EXECUTIVE SUMMARY

VTRA 2010 FINAL REPORT

Preventing Oil Spills from Large Ships and Barges In Northern Puget Sound & Strait of Juan de Fuca

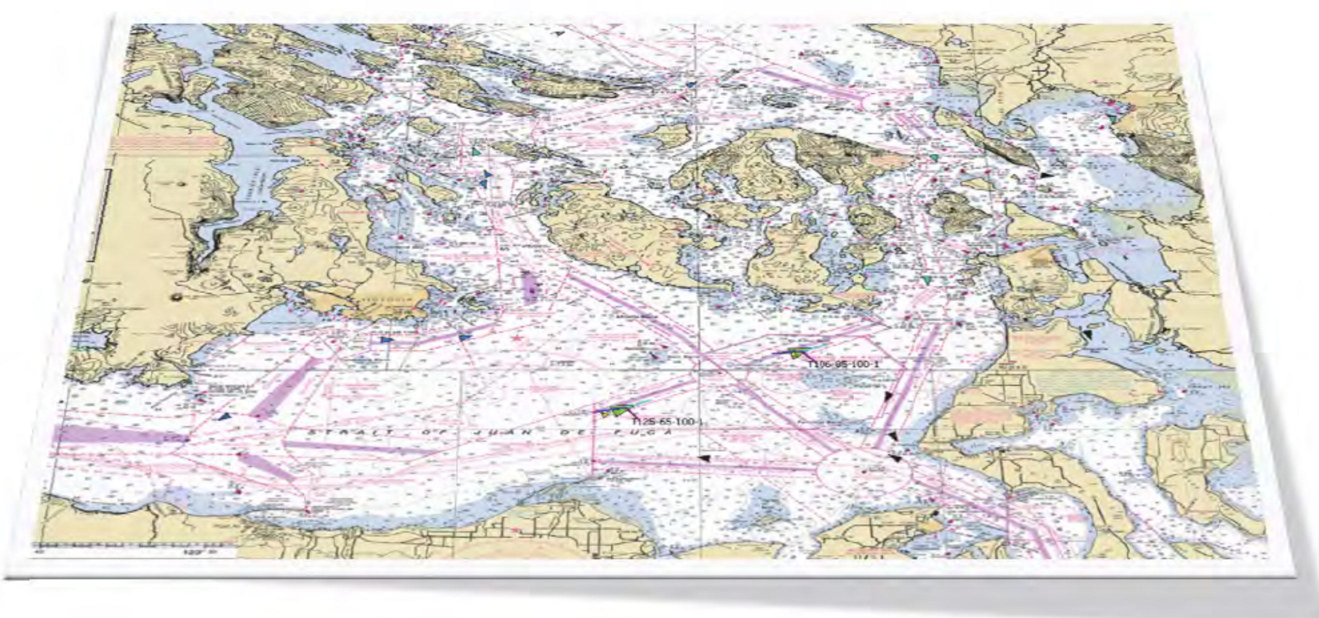

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Table Contents

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This study was guided by a VTRA 2010 steering committee formed primarily of members from the PSP Oil Spill Workgroup and the Puget Sound Harbor Safety Committee. The contents of this document do not necessarily reflect the views of the PSP Oil Spill Workgroup, the Puget Sound Harbor Safety Committee or the VTRA 2010 Steering Committee in particular.

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PREFACE

This report is submitted by Johan Rene van Dorp (George Washington University) and Jason R.W. Merrick (Virginia Commonwealth University), GW/VCU hereafter. The content of the report describes a vessel traffic risk assessment (VTRA) conducted 2012-2014. To distinguish the study described herein from the previous VTRA study conducted 2006-2008 utilizing 2005 VTOSS data, it will be labeled VTRA 2010. The starting point for the VTRA 2010 analysis is the updated VTRA 2005 model with 2010 VTOSS data, as agreed upon in the scope of work between GW and the PSP. The update of the VTRA 2005 model to using VTOSS 2010 data was separately funded by the Makah Tribal Council [19]. The VTRA study area covers US/Canadian trans-boundary waters including: portions of the Washington outer coast, the Strait of Juan de Fuca and the approaches to and passages through the San Juan Islands, Puget Sound and Haro-Strait/Boundary Pass. The VTRA area is divided in 15 separate waterway zones outlined in Figure 1. This study has been funded in part by the United States Environmental Protection Agency (EPA) through their National Estuary Program, via a grant agreement (#2013-028) with the PSP. The waterway zone analysis results presented in this report was also funded by the Makah Tribal Council.

Both the Puget Sound Partnership (PSP) and the Makah studies utilized the extensive technical work already completed by the George Washington (GW) University and Virginia Commonwealth University (VCU) under previously funded maritime risk assessment (MRA) projects. Specifically, the Prince William Sound Risk Assessment (1996), The Washington State Ferry Risk Assessment (1998), The San Francisco Bay Exposure Assessment (2004) and the 2005 Vessel Traffic Risk Assessment (VTRA 2005). The VTRA 2010 analysis tool evaluates the duration that vessels travel through the VTRA study area, referred to as vessel time exposure (VTE), by vessel type and the potential accident frequency and oil losses from a class of focus vessels. The inclusion of the time on the water element in the evaluation of exposure sets the VTRA 2010 methodology apart from count based approaches that focus on, for example, number of annual/monthly vessel transits, visits or calls. The value of a duration based approach versus a count based approach is that the former appropriately distinguishes between short and long transits in the evaluation of vessel traffic risk as well as differing vessel speeds. The VTRA 2010 methodology has been well documented and peer-reviewed in the academic literature and continuously improved over the course of the above maritime risk assessment projects. A reference list is provided at the end of this document.

From the outset of this project the support from the United States Coast Guard (USCG) District 13, including Sector Puget Sound, and the Puget Sound Harbor Safety Committee (PSHSC) have been unwavering. In particular, Mark Ashley's (USCG), John Veentjer's (Chair of the PSHSC), Del Mackenzie's (Puget Sound Pilots), Mike Moore (Pacific Merchant Shipping Association) and Norm Davis' (Department of Ecology) support have been instrumental in providing the necessary data for this work. The PSHSC generously extended their hospitality to allow GW/VCU to present their progress over the course of this project during their meetings every other month from October 2012 through February 2014. The PSHSC provided GW/VCU a public platform to obtain feedback from and access to the maritime/regulatory/stakeholder community during the VTRA 2005 update and the VTRA 2010. The VTRA 2010 study was guided by a steering committee formed primarily of members from the Puget Sound Partnership Oil Spill Workgroup and the Puget Sound Harbor Safety Committee.

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Vessels transiting the Salish Sea traverse waters bordering numerous communities en route to ports in both the US and Canada. The Salish Sea is a large (over 1000 square miles) and diverse water body physically characterized by passages that are broad and deep, as well as narrow ones that are navigationally challenging with swift currents. In addition, it is a biologically rich ecosystem with significant natural resources these communities depend upon.

The Strait of Juan de Fuca serves as the entrance to these U.S. and Canadian ports and facilities and is transited by approximately 10,000 deep draft vessels annually including arrivals and departures. Additional transits occur internally as vessels shift locations. There are also tug and barge movements, ferry operations, fishing and recreational vessels throughout. For example, the U.S. Coast Guard Vessel Traffic Service (VTS) alone handles approximately 230,000 transits annually with about 170,000 of those being Washington State Ferries meaning there are more than 50,000 transits other than ferries. The Puget Sound Pilots report nearly 8,000 assignments annually which provide a good metric for how many deep draft vessel movements there are on the U.S. side.

The area includes an International Maritime Organization (IMO) approved Traffic Separation Scheme (TSS) that governs vessel traffic in the system and its approaches. It is actively managed by a joint U.S. - Canadian Cooperative Vessel Traffic Service (CVTS). At the western entrance to the Strait of Juan de Fuca, it includes the extent of Tofino Traffic's radar coverage; approximately 60 miles out to sea, and extends throughout the Puget Sound region north to Vancouver, British Columbia, and south to Tacoma, Washington and Olympia, Washington. Radar is supplemented by Automatic Identification System (AIS) transponders, radio communications and advance notices for arriving vessels.

