CHAPTER 2

VTRA 2010 FINAL REPORT

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

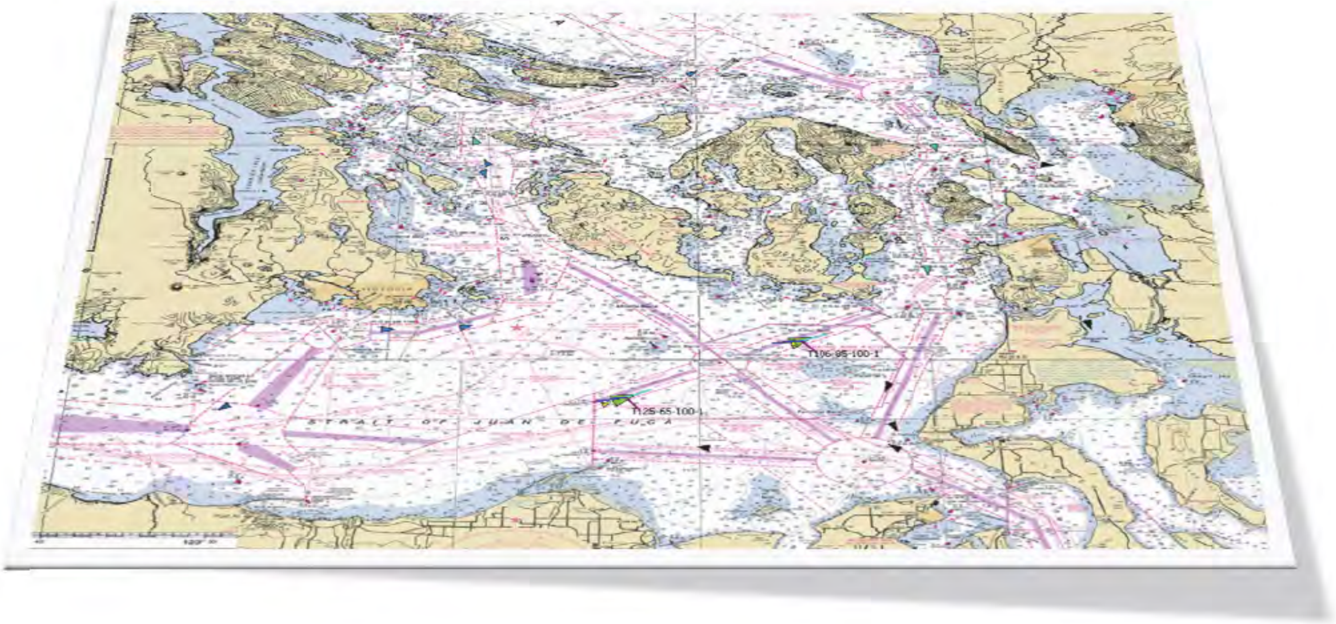

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Table Contents

2. SUMMARY 2005 VTRA MODEL METHODOLOGY

Is it safer for a river gambling boat in New Orleans to be underway than to be dockside? Should wind restrictions for outbound tankers at Hinchinbrook Entrance in the Prince William Sound Alaska be lowered from 40 knots to 35 knots? Is investment in additional life craft on board Washington State Ferries in Seattle warranted or should the International Safety Management (ISM) code be implemented fleet wide? Can enhanced ferry service in San Francisco Bay and surrounding waters alleviate traffic congestion on roadways in a safe manner? Do potential traffic increases made possible through the addition of a pier terminal at a refinery located north of the San Juan Islands in Washington State increase or reduce oil transportation risk?

The risk management questions above were raised in a series of projects over a time frame spanning more than 10 years and were addressed using a single risk management analysis methodology developed over the course of these projects by a consortium of universities. This methodology centers around stakeholder involvement and dynamic maritime risk simulations of a Maritime Transportation Systems (MTS) that also integrate incident/accident data collection, expert judgment elicitation and consequence models [2]-[3].

It has been peer reviewed by the National Research Council [4], top experts in the field of expert elicitation design and analysis, and has been continuously improved over time since its initial development in 1996. The model has previously been used in the Prince William Sound Risk Assessment ([5]-[8]), the Washington State Ferries Risk Assessment[9], and the Exposure Assessment of the San Francisco Bay ferries [10]. The model was most recently used during the 2005 VTRA [11] - [13]. Prior to updating with 2010 VTOSS data, data use and model assumptions of the VTRA model have been peer-reviewed [2] - [13].

