other Vessel Incident 1995 – 2010 by Cause

Dots on map represent locations of incidents. Allisions are in red; collisions in orange; groundings in yellow; transfer errors in green; and other, non-impact incidents in blue.

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 35. 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 35: 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
	Transfer Error	1	1	**2**	0.50
	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
	Transfer Error	3	0	**3**	1.00
	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
	Transfer Error	10	2	**12**	0.83
	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
	Transfer Error	25	2	**27**	0.93
	All	42	48	**90**	0.47

Table 35: 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 Vessels	**Allision**	0	13	**13**	0.00
	Collision	0	1	**1**	0.00
	Grounding	6	7	**13**	0.46
	Other, Non-Impact	72	107	**179**	0.40
	Transfer Error	25	7	**32**	0.78
	All	103	135	**238**	0.43
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
	Transfer Error	64	12	**76**	0.84
	All	189	240	**429**	0.44

Appendix D Characterization of Bunkering and Cargo Transfer Incidents

Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study

Characterization of Bunkering and Cargo Transfer Incidents

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Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study Characterization of Bunkering and Cargo Transfer Incidents

Purpose

This report provides data and analyses on transfer-related incidents that occur during bunkering operations and oil cargo transfer operations, including those incidents that provide the potential for spillage and those that involve actual spillage. Information on the nature and rates of bunkering incidents and their geographic locations will assist in determining the potential additional impacts of bunkering activities with the presence of the Gateway Pacific Terminal (GPT). The Statement of Work also includes a forecast the potential size and geographic impact of a crude oil cargo, refined product cargo, or vessel bunker fuel release from a bunkering or cargo transfer accident.

Executive Summary

Incidents that occur as a result of errors during bunkering operations and oil cargo transfer operations were analyzed with respect to the following criteria:

- Historical incidents in the GPT study area during 1995 – 2010;
- Incident occurrence by GPT subarea;
- Incident occurrence by activity (at-anchor or at-dock);
- Annual number of incidents;
- Spillage probability per incident; and
- Spill volume probability distributions.

The following are the key findings:

- Bunkering transfer errors occur at a rate of about 2.38 incidents per year, or about one incident every five months in the GPT study area;
- The greatest number of bunkering incidents involve other vessels[1] and occur while docked;
- The greatest percentage of incidents occurs in Saddlebag, followed by Guemes;
- The probability of spillage in the event of a bunkering error is 0.92 with no difference by hull type (double or single); and
- Spill volumes for bunkering errors are typically small, with 90% of incidents involving 200 gallons or less, and 95% of incidents involving 500 gallons or less.

Potential environmental impacts from bunkering or cargo spills are not included. Note that the spillage probability with transfers of bunkers and oil cargo are identical because the incident rates rely on the same base data on spillage during transfers. The data from the

[1] "Other Vessels" includes fishing vessels over 60 feet, cruise ships, and regularly-scheduled ferries regardless of size, and all tugs regardless of size.

analyses of previous international historic data do not distinguish between the transfers of bunkers and the transfers of oil cargo. The transfer operations in those data are merely characterized as "oil transfers."

Historical Data Analysis[2]

Vessel incident data for the GPT VTRAS 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. Complete analyses of these data are presented in a separate report. Only the incidents specifically related to transfer errors are discussed in this report.

The annual number of bunkering incidents averaged 2.4, or one incident every five months. The 76 incidents are listed in Table 3. The annual number of transfer error incidents was 2.4, or 38 over 16 years.

Table 1: VTS Vessel Incidents by Vessel Type for Bunkering Errors and Cargo Transfer Errors (1995 – 2010)

Bulk	General Cargo	Tanker	Tank Barge	Other	Total	Avg. Annual	Return Years
2	3	27	12	32	**76**	4.75	0.21

Table 2: Bunkering Error and Cargo Transfer Error Incidents in GPT Study Area (1995 – 2010)

Year	Bunkering Errors	% Total	Cargo Transfer Errors	% Total	Total Transfer Error Incidents
1995	2	2.6%	2	2.6%	**4**
1996	1	1.3%	3	3.9%	**4**
1997	3	3.9%	1	1.3%	**4**
1998	6	7.9%	1	1.3%	**7**
1999	2	2.6%	3	3.9%	**5**
2000	3	3.9%	2	2.6%	**5**
2001	2	2.6%	6	7.9%	**8**
2002	2	2.6%	9	11.8%	**11**
2003	1	1.3%	1	1.3%	**2**
2004	2	2.6%	1	1.3%	**3**
2005	2	2.6%	1	1.3%	**3**
2006	0	0.0%	2	2.6%	**2**
2007	3	3.9%	1	1.3%	**4**
2008	3	3.9%	2	2.6%	**5**
2009	2	2.6%	2	2.6%	**4**
2010	4	5.3%	1	1.3%	**5**
Total	**38**	**50.0%**	**38**	**50.0%**	**76**

[2] Based on Etkin 2013b.

Table 3: Table of Historical Bunkering Error and Cargo Transfer Errors (1995-2010)					
Year	**Location**	**Error Type**	**Anchored or Docked?**	**Spillage**	**Vessel Type Detail**
1995	Cherry Point	Cargo	Docked	Yes	Tank Ship
1995	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
1995	Juan de Fuca East	Bunker	Docked	Yes	Fishing Vessel-Trawler
1995	Juan de Fuca East	Bunker	Docked	Yes	Cargo Vessel-Bulk Carrier
1996	Guemes	Cargo	Docked	Yes	Tank Ship
1996	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
1996	Guemes	Cargo	Docked	Yes	Tank Barge
1996	Guemes	Bunker	Docked	Yes	Fishing Vessel-Trawler
1997	Guemes	Bunker	Docked	Yes	Towboat/Tugboat
1997	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
1997	Juan de Fuca East	Bunker	Docked	Yes	Cargo Vessel-General
1997	Cherry Point	Cargo	Docked	Yes	Tank Barge
1998	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
1998	Saddlebag	Bunker	Docked	Yes	Tank Ship-Product
1998	Guemes	Bunker	Docked	Yes	Towboat/Tugboat
1998	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
1998	Saddlebag	Bunker	Anchored	Yes	Cargo Vessel-General
1998	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
1998	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
1999	Saddlebag	Bunker	Anchored	Yes	Towboat/Tugboat
1999	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
1999	Guemes	Cargo	Docked	Yes	Tank Ship
1999	Cherry Point	Cargo	Docked	Yes	Tank Ship-ATB
1999	Cherry Point	Cargo	Docked	Yes	Tank Ship-Crude
2000	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
2000	Cherry Point	Cargo	Anchored	Yes	Tank Ship-Crude
2000	Saddlebag	Bunker	Docked	Yes	Fishing Vessel-Trawler
2000	Guemes	Bunker	Docked	Yes	Fishing Vessel-Trawler
2000	Guemes	Bunker	Docked	Yes	Towboat/Tugboat
2001	Guemes	Bunker	Docked	Yes	Fishing Vessel
2001	Cherry Point	Bunker	Anchored	Yes	Towboat/Tugboat
2001	Guemes	Cargo	Docked	Yes	Tank Ship-Crude
2001	Guemes	Cargo	Docked	Yes	Tank Ship-Product
2001	Guemes	Cargo	Docked	Yes	Tank Ship
2001	Cherry Point	Cargo	Docked	Yes	Tank Ship-ITB
2001	Cherry Point	Cargo	Docked	Yes	Tank Ship-Crude
2001	Guemes	Cargo	Docked	No	Tank Barge
2002	Cherry Point	Cargo	Docked	Yes	Tank Ship-ITB
2002	Cherry Point	Cargo	Docked	Yes	Tank Barge

Table 3: Table of Historical Bunkering Error and Cargo Transfer Errors (1995-2010)					
Year	**Location**	**Error Type**	**Anchored or Docked?**	**Spillage**	**Vessel Type Detail**
2002	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
2002	Cherry Point	Cargo	Docked	Yes	Tank Ship
2002	Cherry Point	Cargo	Docked	Yes	Tank Ship-ATB
2002	Juan de Fuca East	Cargo	Anchored	Yes	Tank Ship-Product
2002	Guemes	Cargo	Docked	Yes	Tank Barge
2002	Cherry Point	Cargo	Docked	Yes	Tank Barge
2002	Juan de Fuca East	Cargo	Docked	Yes	Tank Ship-Crude
2002	Juan de Fuca West	Bunker	Docked	No	Towboat/Tugboat
2002	Cherry Point	Bunker	Docked	No	Cargo Vessel-Bulk Carrier
2003	Guemes	Bunker	Docked	Yes	Towboat/Tugboat
2003	Cherry Point	Cargo	Docked	Yes	Tank Ship-Crude
2004	Saddlebag	Bunker	Docked	Yes	Fishing Vessel-Trawler
2004	Guemes	Cargo	Docked	Yes	Tank Barge
2004	Saddlebag	Bunker	Docked	Yes	Fishing Vessel
2005	Guemes	Bunker	Docked	Yes	Passenger Vessel
2005	Cherry Point	Bunker	Docked	Yes	Tank Barge
2005	Guemes	Bunker	Docked	No	Fishing Vessel
2006	Guemes	Bunker	Docked	Yes	Tank Barge
2006	Guemes	Cargo	Docked	Yes	Tank Ship
2007	Saddlebag	Bunker	Docked	Yes	Fishing Vessel-Trawler
2007	Cherry Point	Bunker	Docked	Yes	Towboat/Tugboat
2007	Guemes	Cargo	Docked	Yes	Tank Barge
2007	Guemes	Bunker	Docked	Yes	Fishing Vessel-Factory
2008	Cherry Point	Bunker	Docked	Yes	Towboat/Tugboat
2008	Saddlebag	Bunker	Docked	Yes	Towboat/Tugboat
2008	Cherry Point	Cargo	Docked	No	Tank Barge
2008	Saddlebag	Bunker	Docked	No	Passenger Vessel
2008	Juan de Fuca East	Cargo	Anchored	No	Tank Ship
2009	Juan de Fuca East	Bunker	Docked	Yes	Tank Barge
2009	Juan de Fuca East	Bunker	Docked	Yes	Cargo Vessel-Container
2009	Cherry Point	Cargo	Docked	No	Tank Ship-Crude
2009	Saddlebag	Bunker	Docked	No	Towboat/Tugboat
2010	Saddlebag	Bunker	Docked	Yes	Fishing Vessel-Trawler
2010	Cherry Point	Cargo	Docked	Yes	Tank Ship-Product
2010	Cherry Point	Bunker	Docked	No	Towboat/Tugboat
2010	Guemes	Bunker	Docked	No	Fishing Vessel
2010	Saddlebag	Bunker	Docked	No	Passenger Vessel-Ferry

Errors in Bulk Carrier Transfer Operations

Likewise, there are two types of transfer operations in bulk carriers – bunker fuel transfers (bunkering) and dry bulk cargo transfers. These are independent events with different probabilities and outcomes. The two types of incidents are addressed separately in this report. No incidents of dry cargo spillage from a bulk carrier were recorded in the GPT study area during 1995 – 2010.[3]

Bunkering Error Incidents

The historical incident rate and geographic location of transfer errors occurring during bunkering operations (bunkering errors) were analyzed.

Historical Analysis of Incident Number and Rate

Based on the historical analyses, the key findings related to bunkering incidents are shown in Table 4. Overall, there were 38 incidents, of which 84% were from other vessels. There was an average of 2.4 incidents annually or approximately one incident every 5 months. For bulk carriers, the incident rate was 0.13 per year, or one incident every 8 years.

Table 4: VTS Vessel Incidents Involving Bunkering Errors 1995 – 2010

Vessel Type	Number of Incidents	% Total Bunkering Incidents	Average Incidents Per Year	Average Incidents Per Day	Return Years
Tanker	1	3%	0.06	0.00016	16.0
Bulk	2	5%	0.13	0.00036	8.0
General Cargo	3	8%	0.19	0.00052	5.3
Other	32	84%	2.00	0.00548	0.5
Total	**38**	**100%**	**2.38**	**0.00652**	**0.4**

Bunkering Incidents at Dock vs. at Anchor

Bunkering can occur while docked or while anchored (if from another vessel). Vessel incidents were further broken down by cause and activity for each vessel type within the VTS vessels, as shown in Table 5. The vast majority, 92%, of incidents occur while docked rather than anchored. One incident occurs while docked every six months. One incident occurs while anchored every 5.3 years.

Note that according to the GPT permit application, GPT bulkers will not be bunkering at the GPT dock itself.

[3] Dry cargo spillage is addressed separately in an appendix of this report as well as in Etkin 2013a.

Table 5: VTS Vessel Incidents Involving Bunkering Errors 1995 – 2010 (Docked vs. Anchored)											
Vessel Type	Total	Docked					Anchored				
		No.	% Total	Avg. Annual	Per Day	Return Years	Number	% Total	Avg. Annual	Per Day	Return Years
Tanker	1	1	100%	0.06	0.00016	16.7	0	0%	0.00	0.00000	n/a
Bulk	2	2	100%	0.13	0.00036	7.7	0	0%	0.00	0.00000	n/a
Gen. Cargo	3	2	67%	0.13	0.00036	7.7	1	33%	0.06	0.00016	16.0
Other	32	30	94%	1.88	0.00515	0.5	2	6%	0.13	0.00036	8.0
Total	**38**	**35**	**92%**	**2.19**	**0.00600**	**0.5**	**3**	**8%**	**0.19**	**0.00052**	**5.3**

Geographic Locations of Bunkering Error Incidents

The locations of VTS vessel bunkering incidents that occurred during 1995 – 2010 are in Table 6.

Table 6: Bunkering Incidents Involving VTS Vessels by Subarea 1995 – 2010								
Vessel Type	Juan De Fuca West	Juan De Fuca East	Guemes	Saddlebag	Haro Strait	Rosario Strait	Cherry Point	Total
Tanker	0	0	0	1	0	0	0	**1**
Bulk	0	1	0	0	0	0	1	**2**
Gen Cargo	0	2	0	1	0	0	0	**3**
Other	1	1	11	15	0	0	4	**32**
Total	**1**	**4**	**11**	**17**	**0**	**0**	**5**	**38**

A map of the locations of the bunkering incidents is shown in Figure 1 for all vessel types and in Figure 2 for bulk carriers.

Figure 1: Locations of Bunkering Incidents 1995 – 2010

Red = other vessels; teal = bulk carriers; green = tanker; yellow = general cargo
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* several cases.

Figure 2: Locations of Bulk Carrier Bunkering Incidents 1995 – 2010
Location A = Port Angeles; Location B = Cherry Point

Probability of Spillage with Bunkering Errors

When a bunkering error occurs, there is the potential for spillage but a spill does not necessarily occur. The probabilities of bunker spillage by vessel type, cause, and hull type are shown in Table 7. Note that for tankers, there is a separate probability for bunker spillage and oil cargo spillage. Note that there is no difference between hull types with regard to bunkering spills. There is also no difference between vessel types. For all vessel types and hulls, the probability of spillage is estimated at 0.92. The reason that the probability is so high is most likely attributable to the fact that the "error" is generally discovered when a spill, however small, does occur, with a few exceptions. The practices used in bunkering are similar in the different vessel types with spillage generally coming from hoses rather than from the vessel itself. The probabilities in Table 12 are based on studies conducted on US oil spills.[4]

Note that the spillage probability with transfers of bunkers and oil cargo are identical because the incident rates rely on the same base data on spillage during transfers. The data from the analyses of previous international historic data do not distinguish between the transfers of bunkers and the transfers or oil cargo. The transfer operations are merely characterized as "oil transfers."

Table 7: Bunker Spill Probabilities for All GPT VTS Vessels[5]

Vessel Type	Incident Cause	Hull	Bunker Spill Probability
Tankers ***(V_t)***	**Bunkering Error**	**Single** ***(BH_s)***	0.92
		Double ***(BH_d)***	0.92
Bulk Carriers ***(V_b)***	**Bunkering Error**	**Single** ***(BH_s)***	0.92
		Double ***(BH_d)***	0.92
General Cargo Vessels ***(V_g)***	**Bunkering Error**	**Single** ***(BH_s)***	0.92
		Double ***(BH_d)***	0.92
Other Vessels ***(V_o)***	**Bunkering Error**	**Single** ***(BH_s)***	0.92
		Double ***(BH_d)***	0.92

[4] Etkin and Michel, 2003; Herbert Engineering and Designers & Planners, Inc., 2003.
[5] Based on Etkin and Michel, 2003; Michel and Winslow, 1999; Michel and Winslow, 2000.

Typical Spill Volumes for Transfer-Related Incidents

Bunker oil and cargo oil outflow is generally independent of vessel tonnage for the GPT VTS vessels being analyzed in this study. This is because the oil outflow generally comes through a hose and not from a breach of the cargo or bunker tank. The transfer operation is usually halted as soon as possible after the leak is discovered and the amount of actual spillage is related to the pumping rate, the time until leak discovery, and the time it takes to turn off the pumps/equipment.

Generally, spills due to transfer errors are smaller than the spills that occur with impact accidents (collisions, allisions, and groundings). The data shown in Table 8 are the spill volumes associated with a large number of transfer-related spills reported in US waters. (These data include transfers of cargo.) While the maximum observed transfer-related spillage is 500,000 gallons, the maximum for a particular vessel's bunker spillage when the vessel contains less than 500,000 gallons in bunker fuel would naturally be the bunker capacity of the vessel. Sixty percent of spills are 10 gallons or less. Ninety percent of spills are 200 gallons or less (Table 8 and Figure 3).

Table 8: Spill Volumes for Transfer-Related Incidents[6]

Spill Volume	Probability	Cumulative Probability
1 gallon	0.2500	0.2500
5 gallons	0.2000	0.4500
10 gallons	0.1500	0.6000
20 gallons	0.1200	0.7200
50 gallons	0.1000	0.8200
200 gallons	0.0800	0.9000
500 gallons	0.0500	0.9500
2,000 gallons	0.0400	0.9900
10,000 gallons	0.0090	0.9990
100,000 gallons	0.0009	0.9999
500,000 gallons	0.0001	1.0000

[6] Etkin, 2006.