In terms of major oil spills, defined as over 10,000 gallons in the study area, State of Washington and U.S. Coast Guard records indicate one accident involving a single hull tanker that grounded while anchoring in Port Angeles in 1985 spilling 239,000 gallons of crude oil and two oil barge accidents; one involving a capsizing in the Guemes Channel in January 1988 spilling 70,000 gallons of heavy fuel and an oil barge grounding on December 30,1994 near Anacortes on a transit from Vancouver, British Columbia resulting in an estimated 26,936 gallons of diesel spilled (spills outside of the study area not included). Even though this area has not experienced major oil spills in the past 20 years or so, the presence of tankers in an ever changing vessel traffic mix places the area at risk for large oil spills. While a previous GW/VCU analysis [2] of this area demonstrated significant risk reduction of oil transportation risk due to existing risk mitigation measures[1], the

[1] In [2] a 91.6% reduction in POTENTIAL oil loss was evaluated utilizing the VTRA 2005 model from all Tankers, Articulated Tug Barges (ATB's) and Integrated Tug Barges (ITB's) as a result of the implementation of the one-way zone regime in Rosario Strait, implementation of double hull tankers and the 2005 Escorting Regime.

potential for large oil spills continues to be a prominent public concern heightened by proposed maritime terminal developments. In this study we focus on the following three (although other ones are under consideration) since these three are in advanced stages of a permitting process:

(1) The proposed Gateway bulk carrier terminal at Cherry Point, Washington.
(2) The Trans-Mountain/Kinder Morgan pipeline expansion in Vancouver, BC.
(3) The coal, grain and container terminal expansions at Delta Port, BC.

The purpose of this vessel traffic risk assessment (VTRA) is to evaluate potential changes in risk in light of above three maritime terminal developments and to inform the State of Washington, the United States Coast Guard and the Puget Sound Harbor Safety Committee on what actions could be taken to mitigate potential increases in oil spill risk from large commercial vessel in the VTRA study area. This study was not designed to measure the effectiveness of risk mitigation measures already in place. This study is also intended to inform tribes, local governments, industry and non-profit groups in Washington State and British Columbia on potential risk management options.

Summarizing, this study was conducted because study sponsors and involved stakeholders want to ensure potential risks of maritime development projects above are better understood so informed decisions could be made about additional risk mitigation measures that would add to the continuous improvement efforts of the past.

Description of Methodology

The VTRA analysis is predominantly based on Vessel Traffic Operational Support System (VTOSS) 2010 data and will therefore be referred to as VTRA 2010 hereafter. Vessel traffic collision and grounding risks are evaluated for tank focus vessels (oil tankers, chemical carriers, oil barges and articulated tug barges) and cargo focus vessels (bulk carriers, container ships and other cargo vessels). The VTRA analysis based on the 2010 VTOSS dataset shall serve as a base case year to compare potential changes in risk as a result of above maritime terminal developments against.

For context it is important to recognize that the base case 2010 VTRA analysis includes a series of risk mitigation measures. In addition to the previously mentioned IMO Traffic Separation Scheme and CVTS, vessels are subject to Port State Control and other vessel inspections regimes in both Canada and the United States to enforce international and federal standards. Pilotage is required in both the U.S. and Canada and pilotage areas are comparable. Tug escorts for laden tankers are required and tugs are used to assist vessels into and out of the berths. Moreover, there are a number of risk mitigation measures that have been put in place internationally, federally and locally over the last several decades including double hulls for tankers, protectively located fuel tanks for non-tank vessels (still being phased in), a Puget Sound Harbor Safety Plan with Standards of Care, the implementation of AIS, a traffic procedure governing vessels transiting Turn Point at the boundary between Haro Strait and Boundary Pass northeast of Victoria, Canada and a one-way zone regime in Rosario Strait. This list is not exhaustive.

The VTRA 2010 study area is defined by the black border in Figure 1 covering US/Canadian trans-boundary waters including: portions of the Washington outer coast, the Strait of Juan de Fuca and the approaches to and passages through the San Juan Islands, Puget Sound and Haro-Strait/Boundary Pass. The VTRA 2010 area is divided in 15 separate waterway zones outlined in Figure 1 as well.

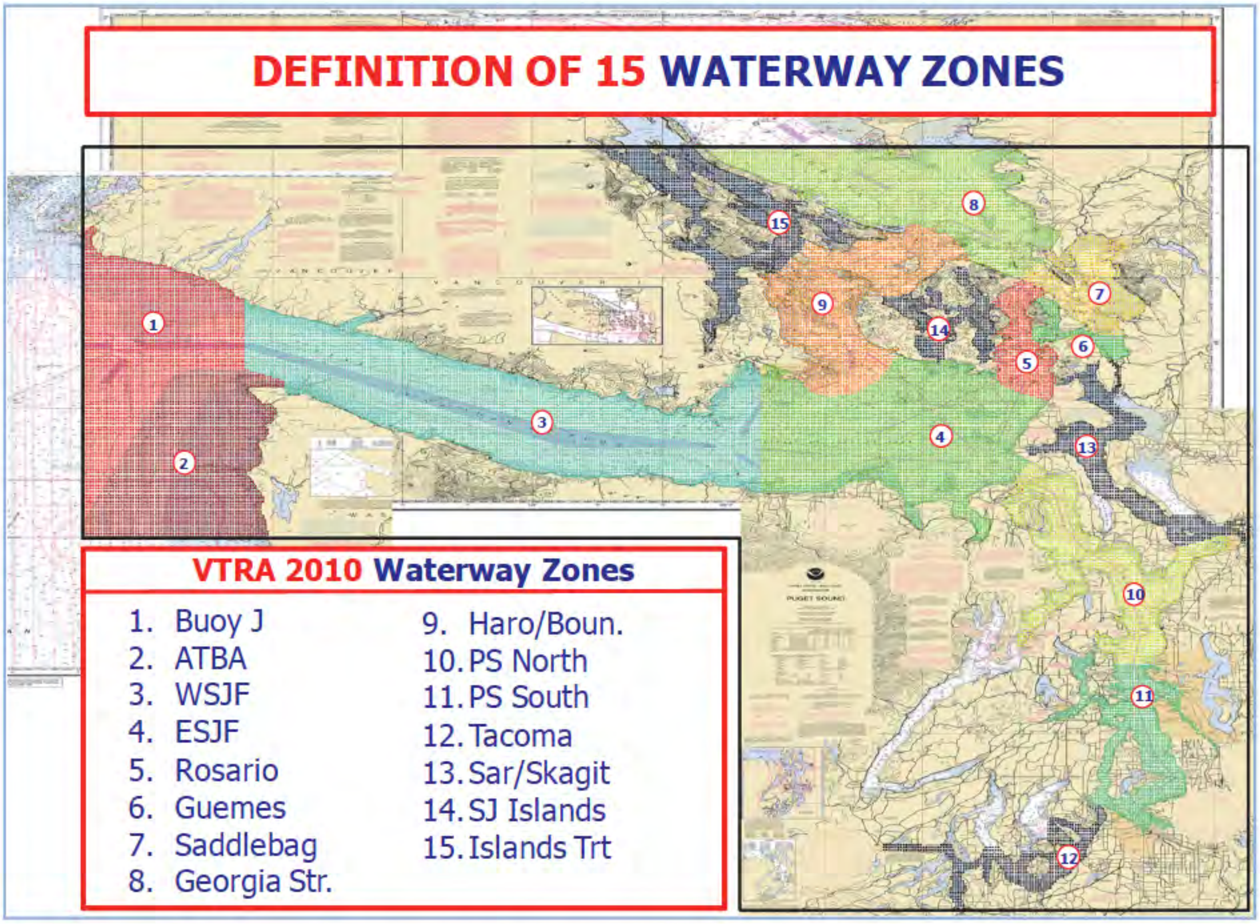

Figure 1. Definition of 15 waterway zones and their descriptors in the VTRA 2010 study area.