Our analysis approach of involving stakeholders has been referred to in [1]as the collaborative analysis approach:

"In collaborative analysis, the groups involved in a policy debate work together to assemble and direct a joint research team, which then studies the technical aspects of the policy issue in question. Representative from all the participating groups are given the ability to monitor and adjust the research throughout its evolution. Collaborative analysis aims to overcome suspicions of distorted communication giving each group in the debate the means to assure that other groups are not manipulating the analysis. The ultimate goal is to generate a single body of knowledge that will be accepted by all the groups in the debate as a valid basis for policy negotiations and agreements. – George J. Busenberg, 1999."

The following is a brief description of this modeling approach. The updating of the 2005 VTRA model using 2010 VTOSS data followed the same collaborative approach used during the construction of the VTRA 2005 model, i.e. by making progress presentations to the Puget Sound Harbor Safety Committee and engaging stakeholders represented therein.

Situations (see Figure 3):

Accidents can only occur when vessels are transiting through the system. Our maritime simulation model attempts to re-create the operation of vessels and the environment for one calendar year within the geographic scope of the study through maritime simulation/ replication. The traffic modeled re-plays the movement of VTS participating vessels (using 2005 VTOSS data) and simulates the movement of smaller fishing vessels, whale watchers, and organized regatta events over a set of representative routes using representative vessel speeds. Representative vessel routes were constructed by vessel type using the 2005 VTOSS data set. Figure 11 provides a graphic of the 158 representative routes constructed for Oil Tankers. Vessels speeds are sampled from representative speed distribution by vessel type estimated using the West Strait of Juan de Fuca 2005 VTOSS data. Figure 12 plots example representative speed distributions for oil tankers, container vessels, bulk carriers and navy vessels used in the 2005 VTRA study. From Figure 12 one observes that the speed profile for oil tankers and bulk carriers is quite similar, whereas container vessels typically travel at higher speeds. The speed profile for navy vessels indicates a lot of variation in their speeds compared to the other vessel types in Figure 12. For each vessel type a representative speed distribution was fitted from vessel West Strait of Juan de Fuca speeds

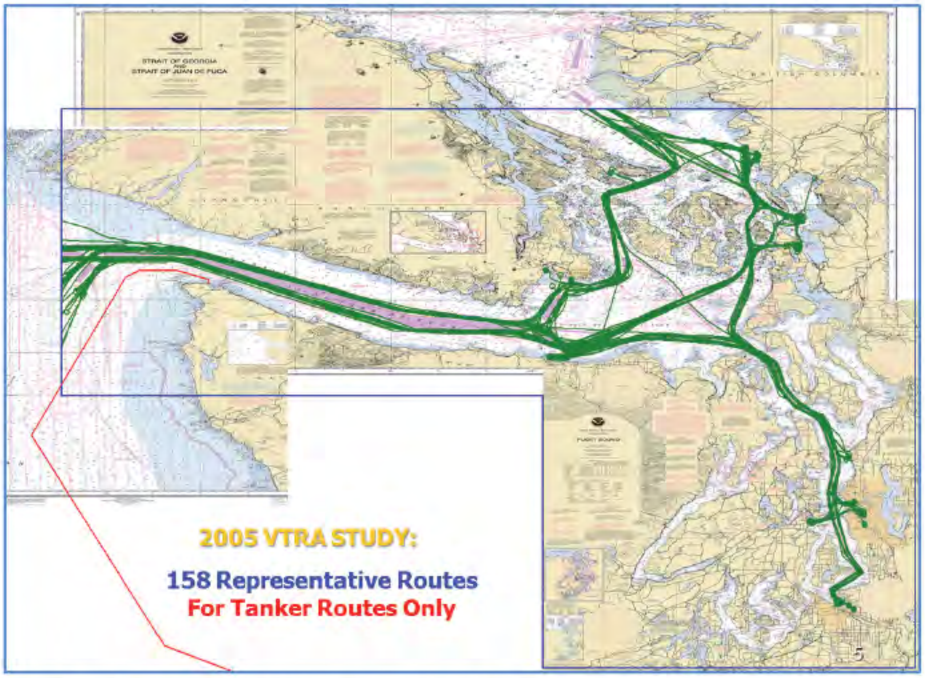

Figure 11.Graphic of 158 representative routes for oil tankers used in VTRA 2005 MTS simulation model.