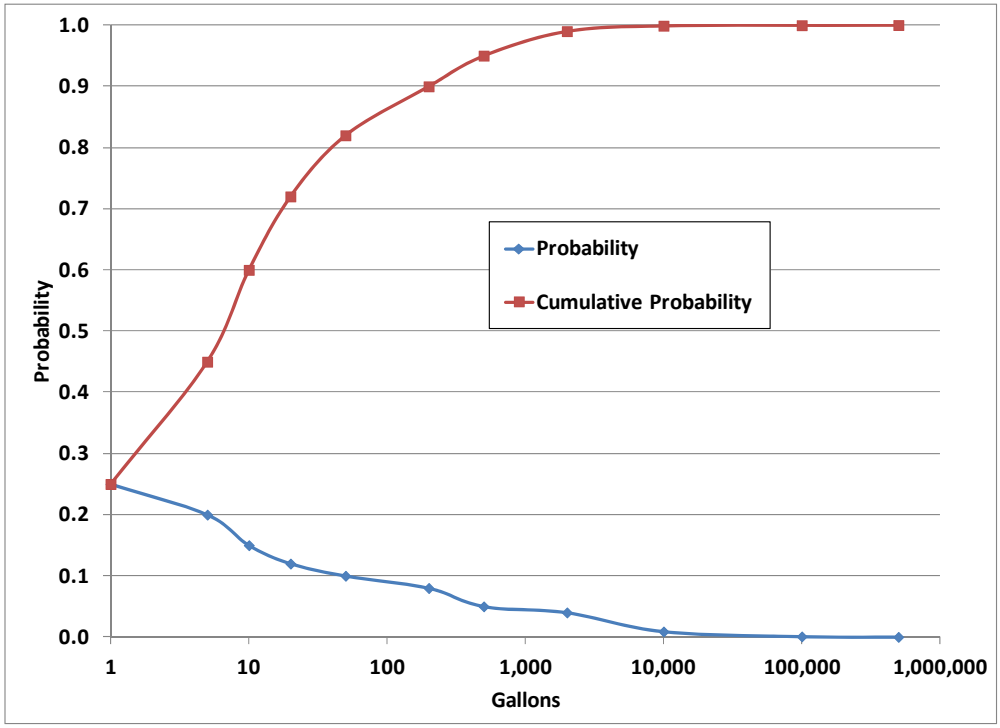

Figure 3: Probability Distribution of Spill Volume for Transfer-Related Oil Spills

Potential Impacts of Oil Spillage due to Transfer Errors

Note that the impacts of any oil spill can be mitigated to some degree with a prompt and effective spill response. The factors that affect the efficacy of spill response measures are complex and depend on the response strategy. In general, the effectiveness of mechanical containment and recovery operations (booms and skimmers or vacuum pumping) is rarely more effective than 5 – 25% on open water.

For transfer operation spills, however, the response effectiveness can be greatly enhanced for a number of reasons:

- Transfer operations conducted at a dockside facility will have response equipment at the dock or in the near vicinity, and onboard the vessel or in the near vicinity at an anchorage;
- Mechanical recovery (vacuum pumping and skimming) will be highly effective (50% to as high as 90%) when conducted under conditions of calm water, well-contained oil (with boom) to increase the thickness of the oil on the water surface), and within a short time-frame after spillage so that oil will not spread;
- Transfer operations are conducted by skilled personnel with spill response preparedness training.

Impacts of oil spills in the GPT study area have been studied extensively[7] and it is beyond the scope of this project to do spill trajectory, fate, and effects modeling and analyses on potential spill scenarios of transfer errors. Brief synopses of the key findings for spill

[7] For example, Etkin, 2005; Etkin and French-McKay, 2005; Etkin, French-McCay, and Beegle-Krause, 2009; French-McCay, Rowe, et al., 2005a, 2005b, 2005c, 2006a, 2006b.

impacts as specifically relevant to the expected spills of bunker fuel, oil cargo, and dry cargo from transfer errors in the GPT study area are presented in this report.

Typical Dockside or Vessel-Side (At-Anchor) Spills

Most transfer-related spills would be expected to be relatively small. For all transfer-related spills (bunkering and cargo transfer) in the US, the 95th percentile spill involved 500 gallons, the 99th percentile spill[8] involved 10,000 gallons. In the GPT study area, during 1972 – 2010, the largest transfer-related spill was one of 21,000 gallons[9] that occurred dockside at Cherry Point refinery in 1972 (*T/V World Bond*) at a time before many of the current spill prevention measures and regulatory practices were in place.

The spill volume is important in that it determines the degree of potential spread of the oil, as shown in Table 9. This table shows dockside transfer spills in Puget Sound during the years 1972 – 2010.

Table 9: Oil Volumes and Slick Spread Expected for Transfer-Related Spills

Percentile Spill	Gallons	Square Miles Coverage[10]		
		Fresh Slick[11]	Rainbow Sheen[12]	Silver Sheen[13]
50th	3	0.0004	0.1	0.3
75th	40	0.006	1	4.5
90th	200	0.03	7	20
95th	425	0.06	15	50
99th	1,900	0.3	70	200
Worst-Case (actual)	21,000	3	760	2,300

With mandatory pre-booming of vessels during oil transfer operations it is highly likely that in the case of a dockside spill the majority of oil spilled would be contained by boom, especially under calm weather conditions. Pre-positioned oil recovery equipment (e.g., vacuum pumps) would recover oil within the containment area. In the event that oil escaped the containment boom, the oil would spread, with its trajectory dependent on winds and currents in the hours after the spill occurred. If the oil escaped containment booming at dockside, the oil would eventually form a thin sheen as it spread. The degree of spreading and the behavior of the oil with regard to evaporation rates, emulsification, dispersion, and dissolution are dependent on the oil type, as well as temperature conditions at the time of the spill.

[8] A percentile spill is that spill volume at which n% of spills are smaller and only 1-n% are larger. For the 99th percentile spill, only 1% are larger.
[9] ERC Spill Databases.
[10] Assuming 25% evaporation for sheen.
[11] 0.1 mm thickness
[12] 0.0003 mm thickness
[13] 0.0001 mm thickness

Impacts of Spills of Heavy Bunker Fuel

The impacts of a bunker spill depend greatly on the type of oil. In the past, most bunker fuels used by tankers, bulk carriers, and general cargo vessels, as well as some other vessels (e.g., tugboats, cruise ships, and ferries) have been heavy fuel oils – Bunker C, intermediate fuel oil (IFO), No. 6 fuel oil, etc. These heavy oils are highly persistent but are less toxic than diesel fuels, marine gas oils, and lighter refined products (gasoline, jet fuel). The more toxic components (benzene, toluene, ethylbenzene, and xylenes) have been removed in the refining process. Heavy fuel oils are nevertheless lighter than water and do float, except in the more rare circumstance that the oil combines with heavier sediments and becomes heavier than water and sinks. The more likely scenario is that the oil will float, be carried in its trajectory by wind (at 3% wind speed) and tides, and cause persistent oiling on nearby shorelines.

Results on ecological impacts from the modeling of a hypothetical spill of 1.05 million gallons of Bunker C (No. 6 fuel) in the Strait of Juan de Fuca[14], a spill volume *several times that that would ever be expected in a bunkering operation or oil cargo spill due to transfer errors*, are summarized here.

The water surface coverage for the 50th and 95th percentile *damage* cases is shown in Table 10. It is important to note that again the percentile damage cases are determined by shoreline impact. Shoreline oiling for these scenarios is detailed in Table 11. Note that while there is a lower spill volume in this scenario, the bunker fuel spreads more and covers more shoreline. This is due to the lesser degree of evaporation of lighter components in the bunker fuel compared with crude oil. These results can be used to extrapolate potential damages for an oil cargo transfer spill in which heavy oil is the cargo, as well as for a bunkering error spill with heavy oil as the fuel.

Table 10: Water Surface Coverage – 1.05 Million Gallon Bunker Spill in Strait of Juan de Fuca

Scenario	Sheen or Thicker Area (sq. miles)	Slick Covered Area (sq. miles)
	>0.01 g/m^2 = 0.00001mm thick	>10 g/m^2 = 0.01mm thick
50th Percentile	1,173 sq miles	2,869 sq miles
95th Percentile	1,173 sq miles	2,869 sq miles

Table 11: Shoreline Area Impact – 1.05 Million Gallon Bunker Spill in Strait of Juan de Fuca

Scenario	Shoreline Coverage	Shoreline Coverage
	≤1,000 g/m^2 = ≤1mm thick	>1,000 g/m^2 = >1mm thick
50th Percentile	79 acres	48 acres
95th Percentile	190 acres	74 acres

The *much more likely* scenario of less than 2,000 gallons or a spill of less than 500 gallons, would involve considerably less spread even when the slick spreads to a thin surface sheen. The largest historical spill of 21,000 gallons, would, of course, have involved more impact, though there are no reliable records of any impacts from the 1972 incident.

[14] French-McCay, Rowe, et al., 2005a, 2005b, 2006a, 2006c.

The approximate spread of these smaller scenarios can be "scaled" down and derived from the modeling results of the 1.05 million-gallon bunker spill as shown in Table 12 and Table 13.

Table 12: Estimated Water Surface Coverage – Bunker Spills in Strait of Juan de Fuca

Scenario		Sheen or Thicker Area (sq. miles)	Slick Covered Area (sq. miles)
		>0.01 g/m^2 = 0.00001 mm thick	>10 g/m^2 = 0.01 mm thick
21,000 gallons	50th %tile	23.5 square miles (15,014 acres)	57.4 square miles (36,723 acres)
	95th %tile	23.5 square miles (15,014 acres)	57.4 square miles (36,723 acres)
2,000 gallons	50th %tile	1.2 square miles (1,426 acres)	5.5 square miles (3,489 acres)
	95th %tile	1.2 square miles (1,426 acres)	5.5 square miles (3,489 acres)
500 gallons	50th %tile	0.6 square miles (375 acres)	1.4 square miles (918 acres)
	95th %tile	0.6 square miles (375 acres)	1.4 square miles (918 acres)

Table 13: Estimated Shoreline Area Impact – Bunker Spills in Strait of Juan de Fuca

Scenario		Shoreline Coverage	Shoreline Coverage
		≤1,000 g/m^2 = ≤1 mm thick	>1,000 g/m^2 = >1mm thick
21,000 gallons	50th %tile	1.6 acres	1.0 acres
	95th %tile	3.9 acres	1.5 acres
2,000 gallons	50th %tile	0.2 acres	0.1 acres
	95th %tile	0.4 acres	0.14 acres
500 gallons	50th %tile	0.04 acres	0.02 acres
	95th %tile	0.1 acres	0.03 acres

Impacts of Spills of Diesel Fuels

The air-emission regulation-mandated switchover to diesel fuels away from heavy bunker fuels for larger vessels by 2016 will change the nature of spill impacts. The lighter diesel oils will be less persistent with regards to oiling the shoreline and remaining in the environment for long periods of time. However, the lighter aromatic components in diesel fuel are extremely toxic and could have significant impacts on water column organisms, such as fish, particularly fish eggs and larvae, and invertebrates.

Results on ecological impacts from the modeling of a hypothetical spill of 2.73 million gallons of diesel (No. 2 fuel) in the Strait of Juan de Fuca[15], a spill volume *several times that that would ever be expected in a bunker or oil cargo spill due to transfer errors*, are summarized here.

The water surface coverage for the 50th and 95th percentile *damage* cases is shown in Table 14. It is important to note that again the percentile damage cases are determined by

[15] French-McCay, Rowe, et al., 2005a, 2005b, 2006a, 2006c.

shoreline impact. Shoreline oiling for these scenarios is detailed in Table 15. Note that while there is a lower spill volume in this scenario, the bunker fuel spreads more and covers more shoreline. This is due to the lesser degree of evaporation of lighter components in the bunker fuel compared with crude oil. These results can be used to extrapolate potential damages for an oil cargo transfer spill in which diesel is the cargo, as well as for a bunkering error spill in which diesel is the fuel.

Table 14: Water Surface Coverage – 2.73 Million Gallon Diesel Spill in Strait of Juan de Fuca

Scenario	Sheen or Thicker Area (sq. miles)	Slick Covered Area (sq. miles)
	>0.01 g/m^2 = 0.00001 mm thick	>10 g/m^2 = 0.01 mm thick
50th Percentile	1,282 square miles	1,270 square miles
95th Percentile	2,952 square miles	2,891 square miles

Table 15: Shoreline Area Impact – 2.73 Million Gallon Diesel Spill in Strait of Juan de Fuca

Scenario	Shoreline Coverage	Shoreline Coverage
	≤1,000 g/m^2 = ≤1 mm thick	>1,000 g/m^2 = >1 mm thick
50th Percentile	51 acres	18 acres
95th Percentile	230 acres	119 acres

The *much more likely* scenario of less than 2,000 gallons or a spill of less than 500 gallons, would involve considerably less spread even when the slick spreads to a thin surface sheen. The largest historical spill of 21,000 gallons, would, of course, have involved more impact, though there are no reliable records of any impacts from the 1972 incident.

The approximate spread of these smaller scenarios can be "scaled" down and derived from the modeling results of the 2.73 million-gallon diesel spill as shown in Table 16 and Table 17.

Table 16: Estimated Water Surface Coverage – Diesel Spills in Strait of Juan de Fuca

Scenario		Sheen or Thicker Area (sq. miles)	Slick Covered Area (sq. miles)
		>0.01 g/m^2 = 0.00001 mm thick	>10 g/m^2 = 0.01 mm thick
21,000 gallons	50th %tile	9.9 square miles (6,318 acres)	9.8 square miles (6,259 acres)
	95th %tile	22.7 square miles (14,547 acres)	22.3 square miles (14,247 acres)
2,000 gallons	50th %tile	0.9 square miles (599 acres)	2.2 square miles (1,379 acres)
	95th %tile	2.2 square miles (1,379 acres)	0.9 square miles (593 acres)
500 gallons	50th %tile	0.2 square miles (148 acres)	0.2 square miles (146 acres)
	95th %tile	0.5 square miles (340 acres)	0.5 square miles (333acres)

Table 17: Estimated Shoreline Area Impact – Diesel Spills in Strait of Juan de Fuca			
Scenario		Shoreline Coverage	Shoreline Coverage
		≤1,000 g/m^2 = ≤1mm thick	>1,000 g/m^2 = >1mm thick
21,000 gallons	**50th %tile**	0.4 acres	0.1 acres
	95th %tile	1.8 acres	0.9 acres
2,000 gallons	**50th %tile**	0.04 acres	0.01 acres
	95th %tile	0.17 acres	0.09 acres
500 gallons	**50th %tile**	0.01 acres	0.003 acres
	95th %tile	0.04 acres	0.02acres

References

Etkin, D.S. (2005). *Socioeconomic Cost Modeling for Washington State Oil Spill Scenarios: Phase II.* Prepared for Washington Department of Ecology. Environmental Research Consulting.

Etkin, D.S. (2006). *Trends in Oil Spills from Large Vessels in the US and California with Implications for Anticipated Oil Spill Prevention and Mitigation based on the Washington Oil Transfer Rule*. Prepared for Washington Department of Ecology, Contract No. C040018. Environmental Research Consulting.

Etkin, D.S. (2013a). *Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study: Characterization of Casualty Consequences (Task 5).* Environmental Research Consulting.

Etkin, D.S. (2013b). *Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study: Characterization of Historical Vessel Incidents (Task 4).* Environmental Research Consulting.

Etkin, D.S., & Michel, K. (2003). *Bio-Economic Modeling of Oil Spills from Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay, Vol. II: Spill Volume Report.* Prepared for US Army Corps of Engineers, Sacramento District, Contract DACW07-01-C-0018. Environmental Research Consulting.

Etkin, D.S.; French-McCay, D.; and Beegle-Krause, C.J. (2009). "Oil Spill Risk Assessment – Probability and Impact Analyses with Future Projections." *Proceedings of the 32nd Arctic & Marine Oilspill Program Technical Seminar*: 683–704.

Etkin, D.S.; French-McCay, D.; Rowe, J.; Whittier, N.; Sankaranarayanan, S.; and Pilkey-Jarvis, L. (2005). "Modeling Impacts of Response Method and Capability on Oil Spill Costs and Damages for Washington State Spill Scenarios." *Proceedings of 2005 International Oil Spill Conference*: 457–462.

French-McCay, D.; Beegle-Krause, C.J.; Rowe, J.; Rodriguez, W.; and Etkin, D.S. (2009). "Oil Spill Risk Assessment – Relative Impact Indices by Oil Type and Location." *Proceedings of the 32nd Arctic & Marine Oilspill Program Technical Seminar*: 655-682.

French-McCay, D.; Rowe, J.; Whittier, N.; Asch, R.; Sankaranarayanan, S.; Borowik, A.; Suàrez, C., and Etkin, D.S. (2006a). *Evaluation of the Consequences of Various*

Response Options Using Modeling of Fate, Effects, and NRDA Costs for Oil Spills in Washington Waters, Phase II, Vol. I: Model Description, Approach, and Analysis. Prepared for Washington Department of Ecology. Applied Science Associates, Inc. and Environmental Research Consulting.

French-McCay, D.; Rowe, J.; Whittier, N.; Asch, R.; Sankaranarayanan, S.; Borowik, A.; Suàrez, C., and Etkin, D.S. (2006b). *Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects, and NRDA Costs for Oil Spills in Washington Waters, Phase II, Vol. I: Summary of Results for All Scenarios*. Prepared for Washington Department of Ecology. Applied Science Associates, Inc. and Environmental Research Consulting.

French-McCay, D.; Rowe, J.; Whittier, N.; Asch, R.; Sankaranarayanan, S.; Borowik, A.; Suàrez, C., and Etkin, D.S. (2006c). *Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects, and NRDA Costs for Oil Spills in Washington Water, Phase II, Vol. III: Summary Model Results for Runs Assuming No Response for San Juan Islands – Alaskan North Slope Crude.* Prepared by for Washington Department of Ecology. Applied Science Associates, Inc., and Environmental Research Consulting.

French-McCay, D.; Rowe, J.; Whittier, N.; Sankaranarayanan, S.; Suàrez, C.; and Etkin, D.S. (2005a). *Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects, and NRDA Costs for Oil Spills in Washington Waters. Vol. I. Model Description, Approach, and Analysis*. Prepared by for Washington Department of Ecology. Applied Science Associates, Inc., and Environmental Research Consulting.

French-McCay, D.; Rowe, J.; Whittier, N.; Sankaranarayanan, S.; Suàrez, C.; and Etkin, D.S., and Pilkey-Jarvis, L. (2005b). "Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA Costs of Oil Spills into Washington Waters." *Proceedings of 2005 International Oil Spill Conference*: 467–473.

Herbert Engineering Corp., and Designers & Planners, Inc. (2003). *Evaluation of Accidental Oil Spills from Bunker Tanks (Phase 1)*. Prepared for US Coast Guard Ship Structure Committee and Research and US Coast Guard Development Center,. Report No. SSC-424.

Michel, K., and Winslow, T.S. (1999, May). "Cargo Ship Bunker Tanks: Designing to Mitigate Oil Spillage." *Society for Naval Architects and Marine Engineers (SNAME) Joint California Sections Meeting*.

Michel, K., and Winslow, T.S. (2000). "Cargo Ship Bunker Tankers: Designing to Mitigate Oil Spills." *Marine Technology*, 37(4).

Appendix E Characterization of Casualty Consequences

Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study

Characterization of Casualty Consequences

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ENVIRONMENTAL RESEARCH CONSULTING

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Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study Characterization of Casualty Consequences

Executive Summary

This Vessel Traffic and Risk Assessment Study (VTS) is being conducted by The Glosten Associates (Glosten) for the proposed Gateway Pacific Terminal (GPT) to be located at GPT/Cherry Point in Washington State. The purpose of the study is to assess the potential risks posed by new bulk carrier traffic that the proposed terminal will bring to the Puget Sound.

Current vessel traffic levels and forecasted traffic levels are considered, including GPT-calling bulk carriers and the tugboats assisting them. The area studied includes the designated Puget Sound vessel transit lanes, the maneuvering area near the planned GPT project at GPT/Cherry Point, the local anchorage areas, and the transit routes for tugs assisting GPT. Plans call for 487 total annual visits for the anticipated GPT-bound traffic at full throughput level in 2019 (Revised Project Information Document, 2012). Of the total vessel calls, it is projected that there will be 318 Panamax and 169 Capesize vessels. The GPT-bound vessels will be utilizing the established traffic lanes between Cape Flattery and Cherry Point.