The VTRA 2010 methodology has been developed over the course of over ten years of work in various maritime risk assessment projects. Specifically, the Prince William Sound Risk Assessment (1996), The Washington State Ferry Risk Assessment (1998), The San Francisco Bay Exposure Assessment (2004) and the Vessel Traffic Risk Assessment 2005 (VTRA 2005)[2]. The VTRA 2010 analysis methodology has been well documented and peer-reviewed in the academic literature and continuously improved over the course of these MRA projects. A reference list is provided at the end of this document.

[2] The VTRA 2005 analysis in [11] was limited to vessel traffic risk evaluation associated with Tankers, ATB's and ITB's docking at the Cherry Point terminal.

This study was guided by a steering committee formed primarily of members from the PSP Oil Spill Workgroup and the Puget Sound Harbor Safety Committee (see Figure 2). The study followed a collaborative analysis approach engaging stakeholders from different constituencies by meeting every other month with the larger Puget Sound Harbor safety committee and in separate afternoon sessions with the VTRA 2010 Steering Committee. Both meetings were open to the public. Afternoon sessions were typically attended by additional stakeholders interested in the progress of this study. An appendix is included with the names of stakeholders that participated during the afternoon sessions one time or another.

Puget Sound Partnership VTRA 2010 Steering Committee

VTRA SC Co-Chairs

- Todd Hass (Puget Sound Partnership)
- John Veentjer (Puget Sound Harbor Safety Committee)

Governmental Leads

- Chip Boothe, Norm Davis, Jon Neel (Department of Ecology)
- CDR Matt Edwards, CAPT Scott Ferguson, LCDR Meridena Kauffman, CDR Kiley Ross, (US Coast Guard, Sector Seattle)
- R.E. McFarland (US Coast Guard, District 13)
- Chad Bowechop[3], Keith Ledford (Makah Nation, Native American Tribes)

Maritime sectors: Core Committee Members (organization)

- Environmental organizations: Fred Felleman[3] (Friends of the Earth), Bruce Wishart (Washington Environmental Council)
- Labor: Lori Province (Washington State Labor Council)
- Local government: Mike Doherty[3], Lovel Pratt, (WA Association of Counties)
- Petroleum industry: Frank Holmes[3] (Western States Petroleum Industry), Ed Irish (Tesoro)
- Pilots: Del Mackenzie[3], Jostein Kalvoy, Jonathan Ward (Puget Sound Pilots)
- Steamship lines: Mike Moore (Pacific Merchant Shipping Association)
- Tank vessels: Jeff Shaw (Polar Tankers)
- Tug and barge: George Clark (American Waterways Operators), Mark Homeyer (Crowley)

Figure 2. Organizational Chart of VTRA 2010 Steering Committee.

Our analysis model represents the chain of events that could potentially lead to an oil spill. Figure 3 shows the accident causal chain. We call a situation in which an accident could occur an accident exposure. Maritime Transportation Systems (MTS) have accident exposures from the movement of vessels within it. For each accident exposure, while the vessel is underway, incident and accident probability models are used to calculate the potential accident frequency. This is not a prediction of an accident, but shows a relative propensity that an accident could occur in one

[3] Primary participant attending meetings for organization over course of VTRA 2010 meetings

situation versus another or the relative propensity for one type of accident versus another. The accident exposure and the potential accident frequency are then combined with an oil outflow model to calculate potential oil loss. Throughout this report we shall use the terminology POTENTIAL to indicate that an accident exposure does not necessarily need to lead to an accident or oil loss, but may.

Our analysis tool evaluates the duration that vessels travel through the VTRA study area (referred to as Vessel Time Exposure, abbreviated VTE), by vessel type. The inclusion of the time on the water element in the evaluation of exposure sets the VTRA 2010 methodology apart from count based approaches that focus on, for example, number of annual/monthly vessel transits, visits or calls. The value of a duration-based approach versus a count-based approach is that the VTE approach appropriately distinguishes between short and long transits in the evaluation of vessel traffic risk as well as high and low vessel speeds.

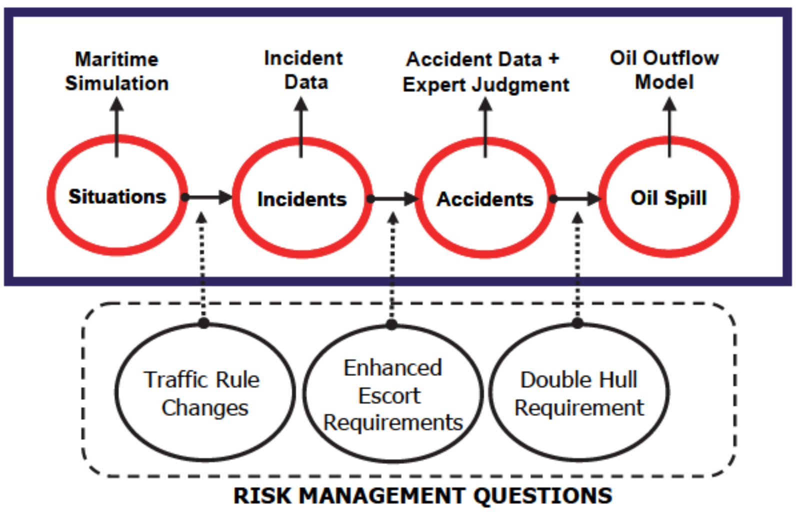

Figure 3. A causal chain of events inter-connected by causal pathways. Risk management questions attempt to block these causal pathways.

Base Case and What-If Results

Figure 4 and Figure 5 are graphical depictions of VTE. For example, Figure 4 and Figure 5 depict that of the total VTE over the 2010 year, 25% (Figure 4) is accounted for by focus vessels and 75% (Figure 5) by non-focus vessels. Non-focus vessels are represented as they can potentially collide with the focus vessel class as well (besides potential collisions amongst focus vessels themselves).

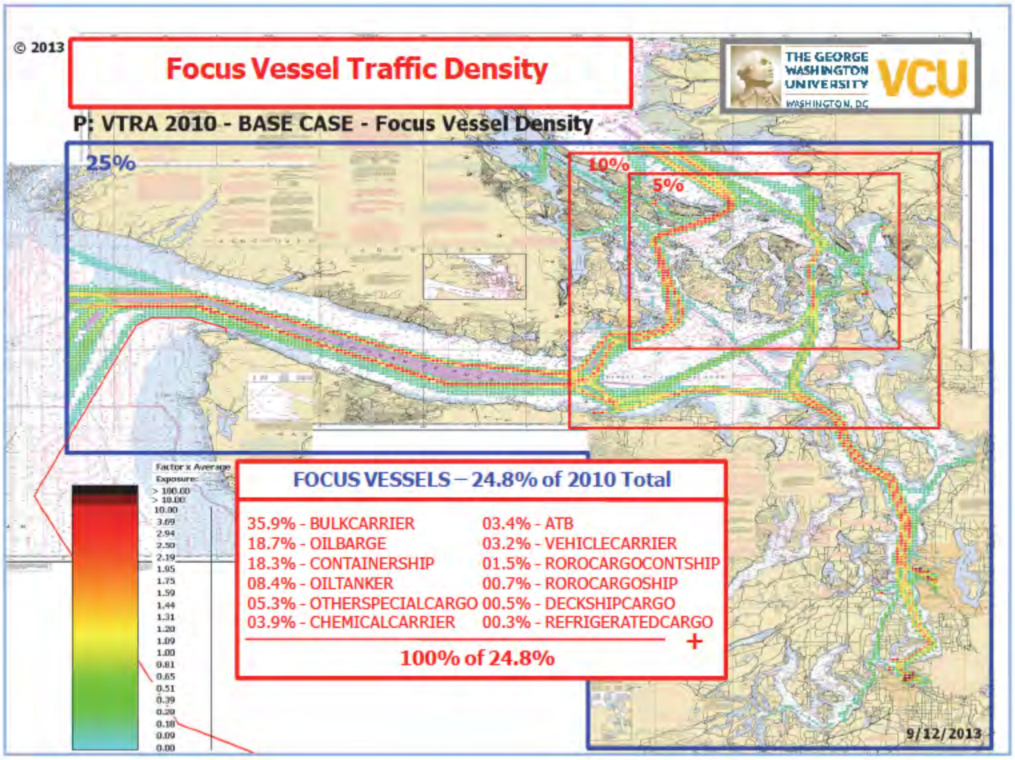

Figure 4. 2D depiction of the traffic density for all focus vessels.