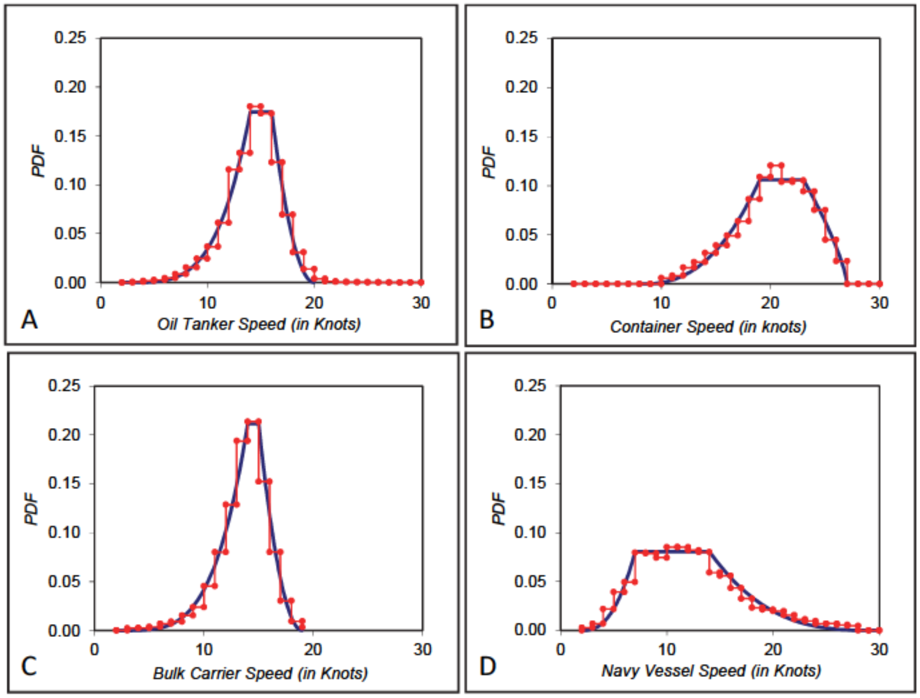

Figure 12.Example representative speed distribution for oil tankers (A), container vessel (B), bulk carriers (C) and navy vessels (D) estimated from VTOSS 2005 data. Step functions indicate the empirical probability distribution functions (pdf), whereas the solid lines are fitted Generalized Trapezoidal Distributions (GTD)[18].

observed in the VTOSS 2005 data. A vessel's sample speed is assumed constant throughout its transit, but subject to location speed changes trumped by traffic rules speed changes according to study area traffic rules implemented in the 2005 VTRA model. Location speed multipliers were estimated by comparing average speeds by vessel type for locations East Strait of Juan de Fuca, Haro-Strait/Boundary Pass, Rosario Strait, Georgia Strait, Guemes Channel, Saddlebag. Puget Sound North, and Puget Sound South to the average West Strait of Juan de Fuca speeds.

The environmental factors modeled include wind, fog, and current. They are replayed hourly using publicly available data sources, such as e.g. the National Climatic Data Center. (See, also [11], Appendix C). The update of the 2005 VTRA also includes updating to 2010 current tables. Other environmental conditions from the 2005 VTRA model are retained as well as traffic modeled therein not calling into VTS centers. Specifically, tribal and commercial fisheries, scheduled and USCG permitted regatta events and whale watching movements from the 2005 VTRA model are retained.

Every minute over a simulation calendar year, the 2005 VTRA model counts situations of moving vessels in which there is the potential for an accident to occur if things start to go wrong (see, e.g., [2]). The traffic conditions and environmental conditions are recorded in these situations and stored in a database representing a one year analysis scenario (for example the base case and various What-If traffic scenarios).