This report provides algorithms on spill probabilities and probabilistic outflow percentages for the scenarios analyzed in the VTS. Spill probabilities were developed based on the historical incidents that resulted in spills. Probabilistic outflow percentage curves were developed from the amount of bunker oil or cargo (oil or dry bulk) that was spilled, based on a historical database of spill sizes. The historical database used to derive these statistics includes incidents and spills from all US waters, principally between 1995 and 2010.

This report also provides equations for estimating the capacities of vessel types analyzed in the VTS. These algorithms and equations were developed for use in the VTS Monte Carlo traffic risk model associated with the Gateway Pacific Terminal Traffic and Risk Assessment Study. This report provides information on dry cargo sweeping as a source of environmental contamination due to dry bulk carriers. Finally, as environmental impacts for spillage of dry bulk commodities are not well understood, a synopsis of known information is presented.

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 Gateway Pacific Terminal Traffic and Risk Assessment Study, as well as for the fulfillment of Task 5 Characterization of Casualty Consequences.

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).
- **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.
- **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 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.

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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 (for 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).

- **GPT VTS Vessels:** vessels for which there are sufficient traffic data and that are therefore included in the analysis of vessel traffic risk.
- **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 GPT VTS 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 zero and one 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 BH_x, bunker hull type SV_x, spill volume O_x, outflow
CS	Cargo spillage	-
BS	Bunker spillage	-
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* = 10 for year 2019
CHx	Cargo hull type	Values for x: d, double hull s, single hull
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
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 *d*, dry cargo

Table A: Equation Variables		
Variable	**Description**	**Potential Values**
SV_x	Spill volume	Values for *x*: *o*, oil cargo *b*, bunker fuel *d*, dry cargo
O_x	Outflow percentage [5]	Values for *x*: *o*, oil cargo *b*, bunker fuel *d*, dry cargo
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.

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}
Incident Cause, I_x	Allision, I_a
	Collision, I_c
	Grounding, I_g
	Other, Non-Impact, I_o
	Transfer Error, I_t

[5] Percentage of vessel adjusted capacity.

The spill probabilities for each vessel/incident cause combination are shown in Table 2. Spill probabilities are shown for single- and double-hull product tankers even though no single-hull tankers will operate in the year 2019 due to IMO regulation. The single-hull tanker spill probabilities are shown, because they are used as a proxy for dry bulker cargo spill probabilities in the VTS Monte Carlo traffic risk model for which this report was compiled. The probabilities of spillage in this table for collisions, allisions, and groundings were derived from outflow models on tankers and tank barges, developed by naval architects and engineers working on behalf of the International Maritime Organization (IMO)[6] to estimate the probability of spillage given various types of vessel accidents. Data was also derived from 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.[7] 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.[8]

Table 2: Cargo Spill Probabilities for Tankers and Tank Barges[9]

Vessel Type	Incident Cause	Hull[10]	Cargo Spill Probability in Incident, *P(CS)*
Product Tanker (V_{pt})	**Collision (I_c)**	**Single**	0.68
		Double	0.15
	Allision (I_a)	**Single**	0.68
		Double	0.15
	Grounding (I_g)	**Single**	0.91
		Double	0.18
	Other, Non-Impact Error (I_o)	**Single**	0.40
		Double	0.40
	Transfer Error (I_t)	**Single**	0.92
		Double	0.92
Crude Tanker (V_{ct})	**Collision (I_c)**	**Double**	0.19
	Allision (I_a)		0.19
	Grounding (I_g)		0.20
	Other, Non-Impact Error (I_o)		0.40
	Transfer Error (I_t)		0.92
Tank Barge (V_{tb})[11]	**Collision (I_c)**		0.13
	Allision (I_a)		0.13
	Grounding (I_g)		0.22
	Other, Non-Impact Error (I_o)		0.40
	Transfer Error (I_t)		0.92

[6] Rawson 1998; NRC 1998; NRC 2001; IMO 1995

[7] Yip et al. 2011b.

[8] NRC 1998; NRC 2001; Etkin et al. 2002.

[9] Based on Yip et al. 2011b; Rawson 1998; NRC 1998; NRC 2001; IMO 1995; Etkin et al. 2002.

[10] For tank vessels, hull refers to cargo hull. For all other vessels hull refers to bunker tank hull.

[11] 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.

Probability of Bunker Spillage, *P(BS)*

The relevant variables for determining the probability of bunker[12] spillage, *P(BS)*, are shown in Table 3 and Equations 1 and 2. A "transfer error" of bunker fuel is also called a "bunkering error."

Table 3: Variables for Probability of Bunker Spillage for All GPT VTS 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[13]	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

$$P(BS) = f(V_x, I_x, BH_x) \qquad 1$$

$$P(BH_x) = f(y) \qquad 2$$

The probabilities of bunker spillage by vessel type, cause, and hull type are shown in Table 4.

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 Table 5). The probabilities in Table 4 are based on bunker tank outflow modeling conducted for IMO[14] and studies conducted on US oil spills.[15]

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

[12] 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.

[13] Single- or double hull on bunker tanks for all vessels including tankers, except for tank barges, which do not have bunker tanks.

[14] (Michel & Winslow, 1999), (Michel & Winslow, 2000); (Barone, Campanile, Caprio, & Fasano, 2007)

[15] (Etkin & Michel, 2003); (Herbert Engineering Corp. and Designers & Planners, Inc., 2003).

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 4: Bunker Spill Probabilities for All GPT VTS Vessels [16]

Vessel Type	Incident Cause	Hull	Bunker Spill Probability
Tankers (V_t) [17]	**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
Tank Barge (V_{tb}) [18]	**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

[16] Based on Etkin & Michel, 2003; Michel and Winslow, 1999; Michel and Winslow, 2000; Barone, Campanile, Caprio, & Fasano, 2007; Herbert Engineering Corp. and Designers & Planners, Inc., 2003.

[17] 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.

[18] 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.

Table 4: Bunker Spill Probabilities for All GPT VTS Vessels [16]			
Vessel Type	**Incident Cause**	**Hull**	**Bunker Spill Probability**
	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 [19] (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 4 having a single or double hull are show in Table 5. The exceptions are tank barges, which do not have bunker tanks, [20] and vessels in the Other Vessels category, which will not likely have double hulls within the study period through 2019.

[19] Includes only GPT VTS vessels not in other categories of tanker, bulk, tank barge, or general cargo.

[20] This is referring only to the tank barge and not its associated tug.

Table 5: 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

The above probabilities can also be expressed as the fitted Equations 3 and 4.[21] (The same R^2 applies to both equations.)

$$P(BH_d) = 0.0446y + 0.005 \qquad 3$$

$$P(BH_s) = -0.0446y + 0.995 \qquad 4$$

$$R^2 = 0.999$$

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).

[21] Based on R^2, the coefficient of determination is a value between 0 and 1 that describes how closely a regression line (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.

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[22] 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 stated that utilization in practice hardly exceeds 95%, but could be as low as 65%. (Note: this is a "fully laden" tanker, not one that has offloaded a portion of its cargo at one port and proceeds to the next with less than the original amount.) In two significant dynamic collision risk-modeling studies, the figure of 91% is utilized.[23]

For outflow modeling purposes, IMO uses 98% of volumetric capacity of the cargo tanks.[24] 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[25] stated that 2.5% of the deadweight tonnage of a vessel is typically used for storage of water and bunker oil, with bunker oil assumed to be about 2%.[26] This would mean then that if one was using 95% deadweight tonnage maximum loading value,[27] 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

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[22] Wijnolst & Wergeland, 1997.

[23] Eide, et al., 2007; Behrens, Endresen, Mjelde, & Germann, 2003.

[24] National Research Council (NRC), 1998 and National Research Council (NRC), 2001.

[25] Wijnolst &Wergeland, 1997.

[26] This also bears out in analyses of known bunker capacities and deadweight tonnages as in Etkin and Michel 2003.

[27] Based on (Eide, et al., 2007) and (Behrens, Endresen, Mjelde, & Germann, 2003).

may be somewhat less depending on the contribution of the other minor factors of crew and miscellaneous loads.[28]

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,[29] this needs to be converted to a percentage of DWT as in Equations 5 – 7 to estimate the actual cargo load:

$$K_0(long - tons) = 0.98 \cdot 0.975 \cdot DWT \qquad 5$$

$$K_0(tonnes) = 0.971 \cdot DWT \qquad 6$$

$$K_0(gallons) = 285.4 \cdot DWT \qquad 7$$

The regulatory basis for limiting the maximum amount of oil cargo transported through Puget Sound is clearly based on a limit of 125,000 DWT as per federal regulations[30], that is by the tanker's tonnage.

For tankers transiting Puget Sound, there is a federal regulatory limit of 125,000 DWT for tankers,[31] which translates to a 35.675-million-gallon capacity per Equation 7.

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.[32] In actual practice, however, the expert advice has been that bunker tanks are never more than 70% full in practice.[33]

The recommended formulae for estimating bunker capacity for GPT study vessels are Equations 8 and 9. 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 developed its own equation for 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.

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[28] It is assumed that this is less than 0.5% since it is not even mentioned in the calculations of Wijnolst &Wergeland,1997 and others (Behrens, Endresen, Mjelde, & Germann, 2003; Eide, et al., 2007).

[29] National Research Council (NRC), 1998 and National Research Council (NRC), 2001.

[30] 33 CFR (Code of Federal Register) §165.1303b.

[31] 33 CFR (Code of Federal Register) §165.1303b.

[32] Barone, Campanile, Caprio, & Fasano, 2007; Michel & Winslow, 1999; Michel & Winslow, 2000.

[33] This is the value that was used in the US Army Corps study (Etkin & Michel, 2003), as well as studies for Puget Sound (Etkin, 2001; Etkin, French-McCay, Whittier, Subbayya, & Jennings, 2002; French-McCay, et al., 2008) and other parts of the US (Etkin, 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, French-McCay, & Beegle-Krause, 2009; French-McCay, et al., 2008; French-McCay, et al., 2006), as well as US-wide studies (Etkin, 2002; Etkin, 2003).

$$K_b(V_t) = 5.086DWT + 106{,}924 \qquad R^2 = 0.958 \qquad 8$$

$$K_b(V_g) = 27.545DWT - 64.922 \qquad R^2 = 0.930 \qquad 9$$

Where $K_b(V_t)$ = bunker tank capacity of tankers (in gallons) adjusted for 70% capacity[34]
$K_b(V_g)$ = bunker tank capacity of general cargo vessels[35] (in gallons)
DWT = deadweight tonnage

Calculations for Dry Cargo (Grain)[36] Capacity (K_d)

The *capacity* for dry cargo in bulk carriers depends on the configuration of the vessel (e.g., numbers of holds). The amount of dry cargo that each vessel will carry when "fully" loaded will vary by the commodity being carried. The reason for this is that the *weight* of the cargo is of importance in determining the optimal and safe loading of the vessel. Because the density of dry bulk commodities varies considerably (Table 6), the volume of actual loading relative to the physical volumetric capacity of the bulk carrier holds will vary. There are different "stowage factors" (SF) for different commodities, as shown in Table 6. Stowage factor is the inverse of the density of the cargo [Equations 10 – 12]:

$$Density = \frac{t}{m^3} \qquad 10$$

$$SF = \frac{1}{Density} \qquad 11$$

$$SF = \frac{m^3}{t} \qquad 12$$

[34] 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 & Michel, 2003).

[35] Based on data available for container ships.

[36] In the shipping industry, the term "grain" is used as a proxy for dry cargo as a means of representing the bulk volume that can be accommodated in bulker holds. It does not necessarily imply grain as wheat, barley, rice, etc. This measure can be used for other commodities, including coal. The International Code for the Safe Carriage of Grain in Bulk, commonly called the "International Grain Code," was adopted by the IMO Maritime Safety Committee by resolution MSC.23(59). It applies to ships regardless of size, including those of less than 500gt, engaged in the carriage of grain in bulk, to which part C of chapter VI of the 1974 SOLAS Convention, as amended, applies (A 1.1).

Table 6: Stowage Factors for Dry Cargo on Bulk Carriers							
Commodity	Specific Weight			Stowage Factor			Typical % Capacity Filled [37]
	long tons/m³	kg/m³	long ton/ft³	m³/ long ton	m³/ metric ton	ft³/ long ton	
Anthracite Coal	0.851	865	0.024	1.17	1.20	41.5	
Bituminous Coal	0.780	793	0.022	1.28	1.29	45.3	
Lignite Coal	0.741	753	0.021	1.35	1.35	47.7	
Petroleum Coke	0.600	610	0.017	1.67	1.70	58.8	
Potash	1.261	1,281	0.036	0.79	0.81	28.0	
Wheat/Millet	0.777	790	0.022	1.29	1.29	45.4	87.5%
Corn	0.748	760	0.021	1.34	1.35	47.2	87.5%
Barley	0.590	600	0.017	1.69	1.70	59.8	
Taconite [38]	2.758	2,803	0.078	0.36	0.37	12.8	25%
Wood Chips	0.374	380	0.011	2.67	2.70	94.4	
Sulfur	0.946	961	0.027	1.06	1.08	37.3	
Stone	2.475	2,515	0.070	0.40	0.41	14.3	
Sand	1.576	1,602	0.045	0.63	0.65	22.4	

For example, for iron ore, cargo holds typically hold 25% of their capacity. For grains, the holds will typically hold 87.5% of their capacity.[39] The space required to stow one ton of wood chips requires six times the space required for one ton of iron ore.

Loading pattern is also an important factor for bulk carriers. The patterns vary based on the nature of the cargo and whether there is a homogeneous load (all one commodity) or heterogeneous (more than one type of commodity being carried) and the pattern of unloading planned. There are three typical loading patterns utilized on bulk carriers[40], as shown in Figures 1 – 3. The homogeneous loading pattern (Figure 1) is used for lighter cargoes like grain or coal. The alternate hold loading pattern (Figure 2) is most often used with high-density cargoes to raise the center of gravity. The block-loading pattern (Figure 3) is most typically employed when the vessel is partly loaded.

[37] Filled in only for those commodities for which data were available.

[38] Taconite is a type of iron ore that contains more than 15% iron interlayered with quartz, chert, or carbonate.

[39] Personal communications with bulk carrier industry experts and online communities.

[40] Ship Structure Committee, 2004. (http://www.shipstructure.org); (Lotsberg, 2006).

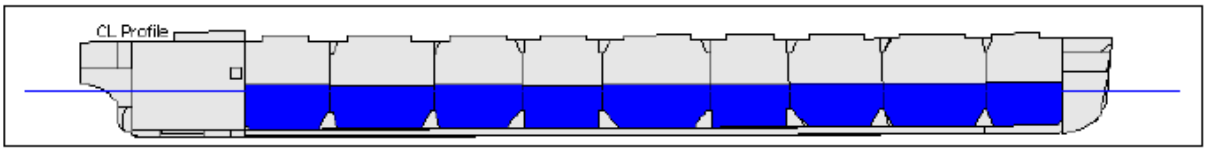

Figure 1: Homogeneous Loading Pattern for Bulk Carrier

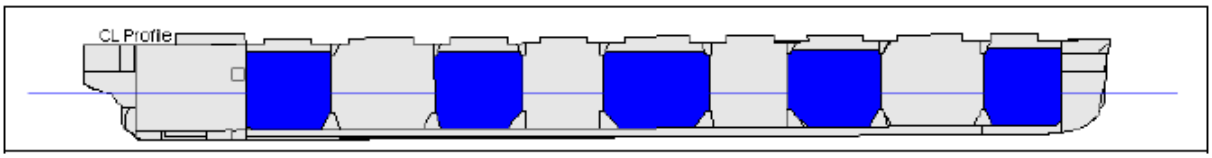

Figure 2*:* Alternate Hold Loading Pattern for Bulk Carrier

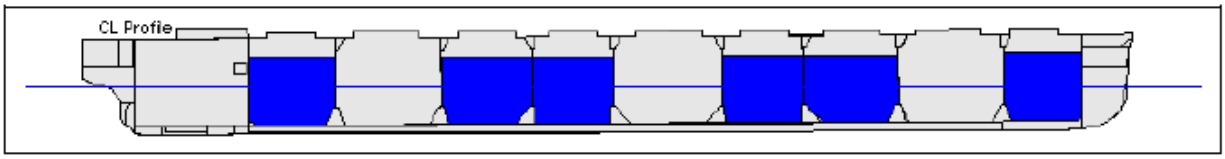

Figure 3: Block Loading Pattern for Bulk Carrier

The loading pattern and precise measurements of cargo loading for each bulk carrier type and dry cargo commodity combination are complex[41] and beyond the scope of this project. For the purposes of the GPT VTS, it is important to estimate the dry cargo load of the bulk carriers that may be transiting the study area in future so that estimates of potential spillage might be made.

The volumetric dry cargo capacity (as grain capacity) can be calculated from deadweight tonnage as in Equation 13:

$$K_d = 1.4DWT \qquad 13$$

Where K_d = volumetric bulker capacity (as grain capacity) *in cubic meters*

This capacity assumes that the vessel is completely full with grain (with a stowage factor of 1.4 m^3/metric ton). The actual load on board a bulk carrier when "fully loaded" will vary with the bulk commodity. Initially, GPT[42] will be shipping mostly "low-sulfur, low ash coal," which corresponds most closely with lignite coal with an average density 0.021 long tons per cubic foot, giving it a stowage factor of 47.7 cubic feet per long ton or 1.35 cubic meters per metric ton (tonne), which is slightly lower than the grain capacity, as in Equation 14:

$$K_{coal} = 1.35DWT \qquad 14$$

[41]See IACS 2006.

[42] Based on information in the Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study Request for Proposal 31 March 2011.

This capacity should then be further adjusted to take into account that the cargo holds are rarely completely full but rather about 84% full[43] when the vessel is filled with coal with a homogeneous holding pattern (Figure 1) as in Equations 15 and 16:

$$adjustedK_{coal} = 0.84 \cdot 1.35DWT \qquad 15$$

$$adjustedK_{coal} = 1.134DWT \qquad 16$$

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.

Table 7: Variables for Probability Distributions of Oil Cargo Spillage Volume

Variable	Values
Vessel Type, V_x	Tanker, V_t
	Tank Barge, V_{tb}
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 17.

$$SV_o = O_0 \times K_o \qquad 17$$

The percentage outflow (O_o) is a function of the vessel type (V_x) and incident type (I_x), as in Equation 18.

$$O_0 = f(V_x, I_x, CH_x) \qquad 18$$

[43] The 84% was derived by multiplying the 87.5% known for grains (SF of 1.4) with the ratio of the coal stowage factor and the grain stowage factor. The coal is slightly heavier than the grain and thus would fill up somewhat less of the hold to achieve the same weight.