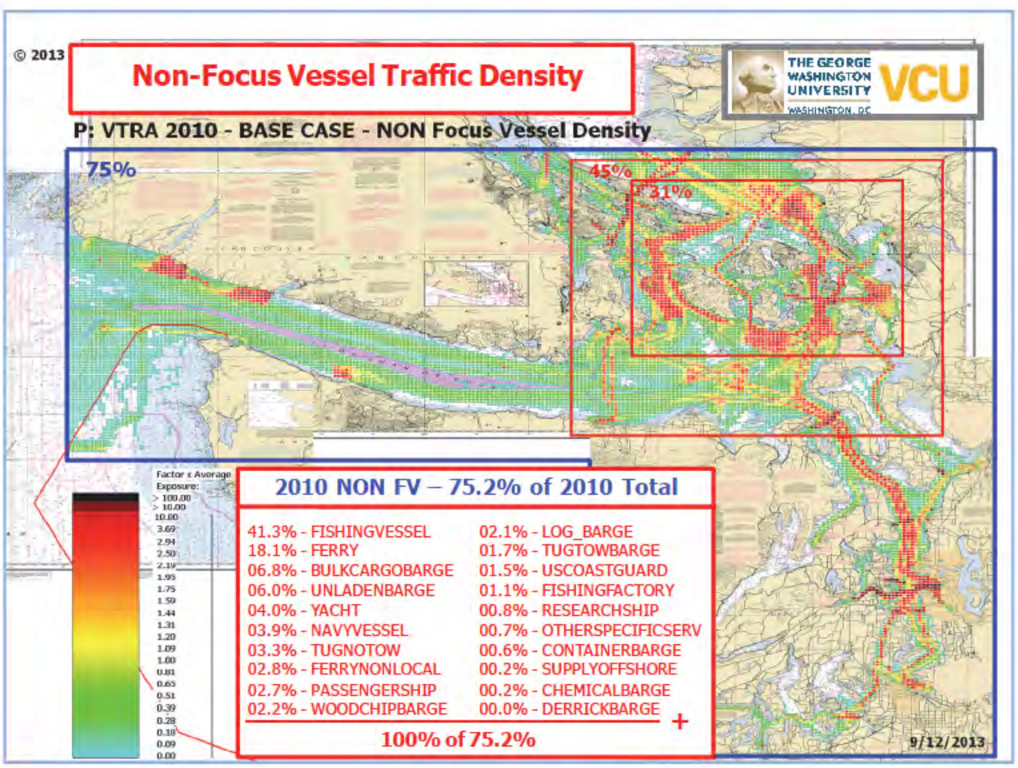

Figure 5. 2D depiction of the traffic density for all non-focus vessels.

Figure 5 shows that 41.3% of the non focus vessels VTE are accounted for by fishing vessels, about 18.1% by ferries, about 6.8% by bulk cargo barges, etc.

Approximately nine cargo focus vessels enter and leave Juan de Fuca Strait daily totaling about 6400 transits annually. Similarly, approximately 1400 tank focus vessels travel east and west annually (i.e. about 2 tank focus vessel per day enter and leave in Juan de Fuca Strait 2010). Totaling the VTE for tank focus vessels (Oil barges – 18.7%, Oil Tanker – 8.4%, Chemical Carrier – 3.9%, ATB – 3.4%) we arrive at 34.3% in Figure 4. Hence, about 18.7%/34.3% = 54.5% of the total tank focus vessel VTE is accounted for by oil barges that primarily travel within the VTRA study area in a north south direction (see Figure 36 and Figure 37) and therefore many would not be captured as entrance counts to the Strait of Juan de Fuca. Totaling the VTE for cargo focus vessels in Figure 4 we arrive at 65.7%. Therefore:

Finding 1: Within the VTRA 2010 study area about 34.3% of the total time that focus vessels are underway is accounted for by vessels that carry oil products as cargo. The remainder 65.7% is attributed to focus vessels that carry other cargo.

Informed by vessel time exposure, the VTRA 2010 analysis tool evaluates POTENTIAL accident frequency and POTENTIAL oil losses for tank focus vessels and cargo focus vessels. The Base Case Scenario (Case P) analysis, based on Vessel Traffic Operational Support System (VTOSS) 2010 data, serves as a reference point to evaluate relative risk changes due to selected potential maritime terminal developments. The Steering Committee chose to model traffic level impacts of maritime terminal development projects that were in advanced stages of a permitting process. Each planned project forms a What-If scenario and associated What-If vessels are added to the 2010 Base Case year, while keeping other traffic levels constant. Specifically, the following What-If Scenario's were suggested for further analysis:

Case Q - GW 487: The Gateway bulk carrier terminal: 487 bulk carriers (318 Panama class and 169 Cape class).

Case R - KM 348: The Trans-Mountain/Kinder Morgan pipeline expansion: 348 crude oil tankers (each 100,000 DWT).

Case S - DP 415: The combination of proposed changes at Delta Port: 348 bulk carriers and 67 container vessels.

Case T - GW-KM-DP: All three of the above scenarios operating at the same time.

Moreover, the Steering Committee recommended that bunkering operations supporting these potential development projects be represented as well in the analysis.

Figure 6 and Figure 7 visualize graphically one of the VTRA 2010 analysis output formats in a manner that hopefully waterway users, regulators and the public can understand. Figure 6 and Figure 7 are 3D visualizations of POTENTIAL oil losses within this study area and their