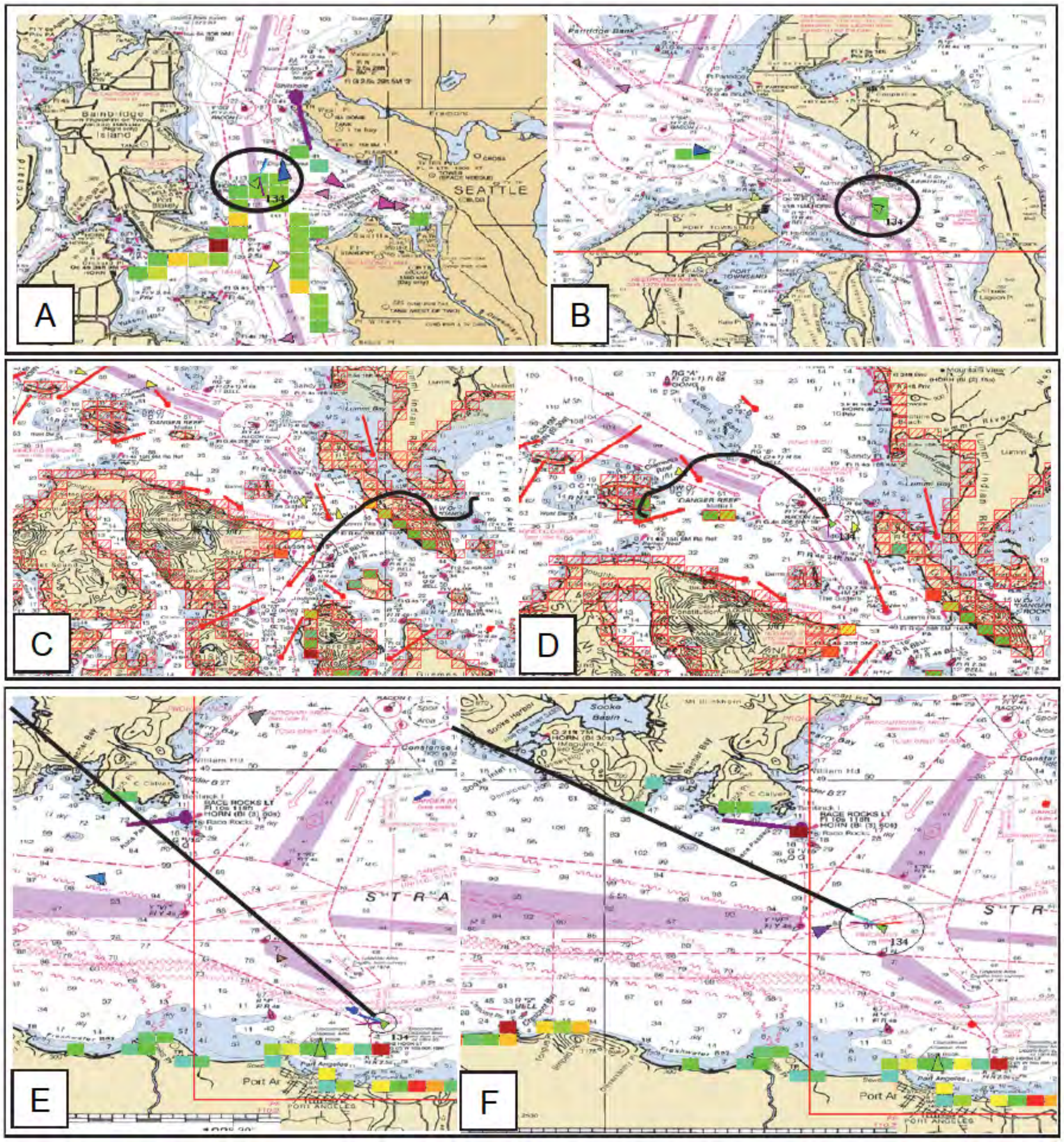

Figure 13.Graphical depiction of counting situations in the VTRA simulation model.

Incidents & Accidents (see Figure 3):

Incidents are the events that immediately precede the accident. The types modeled include, propulsion losses, total steering losses, loss of navigational aids, and human errors. An exhaustive analysis of all possible sources of study area relevant accident, near miss, incident, and unusual event data was performed (see, e.g. [11], Appendices A and B). The accident types included in this study are collisions between two vessels, groundings (both powered and drift), and allisions that involve the FV's. The simulation counts the situations in which accidents could occur, while recording variables that could affect the chance that an accident will occur; these include the proximity of other vessels, the types of the vessels, the location of the situation and its wind, visibility and current. Thankfully, incidents and accidents in this geographic area are rare and there is not enough data to say how each of these variables affects the chances of an accident[7]. To determine this, we turned to maritime experts. The VTRA model is calibrated to historically observed, but geographically restricted accident and incident data (see [11], Appendix E). As such, the annual accident and incident rates generated by the VTRA model for the base case scenario coincide with geographically restricted historically observed accident and incident rates for the calibration data set.