Oil Cargo Outflow Probability for Tankers in Impact Accidents

The probability distribution of percentage of outflow for tankers involved in impact accidents is as shown in Table 8. 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] This 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 as per Equation 7. 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
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

Oil Cargo Outflow Probability for Tankers in Other, Non-Impact Incidents

The probability of percentage outflow for tankers involved in Other, Non-Impact incidents 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,[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.

[44] Etkin D., 2001; Etkin D., 2003; Etkin & Michel, 2003, Etkin & Neel, 2001; (Etkin, French-McCay, & Beegle-Krause, 2009.

[45] Rawson, Crake, & Brown, 1998; Yip, Talley, & Jin, 2011; National Research Council (NRC), 1998; National Research Council (NRC), 2001.

[46] Based on Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009; Rawson, Crake, & Brown, 1998; Yip, Talley, & Jin, 2011b; NRC, 1998; NRC, 2001.

[47] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

Table 9: Oil Cargo Outflow Probability for 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 tank barges [49] involved in impact accidents (collisions, allisions, and groundings) is as shown in Table 10. 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 10: Oil Cargo Outflow Probability for 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
50%	0.002	1.0000

The probability distribution of percentage of outflow for Tank Barges [52] involved in involved in Other Non-Impact incidents is as shown in Table 11. The percentage oil outflow

[48] Based on Etkin & 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 & Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

[51] Based on Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel, 2001; Etkin &Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009; Rawson, Crake, & Brown, 1998; Yip, Talley, & Jin, 2011b; NRC, 1998; NRC, 2001.

probabilities are based on international studies of the amount of oil actually spilled compared with the reported amount of oil cargo on the tanker,[53] 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 Tank Barges in Other, Non-Impact Incidents

% Actual Cargo Outflow	Probability $P(O_o)$[54]	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 12. 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,[55] 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.

[52] Note that the oil outflow only comes from the tank barge itself. Tugs (towboats and tugboats) are separately tracked under Other Vessels.

[53] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel 2001; Etkin & Michel 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

[54] Etkin, 2001; Etkin, 2002; Etkin, 2003.

[55] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin &Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

Table 12: Oil Cargo Outflow Probability from Tanker Transfer Errors		
% Actual Cargo Oil Outflow	**Probability $P(O_o)$ [56]**	**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

[56] Based on analyses conducted in Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin &Neel 2001; Etkin, 2006.

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 13. 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.[57]

Table 13: Oil Cargo Outflow Probability from Tank Barge Transfer Errors

% Actual Cargo Outflow	Probability $P(O_o)$[58]	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 19.

$$SV_b = O_b \times K_b \qquad 19$$

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 14. Note that there is

[57] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel 2001; Etkin& Michel 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

[58] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin & Neel 2001; Etkin, 2006.

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.[59] The approach was verified by oil outflow modeling conducted for IMO.[60]

Table 14: Bunker Outflow Probability from All Vessel Impact Accidents

% Actual Bunker Outflow	Probability $P(O_b)$[61]	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
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[62] 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.[63]

[59] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

[60] Michel & Winslow, 1999; Michel & Winslow, 2002; Barone, Campanile, Caprio, & Fasano, 2007; Yip, Talley, & Jin, 2011a.

[61] Etkin & Michel, 2003; Etkin, 2001; Etkin, 2002; Herbert Engineering, et al. 2003; Michel & Winslow 1999; Michel & Winslow, 2002; Barone, Campanile, Caprio, & Fasano, 2007; Yip, Talley, & Jin, 2011a.

[62] Also referred to as "bunkering errors".

[63] Etkin, 2001; Etkin, 2002; Etkin, 2003; Etkin & Neel, 2001; Etkin & Michel, 2003; Etkin, French-McCay, & Beegle-Krause, 2009.

Table 15: Bunker Outflow Probability from Tankers, Bulk Carriers, and General Cargo Vessels due to Transfer Errors during Bunkering Operations		
% Actual Bunker Outflow	**Probability $P(O_b)$** [64]	**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 16. 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. [65]

Table 16: Bunker Outflow Probability from Other Vessels: Transfer Errors during Bunkering		
% Actual Bunker Outflow	**Probability $P(O_b)$** [66]	**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

[64] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin and Neel 2001; Etkin 2006.

[65] Etkin 2001; Etkin 2002; Etkin 2003; Etkin and Neel 2001; Etkin and Michel 2003; Etkin et al. 2009.

[66] Based on analyses conducted in Etkin 2001, 2002, 2003; Etkin and Neel 2001; Etkin 2006.

Table 16: Bunker Outflow Probability from Other Vessels: Transfer Errors during Bunkering		
% Actual Bunker Outflow	**Probability $P(O_b)$** [66]	**Cumulative Probability**
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

Calculation of Transfer Error Rate and Spill Volume Probability Distributions – Dry Cargo

Dry cargo spillage from bulkers has not been regularly or systematically recorded by Washington Department of Ecology or by the US Coast Guard for Washington State or any other part of the US. Reports to the National Response Center (and the US Coast Guard) for the entire US has only been sporadic. Much of this is due to lack of information on the impacts of these spills and the fact that spillage of dry cargo residues has long been considered to be part of the routine operations of loading, unloading, and transport of bulk dry cargo on bulker vessels. This has led to irregular reporting of incidents. No incidents of dry cargo spillage from a bulk carrier were recorded during 1995 – 2010 in the GPT study area. Due to this paucity of data, an additional ten years back to 1985 and geographies outside the GPT study area were included in the analysis of dry cargo spills.

In US Coast Guard (and National Response Center) records, spills of dry bulk cargo from either barges or bulkers have occasionally been reported, as shown in Table 17. Table 17 statistics are from all US waters, including inland navigable waterways. The fact that so few incidents were reported does not necessarily indicate that these spills do not occur, but rather that when they do they are considered minor or inconsequential because of the nature of the commodities and the lack of stringent regulations requiring reporting, or the lack of knowledge of existing regulations.

Table 17: Dry Cargo Incidents (Spills and Potential Spills) in US Waters [67] 1985 – 2010			
Year	**Number of Incidents**		**Total**
	Barges	**Bulkers**	
1985	0	0	0
1986	0	1	1
1987	0	1	1
1988	0	0	0
1989	0	2	2
1990	0	0	0
1991	0	1	1

[67] From ERC spill databases.

Table 17: Dry Cargo Incidents (Spills and Potential Spills) in US Waters[67] 1985 – 2010			
Year	**Number of Incidents**		**Total**
1992	0	1	1
1993	0	0	0
1994	0	0	0
1995	2	1	3
1996	2	0	2
1997	1	0	1
1998	1	0	1
1999	0	0	0
2000	2	0	2
2001	0	2	2
2002	1	1	2
2003	5	0	5
2004	4	3	7
2005	5	1	6
2006	2	1	3
2007	9	0	9
2008	1	0	1
2009	1	0	1
2010	1	1	2
Total	**37**	**16**	**53**

In all of the US, there have been only 53 dry cargo incidents with spillage or potential spillage reported in 26 years (or 2 per year), of which only 16 were from bulkers rather than freight barges (or 0.62 per year). Details of these incidents are shown in Table 18.

Table 18: Details of Bulk Carrier Dry Cargo Incidents in US Waters (1985 – 2010)

Date	Location	Waterway	Vessel Name	GRT	DWT	Cause[68]	Material	Amount Spilled (lbs)
11/30/1986	Lorain, OH	Navigable Waters NEC	*American Mariner*	15,396	36,171	Transfer	Coke Dust	20
5/7/1987	Sault Ste. Marie, MI	St. Marys River	*H. Lee White*	21,815	35,019	Transfer	Taconite Dust	1

[68] While no incidents were directly attributed to transfer errors, the incidents noted as "transfer" were reported to have been at a dock loading/unloading facility at the time of the incident. It is therefore assumed that there may have been transfer operations going on at the time of the reported incident or prior to the report of evidence of material in the water.

Table 18: Details of Bulk Carrier Dry Cargo Incidents in US Waters (1985 – 2010)								
Date	**Location**	**Waterway**	**Vessel Name**	**GRT**	**DWT**	**Cause** [68]	**Material**	**Amount Spilled (lbs)**
5/10/1989	Buffalo, NY	Buffalo River	*Henry Steinbrenner*	7,041	13,910	Transfer	Coal Dust	5
5/14/1989	Duluth, MN	Lake Superior	Unknown			Unknown (Underway)	Coal Dust	3
8/28/1991	Traverse City, MI	Lake Michigan	*William R. Roesch*	9,639	19,800	Transfer	Coal Dust	50
7/30/1992	Dearborn, MI	Navigable Waters NEC	*Kaye E. Barker*	11,949	25,345	Transfer	Taconite Dust	2
5/27/1995	Thousand Islands, NY	St. Lawrence River	*Tadoussac*	20,634	28,800	Unknown (Underway)	Taconite Dust	500
6/11/2001	Bristle, PA	Delaware River	Unknown			Transfer	Cement	1
9/26/2001	San Francisco, CA	San Francisco Bay	*Andros*	35,447	64,843	Transfer	Lime	1,250
12/13/2002	Newport News, VA	James River	*The Thornhill*	22,354	37,939	Transfer	Coal Dust	unknown (minor)
7/10/2004	New Orleans, LA	Mississippi River	*Sanaga*	17,784	28,215	Dumping	Coal Dust	unknown (minor)
10/7/2004	Port Everglades, FL	Atlantic Ocean	Unknown			Grounding	Cement	0
12/9/2004	Dutch Harbor, AK	Pacific Ocean	*Selendang Ayu*	39,775	72,937	Grounding	Grain (Soybeans)	132,000,000
3/10/2005	San Francisco, CA	San Francisco Bay	Unknown			Equipment Failure (Underway)	Concrete Dust	unknown (minor)
9/25/2006	New Haven, CT	Long Island Sound	*Barkald*	28,924	49,463	Sinking	Coal	unknown (minor)
4/14/2010	Portland, OR	Columbia River	*Hellenic Sea*	36,448	65,434	Transfer	Coal Dust	unknown (minor)

It is worth noting that on December 7, 2012, the bulk carrier *Cape Apricot* allided with a conveyer system at Westshore Terminal in Vancouver, British Columbia, resulting in an

estimated 66,000 lbs[69] of coal to spill from the conveyer system. This event occurred outside of the study area and study period, and therefore was not included in development of outflow equations. The commodities spilled (or potentially spilled) have included those shown in Table 18. Fifty-eight percent of the incidents involved coal. One of the bulker incidents occurred in Washington waters, though outside of the area of the GPT study zones. In 2010, there was a spill of an unknown amount of coal at the United Harvest[70] facility on the Columbia River in Portland, Oregon[71]. The spill (or potential spill) causes have included those shown in Table 19.

Table 19: Dry Cargo Incidents Reported in US Waters 1985 – 2010[72]

Commodity	Barges	Bulkers	Total
Cement	1	1	2
Coal	23	8	31
Concrete	0	2	2
Fertilizer	4	0	4
Grains	3	1	4
Lime	1	1	2
Limestone	1	0	1
Sand	1	0	1
Sulfur	1	0	1
Taconite (Iron Ore)	1	3	4
Wood Chips	1	0	1
Total	**37**	**16**	**55**

Table 20: Causes of Dry Cargo Incidents in US Waters 1985 – 2010[73]

Cause	Barges		Bulkers		Total	
	Number	%	Number	%	Number	%
Impact Accident	0	0%	2	13%	2	4%
Other Non-Impact Error	32	86%	5	31%	37	70%
Transfer Error	5	14%	9	56%	14	26%
Total	**37**	**100%**	**16**	**100%**	**53**	**100%**

[69] Jackson, 2012.

[70] United Harvest is a grain terminal. Yet, the incident record reported the spilled commodity as coal.

[71] Also reported as Kalama, Washington.

[72] Includes inland navigable waterways. From ERC spill databases.

[73] Includes inland navigable waterways. From ERC spill databases.

Of the bulker incidents that occurred during the study period time (1995 – 2010), two (20%) involved groundings. Considering the data over the years 1985 – 2010, the percentage of groundings is 13%. Note that there were no reported incidents involving collisions or allisions that resulted in any spillage or potential spillage of dry cargo. There have been many collisions, allisions, and groundings of bulker vessels in US waters over the course of the 16-year time period, with an annual average of about 40 incidents per year that cause spillage of at least 50 gallons bunkers[74], while there have been only two groundings of bulkers have caused any spillage of dry cargo. There have been no incidents of collisions or allisions causing spillage or potential spillage of dry cargo. With no groundings of bulkers in Washington waters, this leaves a probability of zero for spills of dry cargo.

Another more conservative approach is presented for transfer error in Table 21. These are estimates of probabilities of spillage by cause *per transit* based on the number of incidents that occurred in the US over 16 years and the approximate number of port visits. It can be assumed that each port visit is one day, based on a rough estimate from Etkin, based on operators' experience. Actual durations would vary above and below this average. This would reduce and increase the estimated incident rate, respectively.

Table 21: Forecast Bulker Dry Cargo Transfer Error Rate From 1995 – 2010 Data

GPT Cause	Incidents in 16 years	Estimated Transit-Days in 16 years[75]	Probability of Incident Involving Spillage of Dry Cargo[76] Per Transit-Day
Transfer Error	4	155,200	0.0000258

The probability of a dry cargo spill is independent of the probability of a bunker spill in bulk carriers. The amount of spillage from the historical data is uncertain in most cases because of the lack of follow-up after the initial reports, and difficulties in estimating the amount of spillage after material sank into the water. In one case, 500 pounds of taconite (iron ore) was reported to have spilled from a bulker in the St. Lawrence River in 1995 due to unknown causes. The paucity and inaccuracy of data on spill amounts of dry cargo presents a challenge for estimating a probability distribution of spill volumes. There are also no outflow models to estimate the amount of dry cargo that would be spilled in different types of accidents. The dry bulk cargo spill probability given a transfer error is assumed to be the same as that of a bunker's and cargo oil, 0.92. Similarly, the spill probability of a bulker given an impact incident is assumed to be equal the spill probability of a single-hull product oil tanker given an impact incident: 0.68 for collisions and allisions, and 0.91 for groundings.

Incidents from 1985-2010 are used to estimate the volume and percentage outflow for each incident, Table 22. Incidents for which there was no vessel information were eliminated from the analysis. "Minor" spillages were conservatively (i.e., likely overestimating) assumed to be 20 lbs.

[74] Etkin, 2009.

[75] Based on estimated 9,700 port visits (transits) annually (from Etkin 2010).

[76] This is independent of the probability that there will be an incident that could cause a bunker oil spill.

Table 22: Dry Cargo Incidents (US 1985 – 2010) Analysis								
Vessel Name	**DWT**	**Material**	**Amount Spilled**					
			Pounds	**Metric Tons**	**Cubic Meters**	**Cubic Feet**	**% DWT**	**% Cargo Holding**
American Mariner	36,171	Coke	20	0.009	0.015	0.55	0.000025%	0.000030%
H. Lee White	35,019	Taconite	1	0.0005	0.0002	0.01	0.000001%	0.000002%
Henry Steinbrenner	13,910	Coal	5	0.002	0.003	0.11	0.000016%	0.000019%
William R. Roesch	19,800	Coal	50	0.023	0.031	1.09	0.000115%	0.000136%
Kaye E. Barker	25,345	Taconite	2	0.001	0.000	0.00	0.000004%	0.000004%
Tadoussac	28,800	Taconite	500	0.227	0.008	0.30	0.000788%	0.000938%
Andros	64,843	Lime	1,250	0.568	0.460	16.33	0.000875%	0.001042%
The Thornhill	37,939	Coal	20	0.009	0.012	0.44	0.000024%	0.000028%
Sanaga	28,215	Coal	20	0.009	0.012	0.44	0.000032%	0.000038%
Selendang Ayu	72,937	Grain	132,000,000	59,928	77,307	2,745,562	82%	97%
Barkald	49,463	Coal	20	0.009	0.012	0.44	0.000018%	0.000022%
Hellenic Sea	65,434	Coal	20	0.009	0.012	0.44	0.000014%	0.000017%

The typical amounts of reported (and verified) spillage by cause are shown in Table 23. Dry cargo spills are generally very small unless the entire vessel breaks up and/or sinks. The largest incident reported, that of the *Selendang Ayu*, involved a drift grounding in a storm in which the vessel broke up, spilled its bunkers, and released the bulk of its soybean cargo. No incidents involving dry cargo spillage (or potential spillage) during collisions or allisions have been reported.

Table 23: Amounts of Dry Cargo Spillage by Cause [77]			
Dry Cargo	**Amount Spilled** [78]		
	Short Tons	**Long Tons**	**Metric Tons (Tonnes)**
Transfer Error	0.0005 – 0.5	0.00045 – 0.446	0.00045 – 0.454
Other Non-Impact Error	0 – 0.25	0 – 0.223	0 – 0.227

[77] Includes inland navigable waterways. From ERC spill databases.

[78] One short ton = 2,000 lbs. One long ton = 2,240 lbs. One metric ton = 2,204.6 lbs.

Dry Cargo (Grain) Spill Volume Distributions

Dry cargo spill volume is derived by multiplying the bulk outflow percentage times the capacity as in Equation 20.

$$SV_d = O_d \cdot adjustedK_{coal} \qquad 20$$

Note that dry cargo capacities are adjusted for reduced capacity and assume coal as the commodity. The probability distribution of percentage outflow for transfer errors based on the extremely limited data available is shown in Table 24.

Table 24: Dry Cargo Outflow Probability from Transfer Errors

% Cargo Outflow	Probability $P(O_d)$	Cumulative Probability
0.000002%	0.125	0.125
0.000004%	0.125	0.250
0.000019%	0.125	0.375
0.000028%	0.125	0.500
0.000030%	0.125	0.625
0.000136%	0.125	0.750
0.000938%	0.125	0.875
0.001042%	0.125	1.000

A similar distribution could be used for other, non-impact error spills, albeit with the largest spillage adjusted to the largest spillage of that category as shown in Table 23. This would create a probability distribution of outflow as shown in Table 25.

Table 25: Dry Cargo Outflow Probability from Other, Non-Impact Errors

% Cargo Outflow	Probability $P(O_d)$	Cumulative Probability
0.000001%	0.125	0.125
0.000002%	0.125	0.250
0.00001%	0.125	0.375
0.000014%	0.125	0.500
0.000015%	0.125	0.625
0.000068%	0.125	0.750
0.000469%	0.125	0.875
0.000521%	0.125	1.000

For collisions and allisions, there are no data whatsoever on which to base an outflow percentage probability distribution. No incidents have been recorded in US waters between 1985 and 2010 in which dry cargo spilled during a collision or allision incident involving a bulk carrier, that is, not once in 26 years or 252,200 transit days for bulkers. Collisions and allisions have occurred in which bunker fuel spilled from a bulk carrier in US waters, but none

in which any dry cargo spillage was reported. During 1995 through 2010, there was one collision and one allision involving bulk carriers in the GPT study area. Neither of these incidents resulted in the spillage of any bunker fuel, nor the spillage of any dry cargo.