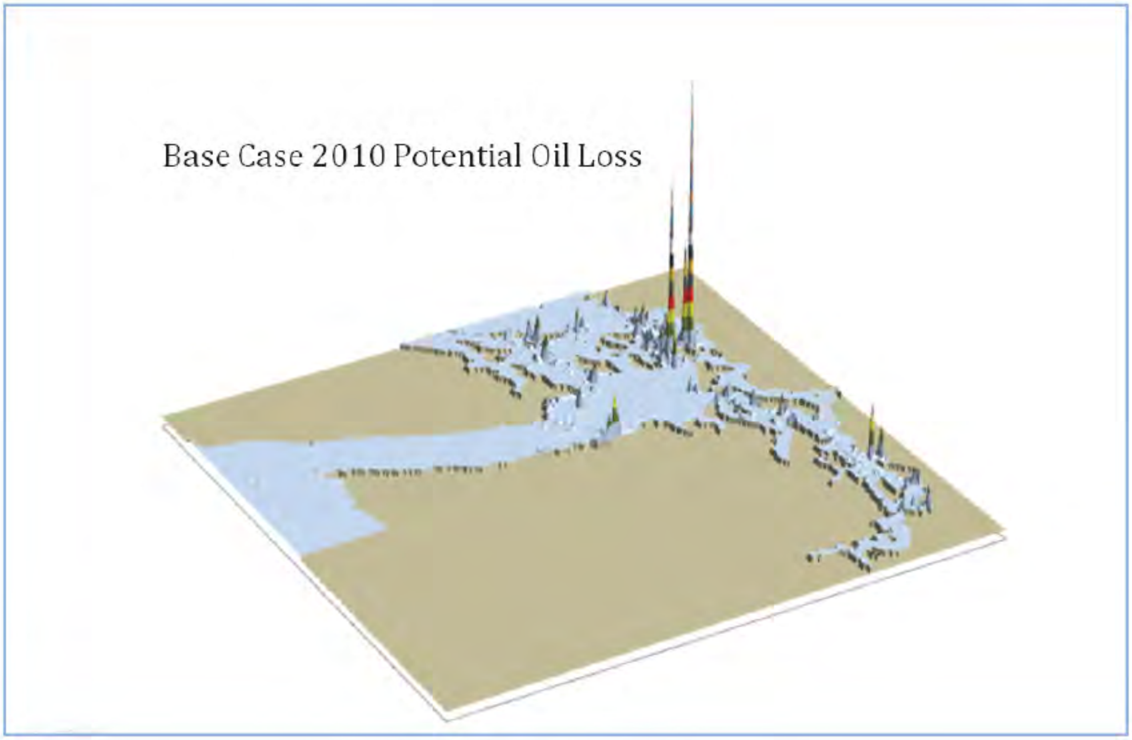

Figure 6. 3D Geographic profile of Base Case 2010 POTENTIAL oil loss (Case P).

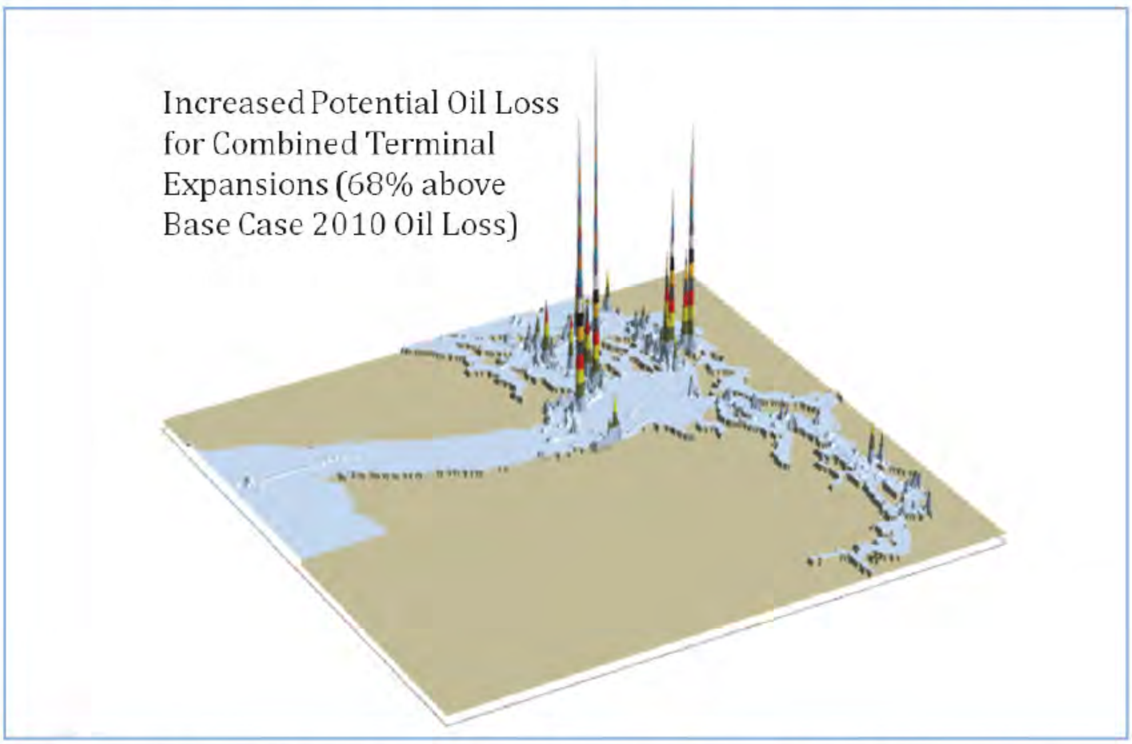

Figure 7. 3D Geographic profile of POTENTIAL oil loss assuming all three What-If Scenarios are operational (Case T).

geographic distribution. Figure 6 depicts POTENTIAL oil losses for the 2010 Base Case Year (Case P), whereas Figure 7 depicts POTENTIAL oil losses when all three What-If scenarios are assumed operational at the same time (Case T). Figure 7 illustrates a 1.68 factor increase in overall POTENTIAL oil losses compared to the Base Case 2010 year without additional risk mitigation. This too demonstrates that throughout the VTRA 2010 we concentrate more on relative comparisons across accident types, oil outflow categories, What-If scenarios and waterway zones and less on the absolute values of the analysis results in our scenario analyses.

For each what-if scenario and each waterway zone we evaluate the total annual focus vessel time of exposure (VTE) for each focus vessel type and compare it to their vessel time of exposure observed in the Base Case 2010 year. Similarly, we evaluate the total oil time exposure (i.e. the total amount of time a cubic meter of oil is moving through the area) for each what-if scenario, taking into account focus vessel fuel and oil cargo, and compare it to the oil time exposure (OTE) observed for the 2010 Base Case year.

The VTE tends to be a driver in the analysis of POTENTIAL accident frequency, whereas the OTE tends to be a driver in the analysis of POTENTIAL oil losses. Figure 8 demonstrates a comparison by waterway zone of the POTENTIAL oil losses for the combined what-if scenario (Case T) to those in the Base Case 2010 year (Case P). A detailed explanation of the output format in Figure 8 is provided in the body of this report on Page 97. Figure 8 shows that while system-wide POTENTIAL oil losses increase by about +68% (1.68) in Case T (green highlight), larger percentages are observed for the following specific waterway zones (Orange and Red highlights):

- Haro Strait/Boundary pass (+375%),
- Buoy J (+344%)
- San Juan Islands (+189%)
- East Strait of Juan de Fuca (+142%),
- West Strait of Juan de Fuca (+104%),
- Georgia Strait (+81%),

Most notably:

Finding 2: The Haro Strait/ Boundary pass and the Buoy J waterway zone specific relative increases in POTENTIAL oil loss are larger than 300% (Red highlights) when all three maritime terminal developments are assumed operational simultaneously. Despite Haro Strait/ Boundary pass and the Buoy J absolute contributions to system-wide POTENTIAL oil losses differing substantially in magnitude, relative changes in both waterway zones deserve further consideration. Be mindful that of the three maritime terminal development projects only the Trans-Mountain/Kinder Morgan expansion involves tankers.