To determine how accident situations differ in terms of relative accident likelihood, we must turn to the experts due to this lack of data. We ask experts to assess the differences in risk of two similar situations that they have extensive experience of. In each question we change only one factor and through a series of questions we build our accident probability model, incorporating the data where we can. Our expert judgment elicitation procedure is described in detail in [2], [14]. An example question is shown in Figure 14; here an oil tanker with an untethered escort is meeting a ferry. The question asks how much an increased wind speed would affect an accident probability given the presence of the specified incident. The experts involved include tanker masters, tug masters, Puget Sound pilots, Coast Guard VTS operators, and ferry masters. A full description of the process, experts and series of questionnaires conducted during the 2005 VTRA is provided in [11], Appendix E. No additional expert judgment elicitation is conducted for the update of the 2005 VTRA model using 2010 VTOSS data.

Oil Spill (see Figure 3):

An oil outflow model [3] for collision and grounding accidents explicitly links input variables such as hull design (single or double, see Figure 15), displacement and speed, striking vessel displacement and speed, and the interaction angle of both vessels to output variables (see Figure 16): longitudinal and transversal damage extents of the tanker. Overlaying these damage extents on a vessel's design (see Figure 15) yields an oil outflow volume totaling the capacity of damaged

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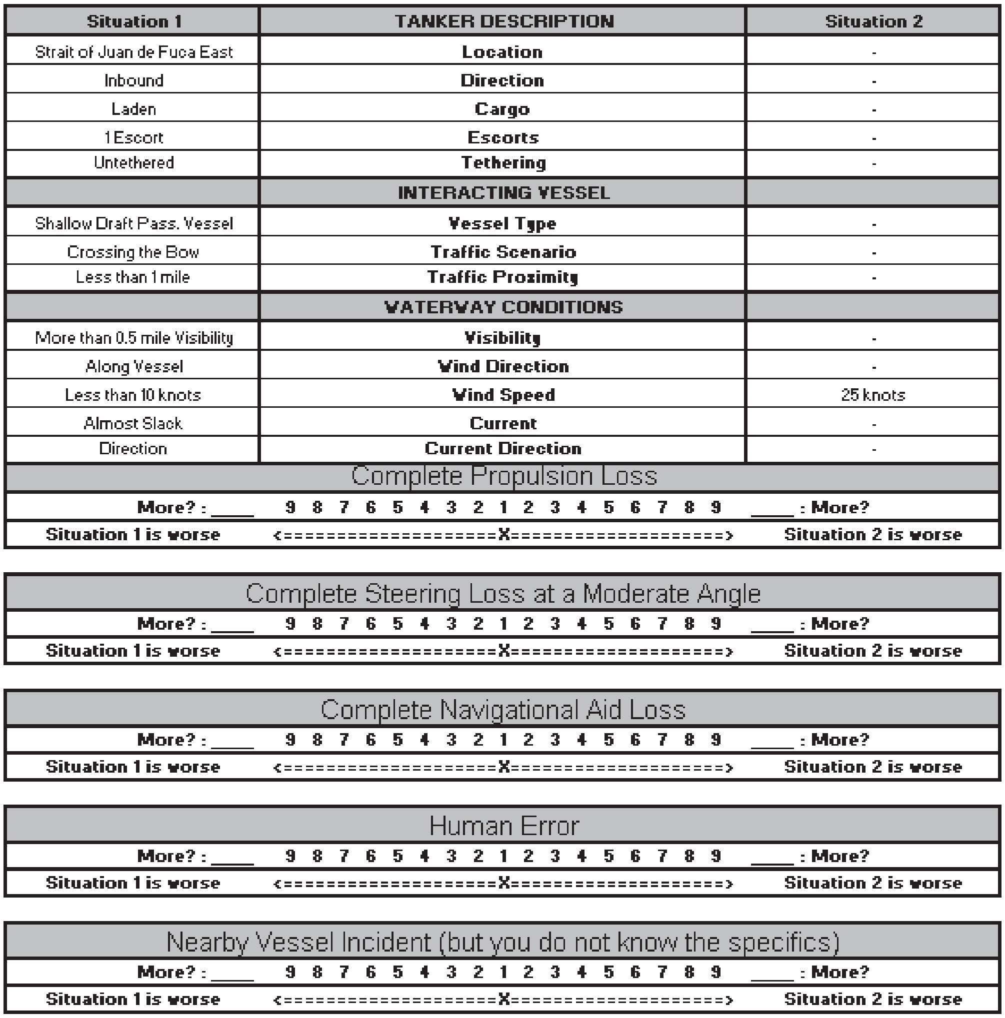
[7] Over the course of our various studies typically less than ten accidents were observed in a time frame of ten years or more to calibrate the VTRA model.

tank compartments. A similar model was developed for grounding accidents during the 2005 VTRA.