For groundings, two incidents have been reported in which there was spillage or potential spillage of dry cargo. One involved no spillage (of cement); the other involved the spillage of 97% of its soybean cargo. The bulk carrier *Selendang Ayu* incident, previously mentioned, is noted for the spillage of bunker oil (and much less so for the spillage of soybeans) in a drift grounding in the Aleutian Islands after engine failure (and power loss) during high winds and heavy seas. The winds were reported to be Beaufort force 7 to 11 (near gale to violent storm), averaging force 9 (47 – 54 mph). This would create waves of 23 – 32 feet up to 52 feet when at Beaufort 11.[79] In addition, due to the weather conditions and remoteness of the incident location, rescue tugs were unsuccessful in assisting the vessel.

These are highly unlikely conditions for most of the GPT study area with regard to weather conditions.

According to studies on Puget Sound conducted to determine the benefits of tug escorts for vessels,[80] there exists the potential for drift groundings within the GPT study area, but tug escorts would help to reduce the probability of drift groundings for all >300 GRT vessels by 65%.[81]

The fact that only one grounding incident in which any dry cargo spillage was recorded in 26 years in *all US waters*, or about once in an estimated 252,200 bulker transit days (0.000004 per transit day), demonstrates the highly unlikely probability of an event occurring in the GPT study area at all, let alone spilling a majority of its dry cargo. The fact that the weather conditions that led to the catastrophic drift grounding of the *Selendang Ayu* and its breakup and release of dry cargo in addition to its bunkers is highly unlikely in the GPT study area further supports that assumption.

Dry Cargo Sweeping as an Input

Note: This section is added as the research team considers it to be important information on dry cargo inputs to the environment and an important part of the environmental impact assessment of GPT as relates to dry cargo shipping. While the inputs from dry cargo sweeping and washing of decks are more part of "routine operations" than spillage per se, it is likely to be of concern to stakeholders in the Puget Sound area. Implementation and enforcement on regulations on dry cargo sweeping inputs (as part of the EPA Vessel General Permits or as a separate guidance from the US Coast Guard) are likely to be implemented in Washington in the future.

With bulkers there are continuous inputs of dry cargo due to sweeping and washing of decks that are part of standard operating procedures.[82] The only place in which these practices are at

[79] Based on National Transportation Safety Board (NTSB), 2004.

[80] US Coast Guard, 1999; The Glosten Associates, et al. 2005.

[81] US Coast Guard, 1999

[82] PMG and ERC, 2003.

all curtailed are in the nearshore areas (three miles from the shore)[83], especially in the Great Lakes.[84] In the Puget Sound, this would mean potential inputs of dry cargo sweepings in the areas shown in Figure 4.

Dry cargo sweeping practices are also somewhat controlled by the EPA Vessel General Permit regulations. In the proposed 2013 Vessel General Permit (Section 2.2.1) requires that vessel operations "minimize the introduction of on-deck debris into deck wash-down and runoff discharges." It is difficult to estimate what this really means in practice. Conservatively, one should assume that there are still dry cargo wash-downs occurring with all trips, with an average of 300 pounds (0.15 tons) of cargo being washed down with each transit, but that the largest inputs are not occurring due to better practices. A comprehensive study on dry cargo inputs conducted in 2003 found the levels of input with each bulker transport as shown in Table 26 and Figures 5 and 6.[85]

Table 26: Amounts of Dry Cargo Inputs from Wash-Down Operations

Commodity	Commodity Inputs (lbs) per Transit			
	Minimum Input	Maximum Input	Mean Input[86]	Median Input[87]
Iron	10	44,100	324	50
Coal/Coke	10	66,150	382	60
Stone	10	2,000	235	100
Limestone	10	1,000	108	10
Salt	10	600	177	25
Grain	10	4,410	194	20
Sand	10	600	150	20
Mill Scale/Slag	10	2,205	188	20
Potash	10	500	257	160
Gypsum	10	1,000	256	40
All Commodities	10	66,150	305	50

[83] Except for limestone carriers and those vessels for whom it would be a financial hardship not to do cargo sweepings in the nearshore 3-mile zone.

[84] 33 CFR§151 Docket No. USCG-2004-19621. [Federal Register Volume 77, Number 146 (Monday, July 30, 2012)

[85] PMG and ERC, 2003.

[86] Mean input is the average input (i.e., the total amount of input divided by the number of input operations).

[87] Median input is the input size for which 50% of inputs are the same size or smaller and 50% of inputs are larger.

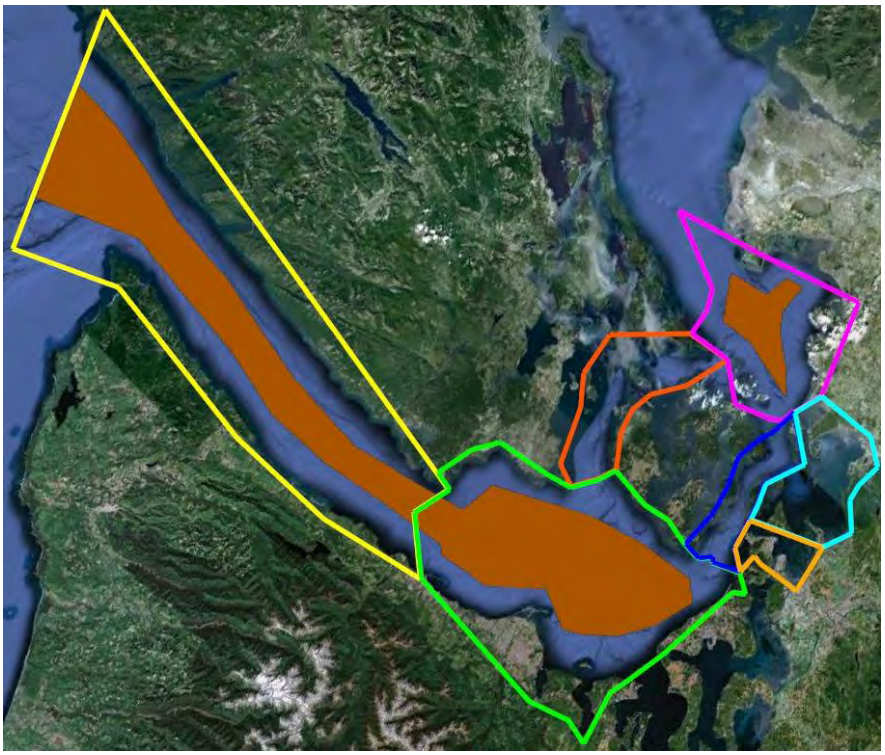

Figure 4: Areas of GPT study zone with potential for dry cargo sweepings inputs

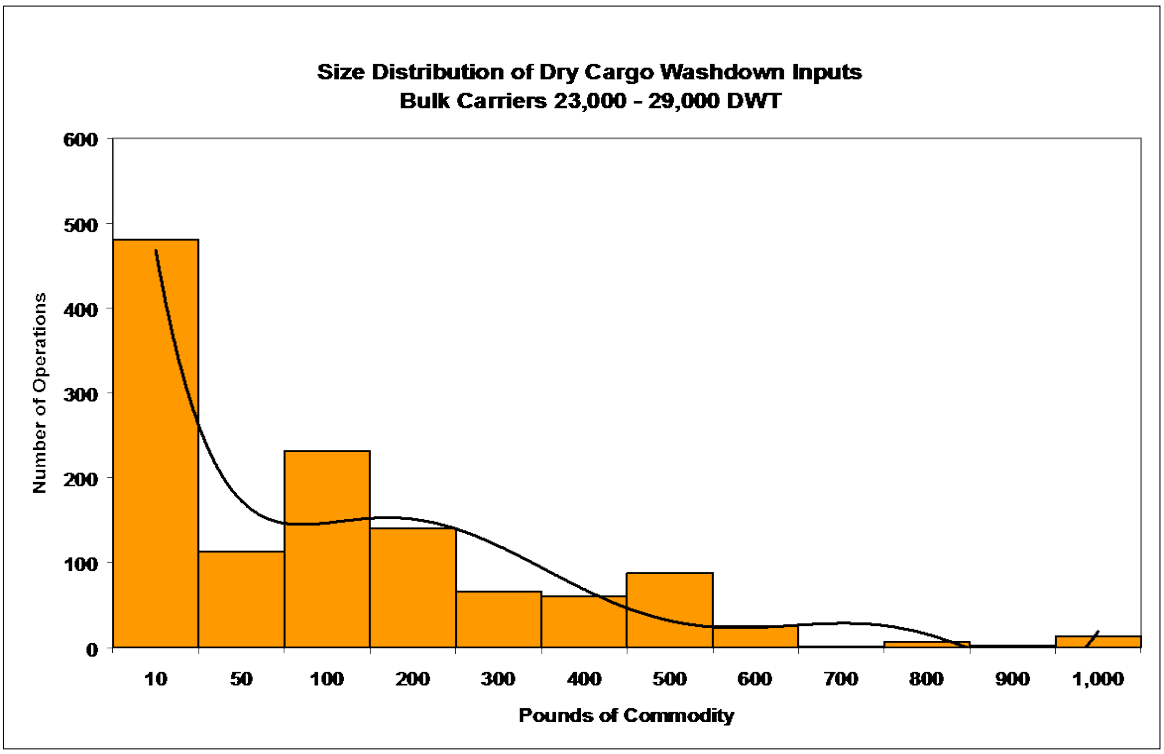

Figure 5: Size Distribution of Dry Cargo Wash-Down Inputs

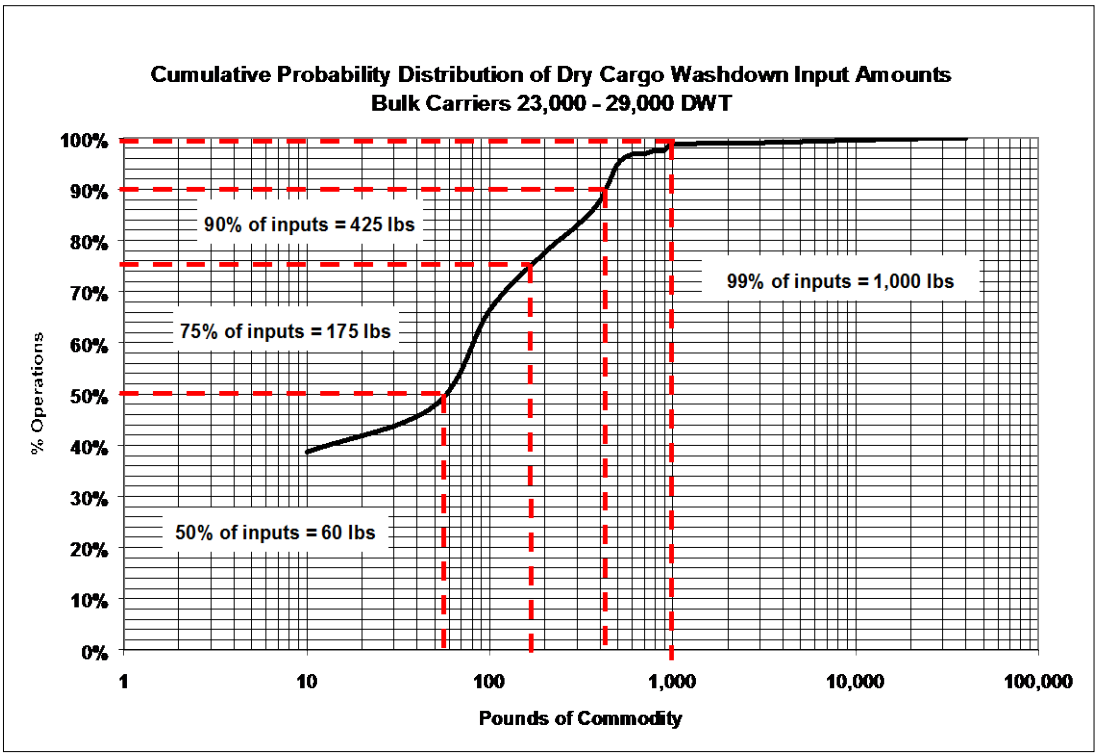

Figure 6: Cumulative Probability Distribution of Dry Cargo Wash-Down Amounts

Potential Impacts of Dry Cargo Spills

There are no specific studies on the impacts of dry cargo spills for the GPT study area. In fact, there are no records of any dry cargo spills in the area over the time period 1995 – 2010. With the potential increase of bulk carriers with the GPT, it is important to understand risks associated with any potential spillage. Data on dry cargo impacts have been summarized from studies conducted in the Great Lakes,[88] which are among the only data available on this topic.

The potential impacts of dry cargo inputs depend on the characteristics of the individual commodities. The degree of solubility in water, length of residence in water, degree of precipitation to the sea bottom, and toxicity to flora and fauna determine the potential for environmental impacts. Impacts from dry cargo transfer errors at dock would be expected to be limited to the immediate area of the transfer at the dock.

Nature of Bulk Commodity: Coal

Bituminous coal includes both anthracite (the hardest coal) and lignite (the softest coal). Its chemical formula is S/C102H78O10N2. Coal typically is composed of fixed carbon (50–72%), fused polycyclic aromatic hydrocarbons (PAHs) (17–37%) and 5–13% of the following ingredients, each of which makes up a proportion of the whole in the range shown – water (3-8%), sulfur (0.5–1.8%), and elemental and compounds of hydrogen (4.2–5.2%) - nitrogen (1.3–1.6%), and chlorine (0.03–0.2%). Coal from the Powder River Basin, the potential source of GPT-bound coal, is sub-bituminous, with a low sulfur dioxide content. The percentages of total PAHs in sub-bituminous coal from the Northern Great Plains (i.e. the Powder River Basin) have been reported to be 5 to 14% (Achten & Hofman, 2009)[89].

After deposition, coal breaks into component fractions, including up to 1.7 mg/gram of PAHs, which are very persistent in sediments. PAHs can be released from coal into water with serious impacts on biota. PAHs are known to have serious impacts on ecosystems and many organisms. PAHs are only slightly soluble in water[90]. There is little data on the physical and chemical changes in coal when it enters marine waters. PAHs as an environmental contaminant are not well studied.[89] The mechanism and impact of coal deposition and breakdown is not part of this study.

Nature of Bulk Commodity: Petroleum Coke

Petroleum coke is a derivative of petroleum that contains elemental carbon and residual mineral impurities. It is relatively insoluble in water but does eventually leach out various components. Leachate from petroleum coke can contain a variety of heavy metals that can impact organisms at relatively low doses. The toxicity of the carbon portion of coke is relatively low, having been measured at LD_{50} > 5,000 mg/kg (rat).

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[88] PMG and ERC, 2003.

[89] Achten & Hofman, 2009.

[90] Neff, 1979 and Moore & Ramamoorthy, 1984.

Nature of Bulk Commodity: Metals and Ores

Ores are minerals or aggregates of minerals that contain a variety of elements – particularly metals – that can be extracted through refining and smelting processes. The ores have different potentials to cause environmental impacts. The magnitude of their impacts depends on their chemical and physical composition. All ores have the potential to accumulate in the benthic regions of the sea (bottoms) and cause transient smothering or crushing of organisms as they fall. The accumulation of the pieces of ore can change the benthic substrate enough to impact the diversity of benthic organisms. The accumulations can create a variety of new habitats and reproductive areas for fish and other organisms.

Copper ore (Cu) is soluble in acidic water but precipitates at pH > 6.5. The maximum safe concentration for aquatic life is 2 µg/L (micrograms per Liter) or 0.002 ppm. Concentrations as low as 16 ppm can cause impacts with severe impacts at 110 ppm. The residence time of mobilized copper in water is 89 years.

Nickel ore is soluble in water of neutral pH. The maximum concentration safe for aquatic life is 65 µg/L (0.065 ppm). Concentrations as low as 16 ppm can cause impacts. Severe impacts occur at 75 ppm. The residence time of mobilized nickel is unknown.

Lead ore, known as galena, is a simple compound composed of lead and sulfur (PbS). It also may contain small amounts of silver (Ag), antimony (Sb), arsenic (As), and copper (Cu). It is nearly insoluble, but acidic and anoxic conditions, which are common in the Great Lakes, will increase the leaching rate. It is very toxic and can have devastating long-term impacts. The maximum safe concentration for aquatic life is 2 µg/L (0.002 ppm). Concentrations as low as 31 ppm can cause impacts, with severe impacts at 250 ppm. The residence time of mobilized lead is unknown, though evidence seems to point at a relatively long life.

Iron ore is the most commonly carried metallic ore. It comes in different forms. There are two main types of iron ore – hematite and magnetite. Hematite typically contains iron oxide (Fe_sO_3, 92.2%); silica (SiO_2, 5.4%); aluminum oxide (Al_2O_3, 1.4%); and traces (< 0.14% each) of phosphorus (P_2O_3), manganese oxide (MnO), calcium oxide or lime (CaO), potassium oxide (KO), sodium oxide (NaO), and sulfur (S). The chemical composition of magnetite is $(Fe,Mn,Mg,Zn,Ni)^{2+}$ $(Fe,Al,Cr,Mn,V)^{3+}{}_2O_4$). It also may contain impurities: titanium, manganese, magnesium, zinc, nickel, aluminum, chromium, and vanadium. Iron oxides tend to leach slowly from iron ores to form stable ferric hydroxide ($Fe(OH)_3$) particles that can precipitate or remain suspended. Acidic and anoxic conditions increase the leaching rate. The solubility of iron ore varies. There are no toxicological data available for iron ore. The maximum safe concentration for aquatic life is 300 µg/L (0.3 ppm), but concentrations as low as 31 ppm can cause impacts. Severe impacts can occur at 40,000 ppm. The residence time of mobilized iron is 160 days.

Taconite is a low-grade iron ore pelletized for blast furnace reduction. Basically, it is an iron-bearing chert containing 25–30% hematite and magnetite. It typically contains iron (65.6%); silica (5.4%); and traces (< 0.3% each) of phosphorus, manganese, calcium oxide, potassium oxide, sodium oxide, and sulfur. It generally is insoluble in fresh water, but slightly soluble under acidic conditions. Since it is composed mainly of iron ores, it has the same basic environmental impacts as hematite and magnetite.

The two common zinc ores are sphalerite and marmatite. Generally they are composed of zinc sulfide (ZnS, 85–89%), iron sulfide (FeS, 8–10%), silica (SiO_2, 1–2%), copper (Cu, 0.3–0.8%), and cadmium (Cd, 0.1%). Zinc will exist as an ion, but at a neutral pH, the solubility is relatively low. It will be released slowly at neutral pH and will tend to precipitate. Acidic and anoxic conditions will increase the leaching rate. Zinc ore is highly soluble in acidic water. It has a relatively low toxicity (LD_{50} > 5,000 mg/kg). The maximum concentration safe for aquatic life is 320 µg/L (0.32 ppm), but concentrations as low as 120 ppm can cause impacts. Severe impacts occur at 820 ppm. The residence time of mobilized zinc is 37 years.

The most common aluminum ore is bauxite. Its chemical composition is aluminum hydroxide ($Al(OH)_2$); aluminum oxide monohydrate ($Al_2O_3 \cdot H_2O$); silica (SiO_2); iron oxide (Fe_2O_3); and traces of calcium and magnesium ($CaO \cdot MgO$), titanium (TiO_2), and potassium and sodium ($K_2O \cdot Na_2O$). Aluminum ore is soluble and mobilized in acidic water. Acidic and anoxic conditions will increase leaching rate of the metals in bauxite. The maximum concentration safe for aquatic life is 5 µg/L (0.005 ppm). Concentrations that cause impacts are unknown. There are no known toxic effects. The residence time of mobilized aluminum is 113 days.