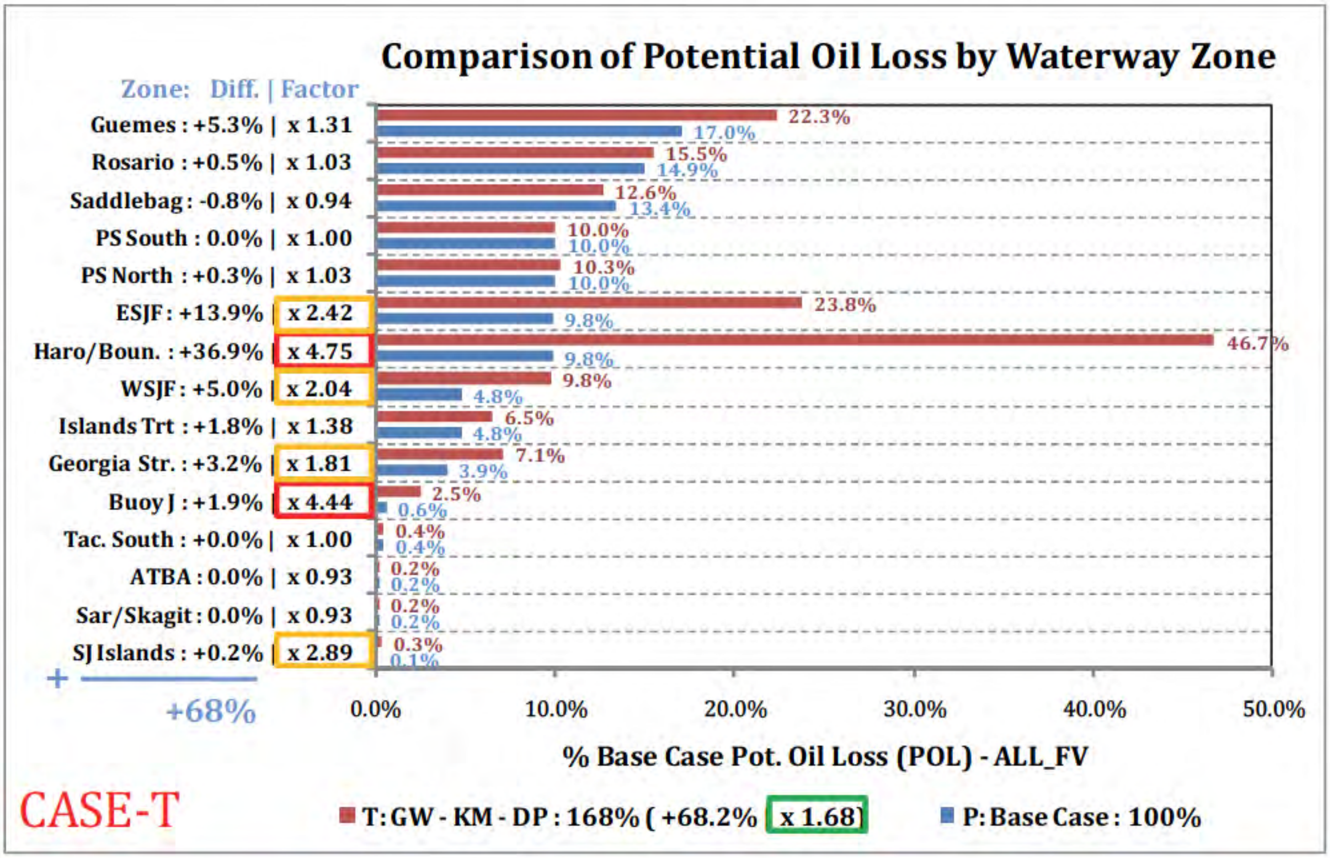

Figure 8. Relative comparison of POTENTIAL oil outflow by waterway zone. Blue bars show the percentage by waterway zone for the base case 2010 year, red bars show the percentage for Case T in terms of base case percentages. Absolute differences by waterway zone and relative multipliers by waterway zone are provided in the y-axis labels. **(see Page 97 for detailed explanation of output format).**

Risk Mitigation and Historical Bench Mark results

A series of risk mitigation measures were proposed to help inform a risk management process. Table 1 provides descriptions of the scenarios analyzed. The effect of risk mitigation measures were applied to VTRA 2010 model's input parameters and the system-wide and waterway zone specific relative effectiveness of these measures were evaluated. Detailed analysis result presentations by waterway zone for What-If and Risk Mitigation Measure (RMM) scenarios are posted at the following url:

http://www.seas.gwu.edu/~dorpjr/tab4/publications_VTRA_Update.html.

We strongly encourage interested parties to visit the url above and study these results to help inform stakeholders when engaging in such a risk management process. In Table 2 (Page 19) the system-wide analysis results for the various scenarios listed in Table 1 (Page 18) are provided.

Historical arrival data of tank and cargo focus vessels was obtained from the Marine Exchange of Puget Sound (MXPS). Tank focus vessel arrival data spanned 1998-2012. Cargo vessel Automatic Independent System (AIS) crossing line count data spanned 2008 – 2012 for crossing lines at the entrance to the West Strait of Juan de Fuca, Puget Sound and Georgia-Strait (see Figure 104 on page 137 for a depiction and general location of these crossing lines). Prior to 2008, AIS was either not available or not considered reliable for use herein. An analysis was conducted on both datasets (described in more detail in Chapter 9) and high and low years were selected from both data sets for benchmarking/ sensitivity analysis. High/Low years were used to define High/Low traffic scenarios by adding/canceling vessel transits to/from the 2010 Base Case (P) and the combined What-If Scenario (T).

The purpose of benchmarking/sensitivity analysis is three-fold. First, to evaluate robustness of the 2010 Base Case (P) and Combined What-If (T) Scenario analyses in light of historical increases or decreases in traffic. Second, the high-low scenario analyses conducted on the Base Case (P) serve as a benchmark to compare (1) changes in risk levels evaluated for the various What-If and RMM Scenarios against (2) changes in risk levels evaluated at historical high/low traffic levels. Third, it provides context regarding changes occurring in the background that in conjunction with What-If Scenarios further inform the potential need for risk management actions. Analysis results for the Bench Marking/Sensitivity Scenarios are included in Table 2 as well.

Table 2 shows (orange highlights) that from a tank focus vessel perspective, the high year adds about 2% of tank focus vessel VTE, whereas the low year removes about 2% of tank focus vessel VTE. Moreover, the blue highlights in Table 2 depict that in a high year for cargo focus vessels about 7%-2% = 5% of focus vessel VTE is added, whereas in the low year only 3%-2% = 1% of focus vessel time VTE is removed. Therefore:

Finding 3: The VTRA 2010 Base Case (Case P) is from a historical perspective an average year in terms of tank focus vessel exposure and a rather low year in terms of cargo focus vessel exposure.

Table 2 also lists POTENTIAL changes in risk from the Base Case 2010 year for the three individual What-If and High/Low Scenarios. By and large changes in risk evaluated for the What-If Scenarios exceed those for the high-year bench mark/sensitivity scenario. With the exception of the Delta Port What-If Scenario this observation applies to vessel time exposure, POTENTIAL accident frequency and POTENTIAL oil loss. For the Delta Port What-If Scenario this observation only applies to POTENTIAL accident frequency. Therefore:

Finding 4: Were any of the three individual maritime terminal developments to come into effect, or any combination thereof, POTENTIAL changes in risk may be deemed significant changes from the Base Case 2010 year risk levels. It would thus only be prudent to consider

the implementation of one or more risk mitigation measures to counter those POTENTIAL risk increases.

Eleven Risk Mitigation Measure (RMM) scenarios were evaluated for their potential effectiveness. For 9 out of the 11 RMM scenario's, evaluated risk reductions were larger than the risk reductions evaluated for the low year Bench Mark/Sensitivity scenarios enacted on the Base Case 2010 year. Therefore:

Finding 5: For 9 out of the 11 RMM scenarios evaluated, their risk reductions may be deemed significant reductions. Hence it is suggested that their associated risk mitigation measures be considered for implementation, should any of three individual maritime terminal projects, or any combination thereof, to come into effect.

One of the challenges of exercising risk management over a large and complex waterway is being cognizant of both waterway zone specific and system-wide effects. One approach could be to evenly distribute potential risk increases across the affected area, i.e. to allow for risk increases in locations that currently have low risk levels compared to those that are already higher. On the other hand, one could aim for an equitable distribution of future risk allowing for each location to have a similar relative percentage increase in risk.