Situation 1	TANKER DESCRIPTION	Situation 2
Strait of Juan de Fuca East	**Location**	-
Inbound	**Direction**	-
Laden	**Cargo**	-
1 Escort	**Escorts**	-
Untethered	**Tethering**	-
	INTERACTING VESSEL	
Shallow Draft Pass. Vessel	**Vessel Type**	-
Crossing the Bow	**Traffic Scenario**	-
Less than 1 mile	**Traffic Proximity**	-
	WATERWAY CONDITIONS	
More than 0.5 mile Visibility	**Visibility**	-
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	25 knots
Almost Slack	**Current**	-
Direction	**Current Direction**	-

Complete Propulsion Loss		
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	<====================X====================>	**Situation 2 is worse**

Complete Steering Loss at a Moderate Angle		
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	<====================X====================>	**Situation 2 is worse**

Complete Navigational Aid Loss		
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	<====================X====================>	**Situation 2 is worse**

Human Error		
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	<====================X====================>	**Situation 2 is worse**

Nearby Vessel Incident (but you do not know the specifics)		
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	<====================X====================>	**Situation 2 is worse**

Figure 14.Example question during 2005 VTRA of a paired comparison questionnaire of situations for tanker collision accident attribute parameter assessment given all incidents.

A total of 80,000 simulation accident scenarios described in the National Research Council SR259 report [15]published in 2001 served as the joint data set of input and output variables used in this "linking" process. The title page of the SR259 report is depicted in Figure 17. The oil outflow model was designed keeping computational efficiency in mind to allow for its integration with a maritime transportation system (MTS) simulation. A full description of the oil outflow model developed during the 2005 VTRA including its parameters and their estimation is provided in [11], Appendix D.

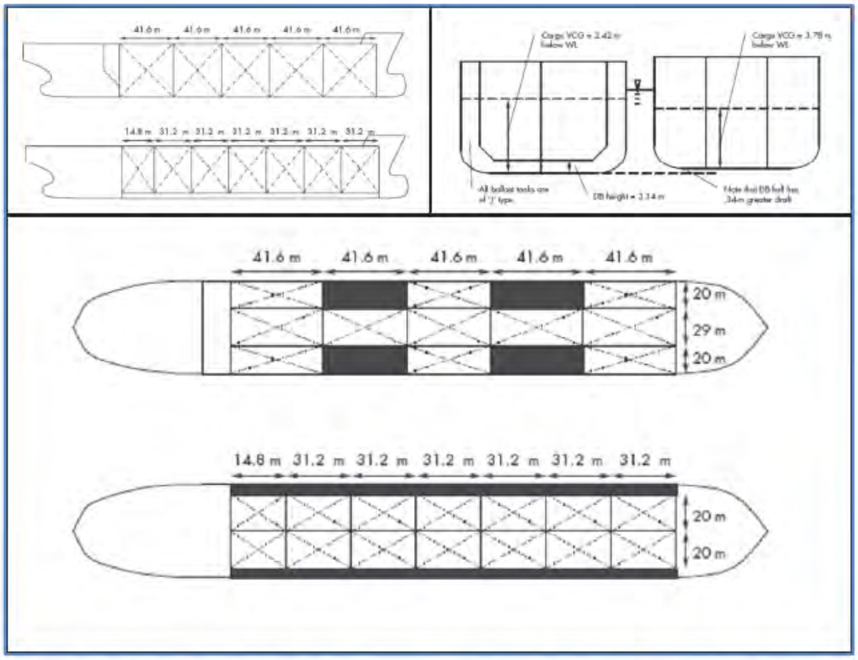


Figure 15. Single hull and double hull 150.000 DWT tanker designs used in 2005 VTRA taken from the National Research Council SR259 report [15].