Manganese ore is composed of manganese oxide (MnO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), and silica (SiO_2). It has a relatively low solubility (< 0.1%) but will dissolve in water regardless of pH. No toxicity information available. Manganese is oxidized and sedimented quickly. Acidic and anoxic conditions will increase the leaching rate. Manganese ore oxidizes and sediments quickly when dissolved. Concentrations as low as 460 ppm can cause impacts. Severe impacts occur at 1,100 ppm. The residence time of mobilized manganese is 292 days.

Nature of Bulk Commodity: Inorganic Salts

Salt or halite is composed primarily of sodium chloride (NaCl), but often contains sodium hexacyanoferrate ($C_6FeN_6Na_4 \cdot 10H_2O$), which is added an anti-caking agent. Sodium hexacyanoferrate releases hydrogen cyanide (HCN) when dissolved in water (Ohno, 1990). Cyanide is extremely toxic to aquatic life – LC_{50} 96 hours of 0.123mg/L (fathead minnows), LD_{100} of 10 mg/kg (rat), and LD_{50} of 1.1 mg/kg (rabbit).Sodium chloride is highly soluble in water.

Fluorspar is an inorganic salt composed of fluorite or calcium fluoride (CaF_2), with traces of silica (SiO_2) and calcium carbonate ($CaCO_3$). It has a relatively low solubility in water (16 mg/L) and thus generally is not available to aquatic life. Its toxicity is relatively low and has been measured at LD_{50} of 4,250 mg/kg (rat). Since calcium fluoride is not very soluble in water, it is not available to aquatic life.

Potash is another inorganic salt compound commonly transported by bulk carriers. There are various potassium-containing compounds that are called potash, including potassium chloride (KCl), also known as potassium muriate; potassium hydroxide (KOH); and potassium carbonate ($K_2 CO_3$), also known as salt of tartar, carbonic acid, and dipotassium salt. Each compound has completely different characteristics.

Another inorganic salt compound is potassium chloride, which is completely soluble in cold water, but tends to become incorporated into mineral structure after dissolution. It is not listed as hazardous material under the Clean Water Act (CWA). Its toxicity has been measured at LD_{50} of 1,500 mg/kg (mouse) and LD_{50} of 2,600 mg/kg (rat).

Potassium hydroxide is completely soluble in cold water, but it chemically reacts with water. Heat is generated if it comes in contact with water or carbon dioxide in the air. It is more toxic than potassium chloride, having a measured toxicity of LD_{50} of 273 mg/kg (rat). (*Note: Considering the reactivity of this compound, it is unlikely to be carried in open containers in vessels.*)

Potassium carbonate also is completely soluble in cold water; however, like potassium chloride, it tends to become incorporated into mineral structures after dissolution. It is less toxic than potassium hydroxide, with toxicity levels measured at LD_{50} of 1,870 mg/kg (rat) and LD_{50} of 2,510 mg/kg (mouse).

Nature of Bulk Commodity: Organic Materials

Like fertilizers, organic materials can cause or contribute to eutrophication and the overproduction of plants such as algae. Decomposing organic matter can deplete benthic oxygen levels, thus creating anoxic conditions, which can damage aquatic animals. The decomposition also can cause the formation of anaerobic sludge that releases toxic methane and hydrogen sulfide.

As organic materials, grains can cause or contribute significantly to eutrophication and benthic oxygen depletion.

Wood chips and pulp are common commodities on bulk carriers. Processed wood consists of cellulose fibers alone or cellulose with lignin. As organic wood chips and pulp, processed wood can cause or contribute significantly to eutrophication and benthic oxygen depletion. Most portions of wood are relatively insoluble, but eventually can break down in water. Lignin in wood pulp can discolor water.

Wood chips and pulp for paper production can contain Dioxin (dioxinium perchlorate, hydronium perchlorate, or perchloric acid, HClO4), a chemical used in processing. Dioxin is highly soluble in water and known to be extremely environmentally hazardous (LC_{100} for *Cyprinun caprio* is 180 ppm/24 hrs at 25ºC). Dioxin and other organic processing chemicals in wood pulp and paper can be extremely injurious to aquatic life.

Nature of Bulk Commodity: Sand, Rocks, and Gravel

Rocks are aggregates that can be composed of a large number of compounds, including metallic ores, and thus can have the impacts of metallic ores as described above. Gravel is composed of crushed rocks. Sand generally is composed of quartzite or silica dioxide (SiO_2). This compound can also be a major component of rocks.

Sand and many of the components of rocks and gravel generally are insoluble. They have no known toxicity and no direct or indirect effects on animals. Their release from a moving vessel briefly may increase turbidity in the water column and smother bottom-dwelling animals as the particles and pieces fall. Accumulations of aggregates and large pieces of building materials could increase habitats for fish by increasing the roughness of the bottom sediment and increasing the diversity of bottom habitats.

Nature of Bulk Commodity: Limestone/Dolomite

Limestone generally is composed of calcium carbonate ($CaCO_3$) or magnesium carbonate ($MgCO_3$), and calcium/magnesium dicarbonate ($CaMg(CO_3)2$). The dolomite form of limestone includes magnesium. It also may have trace elements – often < 1% silica (SiO_2). Different components of limestone can leach out in water. Solubility increases as pH decreases (more acidic). Calcium carbonate has a solubility of 0.001%. Magnesium carbonate has a solubility of 0.01%. Calcium carbonate has a low potential to affect aquatic organisms. Acute aquatic effects have been measured only at very high concentrations (48-hour LC50 of 56,000 mg/L (mosquito fish) and LD50 of 6,450 mg/kg (rat)). Calcium carbonate is not expected to cause oxygen depletion in aquatic systems. No toxicological data are available on magnesium carbonate.

Environmental Significance of Dry Cargo Inputs

Currently, no definitive methodology exists for measuring environmental impact of measured dry cargo discharges since relatively little is known about impacts of these commodities on particular habitats and populations. Most studies on pollutant input have focused on petroleum. There have been two major, but *inconclusive*, studies related to impacts of dry cargo discharges in the Great Lakes: the 1993 study commissioned by the Canadian Coast Guard (CCG) [91] and the 1993 National Oceanic and Atmospheric Administration (NOAA)/Great Lakes Environmental Research Laboratory (GLERL) workshop.[92]

The 1993 CCG study focused on inputs that occurred in ports rather than in shipping lanes. The potential and suspected environmental impacts of dry cargo sweepings and discharges were summarized based on surveys of literature and available studies. The major environmental concerns of study were:

- **Eutrophication:** Oversupply of nutrients can cause increased plant production, which decreases water clarity and quality. Decomposition in shallow water can then decrease oxygen levels.
- **Aquatic habitats:** Pollutants that have a high biological oxygen demand (i.e., use up oxygen to decompose in the water) can deplete oxygen and degrade habitats for fish and other aquatic fauna. Suspended solids can increase turbidity and affect plant production and animal behavior.
- **Loss of wetlands:** Loss of wetland habitats because of discharge of pollutants decreases nursery and brood rearing areas for fish and waterfowl. Loss of wetlands also decreases the cleansing of water before it enters the water.
- **Esthetics:** Visual attributes can be affected adversely by discharges.
- **Toxic substances:** The presence of toxic substances such as heavy metals and organic compounds can have serious environmental impacts.
- **Other issues:** Thermal pollution, water levels, erosion, and loss of habitats are also of concern.

[91] Melville Shipping, 1993a, 1993b.

[92] Reid and Meadows, 1999.

Additional conclusions about specific commodities included the following:

Metals

- Spilled metals generally are bound in ores, thus making them not readily mobile or available to enter reactions that would make them available to organisms.
- The metals would persist in the lakes for a long time, creating long-term (more than 5 years) effects.
- Anoxic conditions in Lake Erie in particular could lead to the release of iron and other metals from the ore.

Coal

- Spilled coal slowly will release small amounts of PAHs in very localized areas.
- Coal would persist, creating long-term (more than 5 years) effects.

Grain/Wood Pulp

- Large amounts of decomposing organic matter can deplete benthic oxygen levels, thus damaging aquatic animals and also causing the creation of anaerobic sludge that releases toxic methane and hydrogen sulfide.
- The biological oxygen demand of spilled grain and wood pulp is small because the individualized spills are small.
- Increases in biological oxygen demand from grain, pulp, and ore metals are small when compared with increases from industrial inputs.

Aggregates/Building Materials

- Finer aggregate particles can cause localized smothering of benthic animals with transitory effects.
- Accumulation of large pieces of aggregates (e.g., rock, limestone) could increase habitats for fish by increasing the roughness of the bottom sediment, thereby increasing the diversity of bottom habitats.

Salts

- Sodium concentrations in the Lakes already are elevated (by a factor of three in the last 50 years), thus making additional input of sodium chloride (halite) a concern.
- Road salt and other forms of halite often contain anti-caking agents, such as sodium hexacyanoferrate (III) that can release toxic cyanide into the water.
- Potash (potassium chloride) is very soluble but tends to incorporate into mineral structure, thus making it less of a threat.

The CCG study included measurements and estimates of inputs from shipping (in Canadian ports only) and evaluations of the potential impacts of the inputs. The major conclusions of the CCG study on the impacts of the inputs based on the amounts involved were as follows:

- Small quantities of dry cargo are spilled in any one event.
- Spills of materials in ports are very small, and spills are diluted with large amounts of water.

- The effects of the spills are probably very small.
- Ships probably have contributed a very small percentage of the material that has accumulated in sediments and that presently is dissolved in the water.
- Many ports have limited water circulation so that materials spilled will tend to accumulate in the harbor, thereby contributing to existing problems.

The cumulative impact of all pollutants from all sources has led to the severe degradation of the overall environment of the Great Lakes. The impacts of any one of these spills or of all spills over the course of 1 year probably are negligible to minor in harbors.

The minor impacts of these spills would have a widespread prevalence throughout the Great Lakes.

In 1993, the NOAA/GLERL workshop was convened to discuss the environmental implications of dry cargo sweeping from vessels in the Great Lakes, including: risk to fisheries and habitats, sediment accumulation and toxicity, and water-column impacts. The workshop concluded that residues of cement, grain, coarse limestone, and wood pulp or chips are not likely to cause serious environmental damage to or produce negative impacts on plants and animals. However, the workgroup also concluded that residues of taconite pellets and finely divided limestone, coal, sand, and possibly slag adversely may alter coarse and rocky substrate habitat by filling interstitial spaces (see Table 27).

Table 27: Suspected Ecological Impacts of Dry Cargo on Fishery Resources and Habitats [93]

Commodities	**Risks to Bottom Habitats** [94]			
	Plant Bed	**Mud/Silt**	**Sand**	**Rocky Shoals**
Iron ore	1, 3	1, 3?	0	1, 6
Coal-coke	5b, 3, 1	3, 1, 5b	3, 1, 6	3, 1, 6
Limestone	1?	5a, 5c	5c, 6 (site dependent)	5c, 6
Gypsum	0?	1?	0	1?
Potash	4a	4a	4a	4a
Fertilizer	4a	4a	4a	4a
Urea-SD	Minor	Minor	Minor	Minor
Grain	4a	Minor	?	?
Float dust	2?	2?	2?	2?

[93] Reid and Meadows, 1999.

[94] 1 = smothering/suffocation, 2 = osmotic stress, 3 = toxicity (a = acute, b = chronic), 4 = nutrient enrichment (a = enhanced productivity, b = over-enrichment and algal blooms), 5 = bottom substrate change (a = physical, b = biological, c = habitat creation), 6 = filling of interstitial spaces in bottom substrate, ? = impact unknown.

Table 27: Suspected Ecological Impacts of Dry Cargo on Fishery Resources and Habitats [93]				
Commodities	**Risks to Bottom Habitats [94]**			
	Plant Bed	**Mud/Silt**	**Sand**	**Rocky Shoals**
Salt	3?	3?	3?	3?
Wood pulp	?	?	?	?
Sand	0	1?	0	1, 6 (minor)
Other mill scale	3?	1, 3	1, 3	?
Slag	3?	1, 3	1, 3	1, 6

The workshop concluded that there is a critical lack of knowledge and a need for research on the toxic effects of iron ore, taconite pellets, coal, coke, rock salt, mill scale, and slag on plants and animals. The workgroup further concluded that specific research is needed to determine and evaluate properly the environmental implications of cargo residues, and recommended a series of studies to accomplish this, including detailed chemical analyses of specific commodities, laboratory experiments (toxicity bioassays and determination of oxygen demand), and related field testing and measurements.

The workshop identified four key questions that should be addressed in determining the potential effects of dry cargo residues that reach and accumulate in soft-bottom sediments:

- Does cargo sweeping adversely affect bottom sediments or biota that resides in or near the sediments?
- What are the chemical compositions of the cargo commodities?
- Are the deposited materials in the sediment from cargo sweeping activities toxic or bioaccumulated by benthic organisms?
- Is deposition of cargo residues changing the physical structure of the bottom sediments (e.g., increasing the amount of hard substrate), therefore changing the habitat for the benthos?
- How do cargo-sweeping activities relate to and compare with other discharges of similar or the same compounds?

Since insufficient data and information currently exist to answer these questions, the workgroup developed a two-tiered approach for conducting a future assessment: (I) assess the toxicity and bioaccumulation of cargo residue-associated contaminants to benthic communities, and (II) then assess cause-and-effect relationships and factors controlling the bioavailability of contaminants associated with cargo residues. The workgroup concluded that *if* impacts of cargo residues on benthic communities *were* observed, Tier II studies would be required to determine cause-and-effect relationships and factors controlling the bioavailability of contaminants associated with cargo residues deposited on soft-bottom sediments. The workgroup then recommended a series of field studies. To date, these studies have not been conducted.

The Water-Column Impacts Workgroup evaluated dry bulk commodities for both toxicological and water-quality effects (Table 28). The workgroup concluded that the short-term changes in

local turbidity that may result from cargo sweepings would be of little demonstrable environmental consequence within the water column. The workgroup concluded that the potential for *toxic* chemicals to be introduced into the water column from dry cargo residues or from any materials used in treating those commodities could not be evaluated properly with currently available information. The workgroup expressed additional concerns regarding possible effects on biotic communities growing proximal to air-water and sediment-water interfaces.

Table 28: Potential Water-Column Effects from Dry Bulk Commodities [95]

Commodity	Toxic Effects	Water Quality Effects	Proposed Severity Rank [96]
Taconite/Iron Ore	Suspected/unknown	Suspected/unknown	1
Coal	Suspected/unknown	Suspected/unknown	2
Coke	Suspected/unknown	Suspected/unknown	2
Limestone	None	Suspected/unknown	10
Gypsum	None	Suspected/unknown	10
Potash	Suspected/unknown	Suspected/unknown	4
Fertilizer	Suspected/unknown	Suspected/unknown	5
Grain	None	Suspected/unknown	6
Rock Salt	Suspected/unknown	Suspected/unknown	3
Sand/Gravel	None	Suspected/unknown	10
Clay and Refractories	None	Suspected/unknown	10
Wood Pulp	Suspected/unknown	Suspected/unknown	9
Slag	Suspected/unknown	Suspected/unknown	7
Mill Scale	Suspected/unknown	Suspected/unknown	8

The major issues identified with respect to water-column impacts were as follows:

- **Cargo statistics:** Detailed information is required regarding identification of bulk cargos carried and regularly washed down.
- **Chemical composition of cargo:** Detailed information is needed to prioritize research into possible environmental effects.
- **Physical characteristics of discharge plume:** Chemical and biological analyses are needed in context of physical properties of discharge plumes.
- **Environmental effects:** Information is needed on bioavailability, solubility, toxicity, and nutrient potential of the materials found in dry bulk cargos.

The workgroup recommended that necessary statistical data on materials shipped, detailed chemical composition of the materials, and amounts of these materials discharged to the waters of the Great Lakes because of cargo sweepings under normal and worst-case conditions be

[95] Reid and Meadows 1999.

[96] Highest concern over commodities with ranking of 1, lowest with ranking of 10.

compiled. The workgroup concluded that the dispersal of materials from cargo sweepings, once introduced into the water column, is known insufficiently. Overall, the workgroup concluded that a series of additional studies would need to be conducted before a reliable environmental risk assessment could be made. None of the additional studies has been completed as of the writing of this report.

Relative Impact Rankings

Based on the data above, ERC rated the chemical and physical characteristics of the major dry cargo commodities by their propensity to cause various types of environmental impacts (as shown in Table 29). The rating scale is such that "5" is the highest impact and "1" is the lowest impact. For each of four basic benthic (bottom) habitat types – plant bed, mud-silt, sand, and rocky shoals – the commodities were rated based on impacts of smothering, toxicity, nutrient enrichment, and substrate change. Water-column impacts included toxicity and water quality. Sediment impacts included accumulation and sediment toxicity.

Total ranks were calculated by adding the ranks for individual impact components for each habitat, water column, and sediment. Total impact ranking scores were calculated for each commodity by calculating a grand total of all individual environmental component scores (i.e., the additive value of each total rank for the four habitat types added to the total ranks for water column and sediment).

Coal and coke received the highest total impact score based on their potential toxicity (primarily from leaching PAHs) and their capacity to cause smothering as well as substrate change. Iron ore also received a relatively high impact score based on its toxicity and potential to cause smothering and substrate change.

It is important to view these ranks and scores as relative numbers rather than as absolute numbers. For example, inputs of the coal or coke are not necessarily twice as harmful as equal volumes or weights of sand or stone because the impact score of coal and coke is 84 and the score for sand and stone is 42. The ranks were computed as a method for compiling the various impact components (e.g., toxicity, smothering) into a single relative score to be able to compare the potential impacts of inputs measured.

Table 29: Ranked Relative Impacts of Dry Cargo Commodities [97]								
Impact Types	Impacts	Commodity Impact Ranking [98]						
		Iron Ore	Coal Coke	Limestone	Cement Sand Stone	Grain	Potash	Salts
Benthic Habitat Plant Bed	Smothering	5	5	3	5	1	1	1
	Toxicity	5	5	1	1	1	1	3
	Nutrient Enrichment	1	1	1	1	5	5	1
	Substrate Change	1	5	1	1	1	1	1
	Total Rank	12	16	6	8	8	8	6
Benthic Habitat Mud-Silt	Smothering	5	5	1	5	1	1	1
	Toxicity	5	5	1	1	1	1	3
	Nutrient Enrichment	1	1	1	1	3	5	1
	Substrate Change	1	5	5	1	1	1	1
	Total Rank	12	16	8	8	6	8	6
Benthic Habitat Sand	Smothering	1	5	1	5	1	1	1
	Toxicity	1	5	1	1	1	1	3
	Nutrient Enrichment	1	1	1	1	3	5	1
	Substrate Change	1	5	5	1	1	1	1
	Total Rank	4	16	8	8	6	8	6
Benthic Habitat Rocky Shoals	Smothering	5	5	1	5	1	1	1
	Toxicity	1	5	1	1	1	1	3
	Nutrient Enrichment	1	1	1	1	3	5	1
	Substrate Change	5	5	5	3	1	1	1
	Total Rank	12	16	8	10	6	8	6
Water Column	Toxicity	5	5	1	1	2	4	3
	Water Quality	5	5	1	1	2	4	3
	Total Rank	10	10	2	2	4	8	6
Sediment	Accumulation	5	5	3	5	1	1	1
	Sediment Toxicity	5	5	1	1	1	2	3
	Total Rank	10	10	4	6	2	3	4
Total Impact Ranking		60	84	36	42	32	43	34

[97] From PMG and ERC, 2003.