Following either approach, we believe that the question "which risk mitigation measure should one implement?" is not the right question to ask, but rather one should ask oneself "which portfolio of risk mitigation measures should one implement". A trial 6 RMM portfolio scenario analysis was conducted which resulted in a by enlarge across the board risk reduction across the various waterway zones considered in the VTRA study area (see Figure 9 and Figure 10). Most notably, evaluated overall risk reduction in POTENTIAL accident frequency (-29%) for the trial 6 RMM portfolio applied to the Combined What-If Scenario (T) resulted in lower POTENTIAL accident frequency (89%) than evaluated for the 2010 Base Case (P) POTENTIAL (green high lights in Figure 9 and Table 2). Evaluated POTENTIAL oil losses for the trial 6 RMM portfolio applied to the Combined What-If Scenario (T), on the other hand, were still higher (+24%) than the Base Case 2010 year (red high lights in Figure 10 and Table 2). Some caution is needed in interpreting the -29% risk reduction in POTENTIAL accident frequency in the green high light in Figure 9 and the -44% risk reduction in the red high light from Case T in Figure 10, as some of the risk mitigation measures efficiency in the 6 RMM trial portfolio are evaluated as maximum potential benefit analyses. Regardless, we arrive at the following conclusion:

Finding 6: While evaluated POTENTIAL risk increases as a result of the three maritime developments may be deemed significant, the VTRA 2010 analysis supports that most of those system-wide risk increases may be mitigated utilizing a well designed RMM portfolio.

In testament to the Puget Sound Harbor Safety Committee stated objective of instilling a safety culture within the Puget Sound maritime community, 4 out of the 11 suggested RMM scenario's

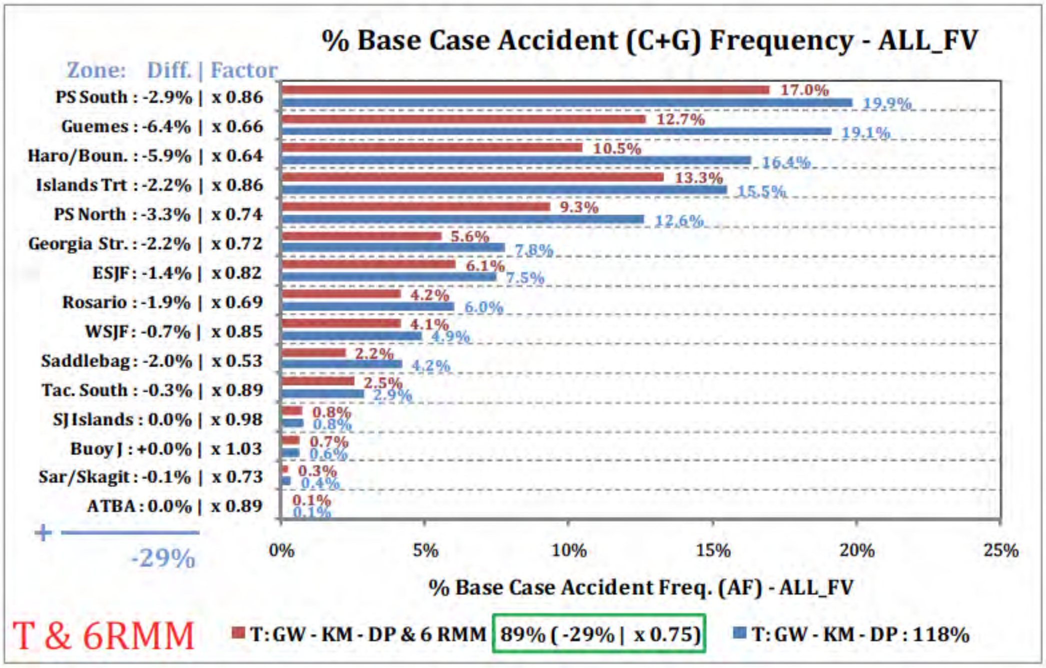

Figure 9. By waterway zone comparison of POTENTIAL accident frequency before and after modeled implementation of a risk mitigation measure port folio enacted on the combined What-If Scenario (Case T). See Page 97 for detailed explanation of output format.

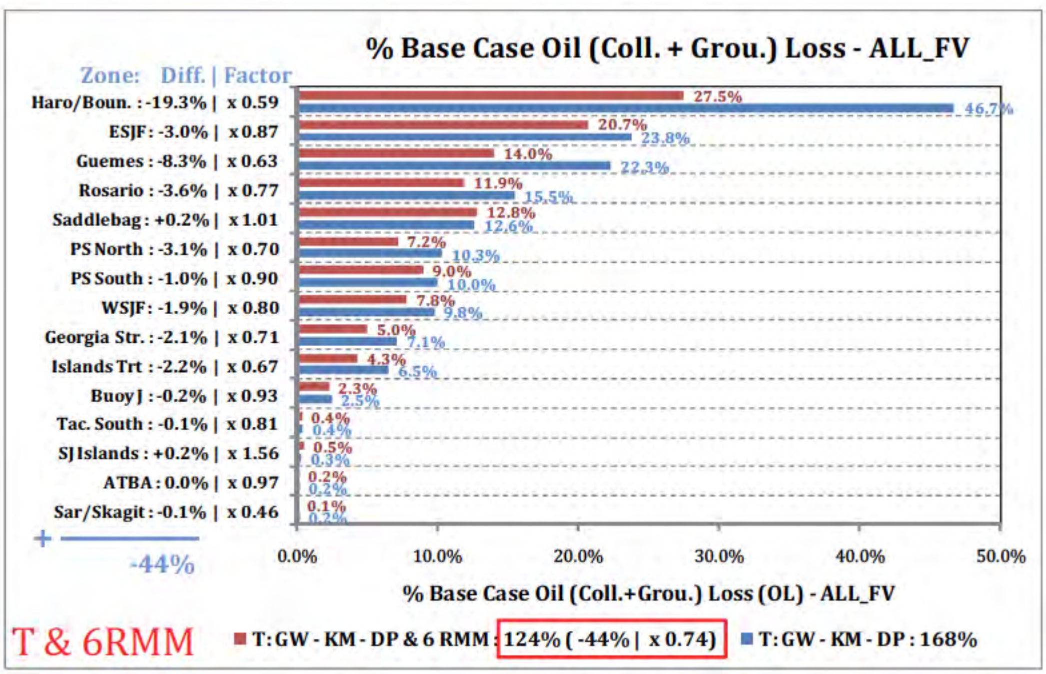

Figure 10. By waterway zone comparison of POTENTIAL oil loss before and after modeled implementation of a risk mitigation measure port folio enacted on the combined What-If Scenario (Case T). See Page 97 for detailed explanation of output format.

involved risk mitigation measures that are currently under consideration or have been partially implemented. The evaluation of these RMM Scenarios was applied to the 2010 Base Case year. Subsequent analyses evaluated risk reductions for these RMM scenarios that exceed risk reduction in risk evaluated for the historical low year scenario. Hence:

Finding 7: Even if none of the three individual maritime terminal developments were to come into effect, it is recommended that the risk mitigation measures applied to the 2010 Base Case Scenario be considered for system-wide implementation in the VTRA study area.

Closing Comments

By providing analyses by waterway zone similar to the one depicted in Figure 8 for the various RMM scenario analyses, an information source is provided to help answer difficult and location specific risk management questions. In our opinion, given the number of communities involved in these waterway zones, these risk management questions can only be answered utilizing the collaborative analysis approach. No doubt, these risk management questions are equally important in other ongoing studies considering the potential risk increases as a result of traffic increases linked to proposed maritime terminal development projects.

We close with the observation that there is a serious need for an electronic data source that is cross-boundary (US and Canadian waters) where the vessel type is consistently defined and verified beyond cargo focus vessel or tank focus vessel classifications. VTOSS and AIS are such cross-boundary data sources and could serve this purpose. However without currently possessing a common and consistently recorded vessel identifier or vessel type classification, VTOSS and AIS unfortunately still required vetting at the individual vessel level for the purpose of the analysis presented in this report. Moreover, with the same eye towards risk management analysis it would be equally beneficial if such datasets records capture cargo or at a minimum cargo levels (laden, unladen, 50% laden, etc.) and a cargo type. In particular, we would like to specifically call out the need for the electronic recording at a much greater consistency of the barge type and cargo content of tug-tows. Not only would studies like these benefit from the availability of such a data source, but the immediacy of having such information available could also benefit first responders responding to a spill scenario both from a response and a safety to the first responder perspective.

Summarizing, we advocate a collaborative systems approach towards answering risk management questions, not one that is just locally targeted missing potential side effects or points of view. Ultimately, we believe that the strength of the VTRA 2010 analysis lies in this systems view, but equally important is the evaluation of relative POTENTIAL risk changes of What-If and RMM scenarios within in a single common framework. No doubt, the risk communication process amongst stakeholders that took place following the collaborative analysis approach in conducting these analyses during the VTRA 2010 and made possible by the Puget Sound Harbor Safety Committee is at least as important.

Table 1. Short description of scenario analyses conducted utilizing the VTRA 2010 model

	WHAT IF SCENARIO ANALYSIS
P - Base Case: 2010	Modeled Base Case 2010 year informed by VTOSS 2010 data amongst other sources.
Q - GW - 487 : Gateway	Gateway expansion scenario with 487 additional bulk carriers and bunkering support
R - KM - 348: Kinder Morgan	Transmountain pipeline expansion with additional 348 tankers and bunkering support
S - DP - 415: Delta Port	Delta Port Expansion with additional 348 bulk carriers and 67 container vessels
T - GW - KM - DP: All Three	Combined expnasion scenario of above three expansion scenarios
	P - Base Case: 2010 - RISK MITIGATION MEASURE (RMM) ANALYSIS
P - Base Case & DH100	Base Case year with 100% double hull fuel tank protection for Cargo Focus Vessels
P - Base Case & HE00	Base Case Year with 100% human error reduction on Oil Barges
P - Base Case & HE50	Base Case Year with 50% human error reduction on Oil Barges
P - Base Case & CONT17KNTS	Base Case Year with max speed of 17 knots for container ships
	Q - GW - 487 : Gateway - RISK MITIGATION MEASURE (RMM) ANALYSIS
Q - GW 487 & NB	Gateway expansion scenario and no bunkering support
Q - GW 487 & NB & OH	Gateway expansion scenario and no bunkering support and traversing only Haro routes
	T - GW - KM - DP: All Three - RISK MITIGATION MEASURE (RMM) ANALYSIS
T - GW - KM - DP & OW ATB	Case T with ATB's adhering to one way Rosario traffic regime
T - GW - KM - DP & EC	Case T with Cape Class bulk carrier given benefit of+ 1 escort on Haro and Rosario routes
T - GW - KM - DP & EH	Case T with all Focus Vessels given benefit of +1 escort vessel on Haro routes
T - GW - KM - DP & ER	Case T with Cape bulkers, laden Tankers, ATB's given benefit of +1 esc. on Rosario routes
T - GW - KM - DP & 6RMM	Case T with benefit OW ATB, EH, ER, P-HE50, Q-NB and P-CONT17 KNTS
	P - Base Case: 2010 - BENCHMARK (BM) & SENSITIVITY ANALYSIS
P - Base Case & LOW TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a low historical year
P - Base Case & LOW TAN	Base Case with Tankers set at a low historical year
P - Base Case & HIGH TAN	Base Case with Tankers set at a high historical year
P - Base Case & HIGH TAN + CFV	Base Case with Tankers and Cargo Focus Vessels set at a high historical year
	T - GW - KM - DP: All Three - BENCHMARK (BM) & SENSITIVITY ANALYSIS
T - GW - KM - DP & LOW TAN + CFV	Case T with Tankers and Cargo Focus Vessels set at a low historical year
T - GW - KM - DP & LOW TAN FV	Case T with Tankers set at a low historical year
T - GW - KM - DP & VAR	Case T with additional variability in timing of What-If Focus Vessel arrivals
T - GW - KM - DP & HIGH TAN FV	Case T with Tankers set at a high historical year
T - GW - KM - DP & HIGH TAN + CFV	Case T with Tankers and Cargo Focus Vessels set at a high historical year

Table 2. Summary of VTRA 2010 system-wide scenario analyses results. Detailed analyses results by waterway zone are dispersed throughout this report and available at: http://www.seas.gwu.edu/~dorpjr/tab4/publications_VTRA_Update.html

	WHAT IF SCENARIO ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case: 2010	100%	100%	100%	100%
Q - GW - 487 : Gateway	+13% | 113%	+5% | 105%	+12% | 112%	+12% | 112%
R - KM - 348: Kinder Morgan	+7% | 107%	+51% | 151%	+5% | 105%	+36% | 136%
S - DP - 415: Delta Port	+5% | 105%	+3% | 103%	+6% | 106%	+4% | 104%
T - GW - KM - DP: All Three	+25% | 125%	+59% | 159%	+18% | 118%	+68% | 168%
	P - Base Case: 2010 - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case: 2010	100%	100%	100%	100%
P - Base Case & DH100	0% | 100%	0% | 100%	0% | 100%	-8% | 92%
P - Base Case & HE00	0% | 100%	0% | 100%	-16% | 84%	-4% | 96%
P - Base Case & HE50	0% | 100%	0% | 100%	-8% | 92%	-2% | 98%
P - Base Case & CONT17KNTS	+4% | 104%	+3% | 103%	-4% | 96%	-6% | 94%
	Q - GW - 487 : Gateway - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
Q - GW - 487 : Gateway	+13% | 113%	+5% | 105%	+12% | 112%	+12% | 112%
Q - GW 487 & NB	-5% | 108%	-1% | 104%	-1% | 111%	-10% | 103%
Q - GW 487 & NB & OH	-4% | 109%	-2% | 104%	-2% | 110%	-7% | 105%
	T - GW - KM - DP: All Three - RISK MITIGATION MEASURE (RMM) ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
T - GW-KM-DP: All Three	+25% | 125%	+59% | 159%	+18% | 118%	+68% | 168%
T - GW - KM - DP & OW ATB	+4% | 128%	+4% | 163%	-29% | 89%	-44% | 123%
T - GW - KM - DP & EC	+1% | 126%	+2% | 161%	0% | 118%	0% | 168%
T - GW - KM - DP & EH	0% | 125%	+0% | 159%	-2% | 116%	-4% | 164%
T - GW - KM - DP & ER	0% | 125%	+0% | 159%	-7% | 111%	-24% | 143%
T - GW - KM - DP & 6RMM	0% | 125%	+0% | 159%	-8% | 111%	-12% | 156%
	P - Base Case: 2010 - BENCHMARK (BM) & SENSITIVITY ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
P - Base Case: 2010	100%	100%	100%	100%
P - Base Case & LOW TAN + CFV	-3% | 97%	-14% | 86%	-5% | 95%	-20% | 80%
P - Base Case & LOW TAN	-2% | 98%	-13% | 87%	-4% | 96%	-22% | 78%
P - Base Case & HIGH TAN	+2% | 102%	+14% | 114%	+3% | 103%	+9% | 109%
P - Base Case & HIGH TAN + CFV	+7% | 107%	+15% | 115%	+4% | 104%	+8% | 108%
	T - GW - KM - DP: All Three - BENCHMARK (BM) & SENSITIVITY ANALYSIS			
	Vessel Time Exposure (VTE)	Oil Time Exposure (OTE)	Pot. Accident Frequency (PAF)	Pot. Oil Loss (POL)
T - GW-KM-DP: All Three	+25% | 125%	+59% | 159%	+18% | 118%	+68% | 168%
T - GW - KM - DP & LOW TAN + CFV	-3% | 121%	-15% | 144%	-2% | 116%	-27% | 141%
T - GW - KM - DP & LOW TAN FV	-2% | 123%	-13% | 146%	-3% | 116%	-23% | 145%
T - GW - KM - DP & VAR	-1% | 124%	-7% | 152%	-3% | 116%	-11% | 157%
T - GW - KM - DP & HIGH TAN FV	+3% | 128%	+15% | 174%	+6% | 125%	+8% | 175%
T - GW - KM - DP & HIGH TAN + CFV	+6% | 131%	+16% | 174%	+8% | 127%	+17% | 184%