[98] Relative ranking of commodity-specific impact within habitat section; 5 = *highest* impact, 1 = *lowest* impact.

References

Achten, C., & Hofman, T. (2009). "Native Polycyclic Aromatic Hydrocarbons (PAH) in Coals - A Hardly Recognized Source of Environmental Contamination." *Science of the Total Environment, 407*(8), 2461-2473.

Barone, M., Campanile, A., Caprio, F., & Fasano, E. (2007). "The Impact of the new MARPOL Regulations on Bulk Carrier Design." *Proceedings of the Second International Conference on Marine Research and Transportation*, 83-92.

Behrens, H., Endresen, Ø., Mjelde, A., & Germann, C. (2003). *Environmental Accounting System for Norwegian Shipping - EASNoS Phase 1.* Hovik, Norway: Det Norske Veritas (DNV).

Eide, M., Endresen, Ø., Breivik, Ø., Brude, O., Ellingsen, I., Røang, K., Hauge, J., and Brett, P.O. (2007). "Prevention of Oil Spill from Shipping by Modeling of Dynamic Risk." *Marine Pollution Bulletin, 54*(10), 1619-1633.

Etkin, D. S. (1999). *Oil Spill Response Reference Guide.* Arlington, MA: Cutter Information Corp.

Etkin, D. S. (2001). *Analysis of Washington State Vessel and Facility Oil Discharge Scenarios for Contingency Planning Standards.* Environmental Research Consulting. Prepared for Washington Department of Ecology, Spills Program, Contract No. C0200096.

Etkin, D. S. (2002). "Analysis of Past Marine Oil Spill Rates and Trends for Future Contingency Planning." *Arctic & Marine Oilspill Program Technical Seminar. 1*, 227-252. Environment Canada, 1999.

Etkin, D. S. (2003). "Analysis of US Oil Spill Trends to Develop Scenarios for Future Contingency Planning." *International Oil Spill Conference*, Vol. 2003 (1), 47–61, American Petroleum Institute.

Etkin, D. S. (2006). *Trends in Oil Spills from Large Vessels in the US and California with Implications for Anticipated Oil Spill Prevention and Mitigation Based on the Washington Oil Transfer Rule.* Environmental Research Consulting. Prepared for Washington Department of Ecology, Olympia, WA, Contract No. C040018.

Etkin, D. S. (2009). *Analysis of US Oil Spillage*. American Petroleum Institute, Publication 356.

Etkin, D. S. (2009). *Oil Spill Risk in Industry Sectors Regulated by Washington State Department of Ecology Spills Program for Oil Spill Prevention and Preparedness.* Environmental Research Consulting. Prepared for the Washington Department of Ecology.

Etkin, D. S. (2010.) "Worldwide Analysis of In-Port Vessel Operational Lubricant Discharges and Leakages." *Proceedings of the 33rd Arctic & Marine Oilspill Program Technical Seminar:* pp. 529 – 554.

Etkin, D. S. (2013). *Gateway Pacific Terminal Vessel Traffic and Risk Assessment Study: Characterization of Historical Vessel Incidents (Task 4).* Environmental Research Consulting.

Etkin, D. S., & Michel, K. (2003). *Bio-Economic Modeling of Oil Spills from Tanker/Freighter Groundings on Rock Pinnacles in San Francisco Bay: Vol II; Spill Volume Report.* Environmental Research Consulting. Prepared for US Army Corps of Engineers, Sacramento District, Contract DACW07-01-C-0018.

Etkin, D. S., & Neel, J. S. (2001). Investing in Spill Prevention - Has It Reduced Vessel Spill and Accidents in Washington State? *Proceedings of 2001 International Oil Spill Conference. 2001, No. 1*, pp. 47-56. American Petroleum Institute.

Etkin, D. S., French-McCay, D., & Beegle-Krause, C. J. (2009). Oil Spill Risk Assessment – Probability and Impact Analyses with Future Projections. *Proceedings of the 32nd Arctic & Marine Oillspill Program Technical Seminar*, pp. 683-704.

Etkin, D. S., French-McCay, D., Whittier, N., Subbayya, S. and Jennings, J. (2002). Modeling of Response, Socioeconomic, and Natural Resource Damage Costs for Hypothetical Oil Spill Scenarios in San Francisco Bay. *Proceedings of the 25th Arctic & Marine Oillspill Program Technical Seminar*: 1,075–1,102.

Etkin, D. S., French-McCay, D., Whittier, N., Subbayya, S., & Jennings, J. (2002). Modeling of Response, Socieconomic, and Natural Resource Damage Costs for Hypothetical Oil Spill Scenarios in San Francisco Bay. *Proceedings of the 25th Arctic and Marine Oilspill Program Technical Seminar*, 1075-1102.

French-McCay, D., Beegle-Krause, C. J., Rowe, J., Etkin, D. S., Moore, C., & Michel, K. (2006). *Evaluation of the Consequences of Various Response Options. Using Modeling of Fate, Effects and NRDA costs for Oil Spills into Washington Waters, Phase II, Volume II. Summary of Results for All Scenarios.* Washington Department of Ecology.

French-McCay, D., Beegle-Krause, C. J., Rowe, J., Etkin, D. S., Moore, C., & Michel, K. (2008). *Oil Spill Risk Analysis Review.* Report JLARC 08-1. Applied Science Associates, Inc., Environmental Research Consulting, Herbert Engineering Corp. Prepared for the State of Washington Joint Legislative Audit and Review Committee.

French-McCay, D., Rowe, J., Whittier, N., Acsh, R., Sankaranarayanan, S., Borowik, A., Suàrez,. C., and Etkin, D. S. (2006). *Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA Costs for Oil Spills in Washington Waters, Phase II.* Applied Science Associates, Inc. and Environmental Research Consulting. Prepared for the Washington Department of Ecology.

French-McCay, D., Rowe, J., Whittier, N., Sankaranarayanan, S., Suárez, C., & Etkin, D. S. (2005). *Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects, and NRDA Costs for Oil Spills in Washington Waters Vol I: Model Description, Approach, and Analysis.* Applied Science Associates and Environmental Research Consulting. Prepared for Washington Department of Ecology.

Herbert Engineering Corp. and Designers & Planners, Inc. (2003). *Evaluation of Acidental Oil Spills from Bunker Tanks (Phase 1).* Report No. SSC-424 Prepared for US Coast Guard Ship Structure Committee and Research, and US Coast Guard Development Center.

Herbert Engineering et al. (1999). *Regulatory Assessment: Use of Tugs to Protect Against Oil Spills in the Puget Sound Area.* Prepared for the US Coast Guard. Report No. 9522-003.

International Association of Classification Societies (IACS). (2006). *Common Structural Rules for Bulk Carriers*. IACS, London, UK. 554 p.

International Maritime Organization (IMO). (1995). *Interim Guidelines for Approval of Alternative Methods of Design and Construction of Oil Tankers under Regulation 13F(5) of Annex I of MARPOL 73/78. Resolution MEPC.66(37).* Adopted September 14, 1995.

Jackson, E. (2012) "Westshore Terminals spends weekend cleaning up coal after ship crash." *Metro News Canada.* December 9, 2012. Accessed online, August 26, 2013. http://metronews.ca/news/vancouver/471436/westshore-terminals-spends-weekend-cleaning-up-coal-after-tanker-crash/#

Lotsberg, I. (2006). Assessment of Fatigue Capacity in the New Bulker Carrier and Tanker Rules. *Marine Structures, 19*, 83-96.

Melville Shipping. (1993a). *Review and Investigation of Procedures Governing the Discharge of Non-Regulated Cargo Residues from Ships into the Great Lakes.* Prepared for the Canadian Coast Guard, Ship Safety by Melville Shipping, Ltd. in association with LGL Ltd., Ottawa, Ontario. Canadian Coast Guard Ship Safety Report SSC 014SS.T8080-2-6861/B.

Melville Shipping. (1993b). *Review and Investigation of Procedures Governing the Discharge of Non-Regulated Cargo Residues from Ships into the Great Lakes: Supplementary Report on Cargo Loss Validation.* Prepared for the Canadian Coast Guard, Ship Safety by Melville Shipping, Ltd., Ottawa, Ontario. Canadian Coast Guard Ship Safety Report SSC 014SS.T8080-2-6861/B.

Michel, K., & Winslow, T. S. (1999). Cargo Ship Bunker Tanks: Designing to Mitigate Oil Spillage. *Society for Naval Architects and Marine Engineers (SNAME) Joint California Sections Meeting.*

Michel, K., & Winslow, T. S. (2000). Cargo Ship Bunker Tanks: Designing to Mitigate Oil Spillage. *Marine Technology, 37*(4).

Moore, J. W. and Ramamoorthy, S. (1984). "Aromatic Hydrocarbons-Polycyclics." In: *Organic Chemicals in Natural Waters: Applied Monitoring and Impact Assessment*. Springer-Verlag, New York, NY. pp. 67-87.

National Research Council (NRC). (1998). *Double-Hull Tanker Legislation: An Assessment of the Oil Pollution Act of 1990.* Washington, D.C.: National Academies Press.

National Research Council (NRC). (2001). *Environmental Performance of Tanker Designs in Collision and Grounding: Method for Comparison.* Washington, D.C.: Marine Board and Transportation Research Board, NRC.

National Transportation Safety Board (NTSB). (2004). *Marine Accident Brief MAB-06/01: M/V Selendang Ayu Accident No. DCA-05-MM-008*. National Transportation Safety Board, Washington, DC.

Neff, J. M. (1979). Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Sources, Fates and Biological Effects. Applied Science Publishers Ltd., Essex, England.

Potomac Management Group (PMG) and Environmental Research Consulting (ERC). (2003). *A Study of Dry Cargo Residue Discharges in the Great Lakes*. Prepared for the US Coast Guard Office of Operating and Environmental Standards, Washington, D.C. USCG Report No. 2003-16814-2..

Rawson, C., Crake, K., & Brown, A. J. (1998). Assessing the Environmental Performance of Tankers in Accidental Grounding and Collision. *SNAME Annual Meeting*.

Reid, D. F., and Meadows, G. A. (1999. *Proceedings of the Workshop on the Environmental Implications of Cargo Sweepings in the Great Lakes*. NOAA Technical Memorandum ERL GLERL-114. National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan.

Revised Project Information Document; Gateway Pacific Terminal, Whatcom County, Washington, Pacific International Terminals, March 2012.

Ship Structure Committee.(2004). *Case Study: Bulk Carriers: Design, Operation, and Maintenance Concerns for Structural Safety of Bulk Carriers*. US Coast Guard, Washington, D.C..

State of Washington Joint Legislative Audit and Review Committee (JLARC). (2009). *Review of Oil Spill Risk and Comparison to Funding Mechanism.* Report 09-2. JLARC, Olympia, WA.

The Glosten Associates, Herbert Engineering, Environmental Research Consulting, and Dr. Martha Grabowski. (2005). *Study of Tug Escorts in Puget Sound*. File No. 04075. Prepared for Washington Department of Ecology, Olympia, Washington. 54 p.

US Coast Guard. (1999). *Regulatory Assessment: Use of Tugs to Protect Against Oil Spills in the Puget Sound Area.* Report No. 9522-002.

Wijnolst, N., & Wergeland, T. (1997). *Shipping.* Delft University Press.

Yip, T. L., Talley, W. K., & Jin, D. (2011). Determinants of Vessel-Accident Bunker Spillage. *Proceedings of the 2011 International Conference of Maritime Economics.*

Yip, T. L., Talley, W. K., & Jin, D. (2011). The Effectiveness of Double Hulls in Reducing Vessel-Accident Oil Spillage. *Marine Pollution Bulletin, 62*(11), 2427-2432.

Appendix F Assembly of Questions for Lummi Fishers

1. Assembly of Questions for Lummi Fishers

1.1 Introduction

This questionnaire was used to gather data for:

- Appendix B: Small Vessel Memo.
- Section 4.4: Traffic Impact on Tribal Fishing.
- Section 4.5: Risk of Collision with Tribal Vessels.

Towards this end, the questionnaire was effective in obtaining the requested information and also served to highlight issues the Lummi fishers believe to be especially pertinent to the study.

The Lummi Natural Resources Commission (LNR, a 12 member natural resources policy setting body elected by Lummi fishers) was given this questionnaire on November 13, 2012. A follow-up meeting was held in the Lummi offices on December 12, which was attended by the members of the LNR including the Lummi Harvest Manager, and several other Lummi fishers. At that meeting, a number of answers were obtained, and clarification provided on other questions to enable the Lummi to complete the questionnaire. On January 4, 2013, representatives from the LNR notified Glosten that all responses to the questionnaire were finalized.

The purpose of the questionnaire, and the follow up meeting with Lummi representatives, was to obtain the following information from the Lummi nation:

- An evaluation of GPT-calling vessels' impact on the tribal fishing fleet, including gear loss, associated Homeland Security exclusion zones, and interference with fishing.
- An assessment of the increased vessel traffic impact on Lummi treaty rights to fish throughout the Lummi Nation's Usual and Accustomed grounds and stations.
- Statistical measurement of impact from the area that the Lummi are temporarily excluded from fishing, multiplied by the expected duration of the temporary exclusion.
- An assessment of the increased vessel usage of anchorages impact on Lummi treaty rights to fish using the same statistical measure: exclusionary area multiplied by duration.

While the Lummi did not respond to every survey question, the Lummi did supply additional information that was not requested that ultimately proved pertinent to the study.

The Lummi response to the questionnaire has been edited by Glosten for the purpose of "readability" and formatting. Questions not answered by the Lummi have been removed from the list of responses. Other written comments provided by the LNR have been incorporated into the text responding to each of the questions. Glosten's edits have been reviewed and found to be accurate by the LNR.

1.2 Additional Data

The Lummi Nation Harvest Manager, Ben Starkhouse, provided additional and updated data in September 2014. These updates are incorporated into the questionnaire responses, and they are listed here:

1. Geoduck was split out from clams and oysters in:
   - Table 1 Lummi Fishing Locations
   - Table 4 Percent of Lummi Fishing Time spent in study areas by subarea
   - Table 8 Lummi Vessel Trips, 2011
2. The dataset was expanded to 2011 in:
   - Table 11 Number of days that a landing occurred by year and month 1995-2011
3. Data extending back to 2006 was provided to supplement data for 2011, previously provided in Table 8 Lummi Vessel Trips, 2011. This additional data is in:
4. Table 9 Lummi Vessel Trips, 2006-2010The Lummi Nation confirmed that the estimated trip length (in hours) given in Table 8 for 2011 could be assumed to apply to a six-year average for 2006 – 2011.

The captions in Table 1, Table 4, Table 8, and Table 11 are marked "Revised." The caption in Table 9 is marked "New."

1.3 Questionnaire

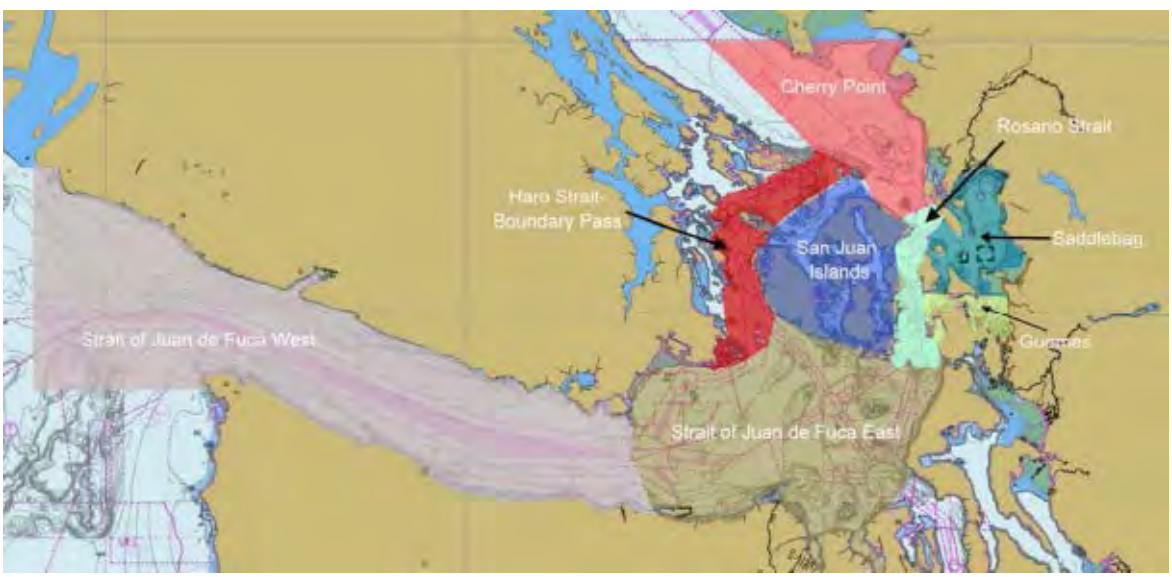

Figure 1 Map of Lummi fishery areas.

Fisheries

1. What fisheries do the Lummi fishermen participate in?

   Sockeye, pink, Chinook, Coho, chum, steelhead, crab, shrimp, halibut, clams, oysters, sea cucumber, sea urchin, geoduck.

2. Referring to the map above (Figure 1), please identify what types of fish that Lummis generally fish for in each area and check the corresponding boxes in Table

1, below. Also, please use a star to indicate the area where the most fishing takes place within each fishery.

Table 1 Lummi fishing locations (Revised)

Fishery	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddle-bag	Guemes Channel	Cherry Point	San Juan Islands
Salmon		X	X	X	X	X	X	X
Halibut		X	X	X	X	X	X	X
Dungeness Crab		X	X	X	X	X	X	X
Clams and Oysters					X	X	X	X
Geoduck,		X		X	X			
Sea Urchins and Sea Cucumbers		X	X	X	X	X	X	X
Shrimp		X	X	X	X	X	X	X
Other								

Note: If the "Other" row is filled out, please include the list of species that would apply to this group.

Please complete

3. Table 2 with the volume in pounds of the annual Lummi fishery harvest for *each* fishery in each of the last three years (2009, 2010, 2011).

Table 2 Lummi harvest volumes, in pounds (2011)

Fishery	2009	2010	2011
Salmon	3,433,762	4,818,945	7,015,186
Halibut	33,355	94,888	109,799
Dungeness Crab	1,961,926	1,506,211	1,684,774
Geoduck, Clams, and Oysters	163,139	278,389	206,192
Sea Urchins and Sea Cucumbers	270,836	310,363	312,413
Shrimp	22,465	34,768	50,010
Other			
Total	5,885,483	7,043,564	9,378,374

4. Please fill out the cells in Table 3 to indicate what portion (percent of total pounds) of each fishery is commercial versus subsistence or ceremonial.

Table 3 Lummi commercial, subsistence, and ceremonial volumes, 2011

Fishery	Commercial	Subsistence/Ceremonial	Total Harvest
Salmon	95%	5%	100%
Halibut	95%	5%	100%
Dungeness Crab	95%	5%	100%
Geoduck, Clams, and Oysters	90%	10%	100%
Sea Urchins and Sea Cucumbers	100%	0%	100%
Shrimp	95%	5%	100%
Other			100%
Total			100%

Note: The sum of the two center columns should total 100 percent

5. Using the map on page 2, please estimate the percentage of time spent in each area during these fishing trips in the following table.

Table 4 Percent of Lummi fishing time spent in study areas by subarea (Revised)

Fishery	Strait of Juan de Fuca West	Strait of Juan de Fuca East	Haro Strait-Boundary Pass	Rosario Strait	Saddle-bag	Guemes Channel	Cherry Point	San Juan Islands
Salmon		10	10	10	35	5	20	10
Halibut		23	23	10	2	2	20	20
Dungeness Crab			10	10	10	5	55	10
Clams and Oysters					46	4	46	4
Geoduck		50		20	30			
Sea Urchins and Sea Cucumbers		10	10	10	5	10	10	45
Shrimp		23	25	10	5	2	15	20
Other								
Total								

Note: If the "Other" row is filled out, please include the list of species that would apply to this group.

Gear

6. We would like to learn more about reef net fisheries. Generally speaking, in which areas (as identified by the map on page 2) are the Lummi reef net sites that are used today?

Lummi currently does not fish any reef nets. However, they are in the process of getting some reef nets for fishing within the next year or two.

a. How many vessels are typically at a reef net site?

Typically there are 3 vessels per reef net site. Lummi hopes to establish between 4-8 reef net sites in the near future.

b. What is the level of activity at these sites, as measured in days per year?

Once the reef net sites are established, they would be fished approximately 20-30 days per year.

7. What is the primary gear used by tribal fishermen for halibut fishing?

Set-lines.

8. What portion of the total annual Lummi salmon harvests are caught using each gear type? Please fill out the shaded areas of Table 5 (the total column should equal 100 percent).

Table 5 Lummi harvest data by gear type, 2011

Fishery	Percent of Total Harvest					Total
	Drift Gillnet	Set Gillnet	Seine	Reef Net	Other	
Chinook	13	18	2			
Chum	16	12	5			
Coho	28	68	1			
Pink	3	2	66			
Sockeye	39		26			
Total	**100**	**100**	**100**			

9. Please provide any data that the tribe has on volume of gear lost by type, location, and year.

Lummi does not have systematically collected quantitative data on gear loss. In 2008, a gear loss forum was held with Lummi fishers and industry representatives. As part of this forum, the LNR Commission was asked to estimate the number of crab pots that were lost each year. Based on anecdotal information it was estimated that Lummi crab fishers lost an average of 40-50 pots per fisher per year. No estimates were determined for other types of gear loss (e.g., gill nets) due to vessel traffic.

a. Is gear loss due to vessel traffic more common in some areas over others? Please explain in detail.

Yes, gear loss is more common in certain areas. Specifically, the tug and tanker holding areas in Saddlebag and Cherry Point, and shipping lanes throughout Lummi's U&A, including the Cherry Point, Haro Strait, Rosario Strait, Guemes Channel, and the Strait of JDF East.

b. Are certain types of gear more likely to be interfered with by vessel traffic than others? Please explain in detail.

Crab pots are particularly susceptible to vessel traffic because of the number of days that crab fisheries are open and where crab fisheries take place. Shrimp pots are equally susceptible, but there are far fewer shrimping days over the course of a year. Halibut gear is also susceptible because shipping lanes overlap good halibut fishing grounds. Salmon gill nets and purse seines are vulnerable to vessel traffic, especially in the Cherry Point, Haro/Boundary Pass, and Rosario Strait regions.

In addition, fishing activities for all species are at risk of being interfered with by Homeland Security and their enforcement of exclusion zones. This interference can mean substantial lost fishing time for individual boats and fishers.

Vessel Activity

1. What is the breakdown of Lummi fishing vessels (seiners, gill netters, skiffs) by vessel type and size (length overall)? Please fill out the shaded areas of Table 6.

Table 6 Lummi fishing vessels by size, 2011

Vessel Types	5-20 feet	20-30 feet	30-40 feet	40-50 feet	50-60 feet	60+ feet	Total Number
Seiners							
Gill Netters							
Skiffs							
Total	**237**	**126**	**11**		**6**	**2**	**383**

Fishing vessels are not registered according to vessel type. I added this row and reported the TOTAL number of Lummi fishing vessels registered by length.

Generally, fishing vessels under 22 feet are considered skiffs. Vessels over 22 feet (that are not seiners) are not necessarily gill netters, they could be crab boats, dive boats, etc.

The 8 boats listed here that are 50+feet are all seiners.

2. What is the total number of Lummi tribal vessels in each fishery, and how many actually participated in each fishery in 2011? Please fill out the shaded areas of Table 7.

Table 7 Number of Lummi fishers by species, 2011

Fishery	Fishers		Gill Netters		Skiffs	
	Total	Active	Total	Active	Total	Active
Salmon	325					
Halibut	61					
Dungeness Crab	167					
Geoduck, Clams, and Oysters	183					
Sea Urchins and Sea Cucumbers	22					
Shrimp	33					
Other						
Total	**506**					

Lummi does not track vessel participation in specific fisheries. As a proxy, I've reported the number of individual fishers that participated in each of the fisheries during the calendar year of 2011. Participation is defined as selling their catch at least once during the year.

These numbers do not include fishing in the Nooksack River or south of Admiralty Inlet.

It is reasonable to assume that for each species (except for salmon and clams/oysters), the number of fishers is roughly equivalent to the number of boats that are used to fish that specific species.

I would guess that the number of boats used in the 2011 salmon fisheries is between 160-200.

This is not the total for the column, but rather the total number of unique fishers that sold catch from a fishery in 2011

Generally, boats are not used in the harvest of clams and oysters. There are about 10-12 boats that participate in geoduck fisheries.

3. Is the number of participants in 2012 expected to be higher or lower than in 2011?

The number of fishers (and vessels) participating in any given year depends on the abundance of salmon, halibut, crab and shrimp in that year as well as the abundance of these species during immediately preceding years. The abundance of these species in previous years contributes to the ability of fishers to have the financial means to pay the overhead costs associated with being a commercial fisher. The number of participants in 2011 is probably similar to the number in 2012.

4. What is the estimated number of vessel traffic days that Lummi vessels are fishing in Puget Sound waters? Please estimate the average numbers of trips that Lummi vessels made by type and fishery in 2011, as well as the typical duration of each trip

(one trip equals two transits). This estimate may be expressed in a range; for example, 20-25 trips, 8-12 hours each.

Table 8 Lummi vessel trips, 2011 (Revised)

Fishery	Total Landings		Gill Netters		Skiffs	
	Annual Trips	Length of Trips	Annual Trips	Length of Trips	Annual Trips	Length of Trips
Salmon	6418	6-12 hrs				
Halibut	216	8-14 hrs				
Dungeness Crab	4353	6-10 hrs				
Clams and Oysters	3078					
Geoduck,	22	6 hrs				
Sea Urchins and Sea Cucumbers	754	6-12 hrs				
Shrimp	72	6-10 hrs				
Other						
Total	**14913**					

Table 9 Lummi vessel trips, 2006-2010 (New)

Species	2006	2007	2008	2009	2010
Salmon	4,091	4,931	5,101	4,110	5,634
Halibut	294	297	188	120	281
Dungeness Crab	3,649	3,984	4,493	5,059	4,330
Clams & Oysters (no vessel time)	5,059	4,366	3,699	2,302	3,715
Geoduck	9	0	25	20	12
Sea Urchins & Sea Cucumbers	250	200	247	465	660
Shrimp	72	62	49	52	90

Lummi does not track the participation of vessels in individual fisheries. Here I have reported the number of landings, by species, for 2011, excluding any landings from the Nooksack River and south of Admiralty Inlet.

The number of landings can reasonably be considered a proxy for the number of vessel trips.

The length of each trip provided here is based on an educated guess of my experience with the fisheries for each species.

5. Please estimate the average annual (by month), number of Lummi fishing vessel trips (one trip equals two transits) for 1995 through 2010.

Table 10 Number of landings by year and month 1995-2010

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jan	308	321	447	305	370	262	456	314	411	337	253	183	303	281	420	440
Feb	221	370	527	405	179	186	436	275	292	261	248	154	287	320	485	411
Mar	184	360	384	525	306	44	331	298	284	234	311	305	522	501	507	609
Apr	167	300	235	509	141	207	132	283	245	291	329	328	165	585	522	211
May	23	18	51	582	143	44	76	56	66	202	232	59	3	221	74	118
Jun	276	36	5	324	947	640	337	33	217	206	253	224	92	37	54	452
Jul	848	1091	659	1178	554	406	578	637	661	660	551	374	547	365	688	334
Aug	3660	1870	4015	1648	1046	1353	1451	1515	1748	1029	698	1363	872	1411	1287	1669
Sep	1608	1853	2953	1364	2609	1878	1847	1854	1583	1932	2451	2230	2338	2654	2473	2987
Oct	1447	1749	1497	1844	2220	1680	2302	1075	1654	2821	2329	2328	2062	1859	1815	2018
Nov	1028	890	844	664	745	776	1037	643	698	1057	528	598	693	588	642	849
Dec	509	375	467	348	401	519	297	674	407	423	327	440	362	349	532	415

The number of landings roughly equals the number of vessel trips. The landings provided in this table do not include landings from fishing in the Nooksack River or from south of Admiralty Inlet, nor do they include Manila clam landings, as they do not typically require a vessel trip.

Generally, the length of a vessel trip is associated with daylight hours. For example, a vessel trip in the summer might be 8-14 hours, while a trip in the winter might be 6-8 hours.

Table 11 Number of days that a landing occurred by year and month 1995-2011 (Revised)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Jan	19	19	16	21	22	16	28	23	23	26	25	21	26	24	29	21	28
Feb	15	22	23	21	19	15	26	23	22	29	26	23	27	19	27	28	25
Mar	8	23	23	30	27	16	28	26	27	31	26	28	31	21	27	30	28
Apr	10	22	14	28	19	18	16	21	23	29	19	29	17	28	26	16	28
May	8	9	12	25	24	21	21	19	14	21	23	14	2	27	23	28	27
Jun	11	11	2	13	28	16	11	15	15	20	25	29	28	26	28	28	30
Jul	29	14	12	16	11	7	14	15	14	19	21	19	24	26	24	26	29
Aug	30	25	29	25	25	27	30	25	28	29	30	30	30	26	29	28	31
Sep	22	27	29	26	26	27	27	29	24	29	30	29	29	29	30	30	30
Oct	28	31	31	31	31	31	31	28	30	31	31	31	31	31	30	31	31
Nov	30	27	29	29	30	29	30	19	29	27	22	24	27	28	24	28	30
Dec	30	15	24	24	25	26	23	27	26	26	25	26	22	20	23	22	16

6. Do shellfish harvesters typically travel to and from their harvesting areas using vessels? If so, please describe.

   Vessel trips <u>are not</u> typically required for commercial manila clam openings, however, a vessel trip may occur for a ceremonial or subsistence manila clam harvest. Vessel trips <u>are</u> typically required for other shellfish openings such as crab, shrimp, geoduck, etc.

7. Where are most Lummi fishing vessels moored?

   85% at Gooseberry Point (GB). 10% in Blaine (B). 5% in Bellingham Bay (BB)

   Most of the boats that are "moored" at Gooseberry are actually trailered out of the water at the end of the day and stored in a boat yard. A handful of boats anchor at Gooseberry or tie up to a dock or pier.

8. Where are Lummi fish delivered? Please fill out the shaded areas of Table 12. If more than one location applies, specify the percentages delivered to each.

Table 12 Lummi delivery locations, 2011

Fishery	Delivery Location
Salmon	50% BB; 25% GB; 25% B
Halibut	75% GB; 25% B
Dungeness Crab	65% GB; 25% B; 10% BB
Geoduck, Clams, and Oysters	Kingston (Geoduck)
Sea Urchins and Sea Cucumbers	100% GB
Shrimp	100% GB
Other	

Fishery Management

1. Are tribal fisheries managed in terms of access days and times? If so, how?

   Yes. Fisheries are opened during specific days, times and areas. The fishing schedules for some fisheries are set preseason, while other fisheries are planned only days ahead of time via conference call with other tribal and co-managers.

2. Are the tribe's scheduled opening and closure days the same as those for non-tribal fishermen?

   Not typically.

3. How are Lummi (and other Indian) fishing vessels identified so that they can be distinguished from non-Indian fishing vessels?

   Lummi vessels are identified with their ID number WN - _ _ _ - XWL. The three spaces between the WN and the XWL are filled by numbers.

Appendix G Puget Sound Pilot Section – Questions for Pilots

Pilots' responses to the following questionnaire are summarized in the GPT VTARAS Section 2.2.3.

Purpose

The Glosten Associates (Glosten) is conducting a Vessel Traffic and Risk Assessment Study on the proposed Gateway Pacific Terminal (GPT) to be located at GPT/Cherry Point. The purpose of the study is to assess the potential risks posed by new bulk carrier traffic the proposed terminal will bring to the Puget Sound.

The study will consider current vessel traffic levels and forecasted GPT traffic levels, including tugs. The study will also consider other potential future traffic that may be operating in the same area.

The study area includes the designated Puget Sound vessel transit lanes, the maneuvering area near the planned GPT terminal at GPT/Cherry Point, the local anchorage areas, and the transit routes for tugs assisting GPT traffic.

The study will assume 487 total annual visits for the anticipated GPT traffic at full build-out. Of the total vessel calls, it is assumed there will be 318 Panamax and 169 Capesize (up to 250,000 DWT) vessels.

Tug Escort and Assist

These questions are to help assess the anticipated increase in tug traffic.

1. Under what conditions (if any) would escort tugs be requested by pilots?

2. On which route and for what purpose would this take place?

3. In your experience, what is the appropriate number of tugs to assist in safe maneuvering to/from berth/anchorage?

4. Is there a specific type tug requested for docking assistance?

5. Is there a specific type of tug requested for escort assistance?

6. What is the impact, if any, of cargo vessel size on the type and number of tugs?

7. Where would the tugs intercept/be dismissed from the ship?

8. Are there differences in the intercept or dismissal points if the ship is laden or unladen?

Transit

These questions are to help assess any changes in your current operations caused by the anticipated increase in GPT-bound cargo.

9. What is the frequency of use for the following routes from Port Angeles to GPT/Cherry Point:
   - Haro Strait/Boundary Pass.
   - Rosario Strait.
   -
   - Strait of Georgia/Vancouver.

10. What are the constraints on using the following routes from Port Angeles to GPT/Cherry Point (Turn Point SOA, etc.):
    - Haro Strait/Boundary Pass.
    - Rosario Strait.

- Strait of Georgia/Vancouver.

11. What are the current speeds from Port Angeles to GPT/Cherry Point through the following transits:
    - Haro Strait/Boundary Pass.
    - Rosario Strait.
    - Strait of Georgia/Vancouver.

12. How are current operations affected by:
    - Seasons.
    - Inclement weather.
    - Other vessel traffic (commercial, fishing, etc.)

13. Are there different pilotage requirements if the Haro Straits/Boundary Pass transit is used?

14. Is there advance notice of arrival requirements?

15. How many times per year do vessels calling at U.S. docks use anchorages in Canada?

16. Considering the above questions, what impacts to your operations, if any, do you anticipate with the projected increase in vessel traffic and changes in size of vessels?

Pilot Requirements

These questions will help Glosten understand other operational issues affecting the pilots, and the impact in the projected increase in vessel traffic bound for GPT.

17. What is the effect of weather upon the pilots' boarding area?

18. Is there any operational impact of ballast water transfers being undertaken while in transit to the berth?

19. What is the controlling depth for transiting:
    - Rosario Strait.
    - Haro Strait/Boundary Pass.
    - Strait of Georgia/Vancouver.

20. What are the Ports of Refuge and anchorages along transit routes for the pilotage waters between Port Angeles and GPT/Cherry Point in case of a disability?

21. Are additional vessel movements conducted specifically for bunkering?

22. At what locations does bunkering typically occur for vessels calling at GPT/Cherry Point?

23. What has been the frequency of mechanical (engine) failure during transits of the areas in question?

24. How do the Puget Sound Pilots exchange information with Canadian Pilots when transiting Haro Strait/Boundary Pass?

25. How is the Canada/US Cooperative Vessel Traffic Service (CVTS) information shared?

26. How do vessels using the Haro Strait/Boundary Pass route coordinate pilotage when the vessel may pass through both US and Canadian waters?

27. What pilots (US or Canadian) would be required if a vessel shifts from anchorage in Vancouver, British Columbia to the GPT Terminal berth at GPT/Cherry Point?

28. Based upon your experience, what do you think the changes in vessel traffic (percentagewise) would be once GPT is operating at full capacity?

29. In the question above, what are the changes in vessel traffic (percentagewise) that would impact pilotage requirements?

Berth Operations

These questions pertain to berth operations. Please consider berthing operations at the proposed GPT to be very similar to the other existing GPT/Cherry Point berthing sites.

30. Do the pilots foresee environmental limits for docking and undocking at the proposed Gateway Pacific Terminal, i.e. tide, current, wind, sea swell, waves?

31. What are the weather limits for remaining at berth at GPT/Cherry Point?

32. Is there a preferred direction of berthing (port/starboard side to) to accommodate weather or prevailing currents, i.e. approach berth into the current/wind or with it?

33. What operational options do the pilots have to berth/depart during inclement weather?

Anchorages

These questions are to help assess which anchorages are typically used and the reasons why.

34. What considerations are taken into account when selecting an anchorage for a ship calling at GPT/Cherry Point?

35. What are the advantages of one anchorage area over another (if any)?

36. Are anchorages available during all weather conditions? If not, what criteria are used to determine availability?

37. Based upon your experience, what are the maximum wind/sea conditions that would for anchoring in these areas?

38. What are the impacts and challenges of shifting on/off the berth during the loading process to anchor?

39. For the pilots calling at Westshore Terminal, is congestion at anchorages and issue?

Weather and Environmental Factors

These questions may have been covered under previous sections; however, we would like to know specifically the impact of weather upon operations.

40. In your experience, what are the weather and environmental factors, i.e. tide, current, wind, sea swells, and waves, that have the greatest impact upon pilot operations?

41. What is the frequency of operational changes due of weather and environmental factors?

42. What alternative operations are enacted during inclement weather for:
    - Pilot boarding.
    - Transit.
    - Berthing.
    - Anchorage.

43. Do the local magnetic disturbances have any impact on navigation if the ship loses its gyro compass during the transit?

Conclusion

Are there any other operational considerations we should consider for our traffic analysis and risk assessment, with the assumption the Gateway Pacific Terminal is operating at the projected full capacity of 487 total annual visits, of which 318 will be Panamax and 169 Capesize (up to 250,000 DWT) vessels?