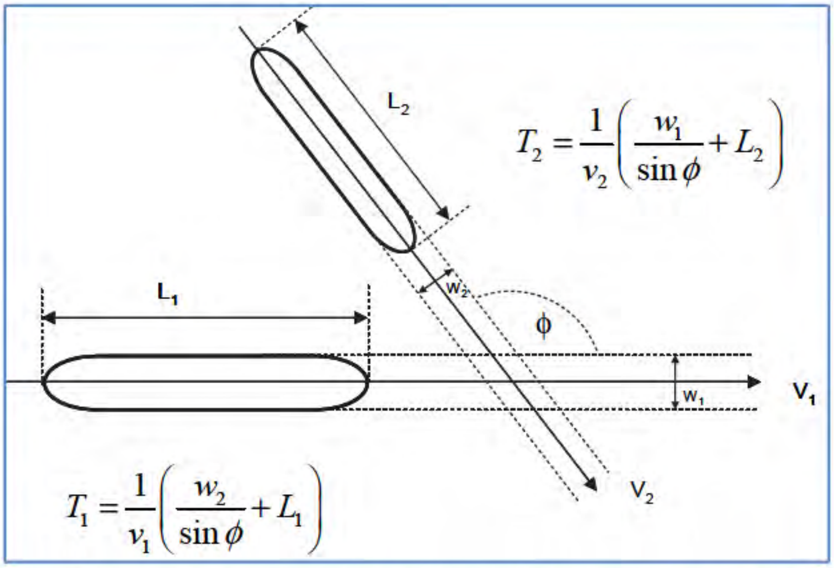
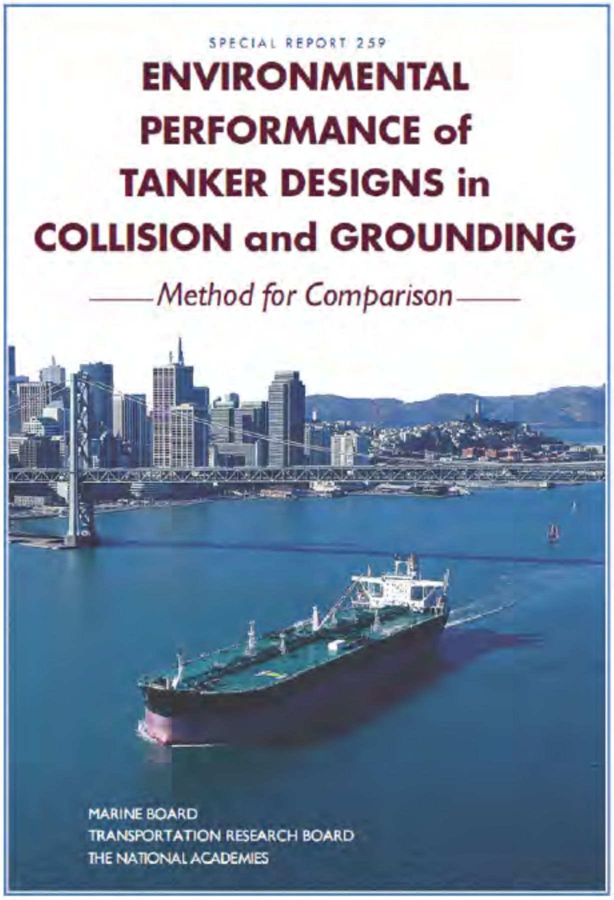


Figure 16.A schematic of a striking ship-struck ship probability model used in the 2005 VTRA.



SPECIAL REPORT 259

ENVIRONMENTAL PERFORMANCE of TANKER DESIGNS in COLLISION and GROUNDING

Method for Comparison

MARINE BOARD
TRANSPORTATION RESEARCH BOARD
THE NATIONAL ACADEMIES

Figure 17. Title page of National Research Council SR259 report [15]

Format of Scenario Analysis Results and Comparisons (See Figure 18)

A potential risk mitigation scenario to be analyzed with the VTRA update is whether from a vessel risk perspective it makes sense to allow for bulk carriers docking at the Gateway facility being considered to travel north through Haro-Strait Boundary Passes as opposed to only using a northerly route through Rosario Strait. The 2005 VTRA only modeled a northerly route for Gateway vessels through Rosario Strait. 2005 VTRA model output allows for a visual assessment of the effectiveness of a risk mitigation scenario by comparing its geographic profile of vessel risk to that of other vessel traffic risk mitigations scenarios to a baseline geographic profile of vessel traffic risk (see Figure 18 for an example of such a geographic profile of vessel risk[8]). An advantage of the geographic profile display format in Figure 18 is that it allows for a direct visual

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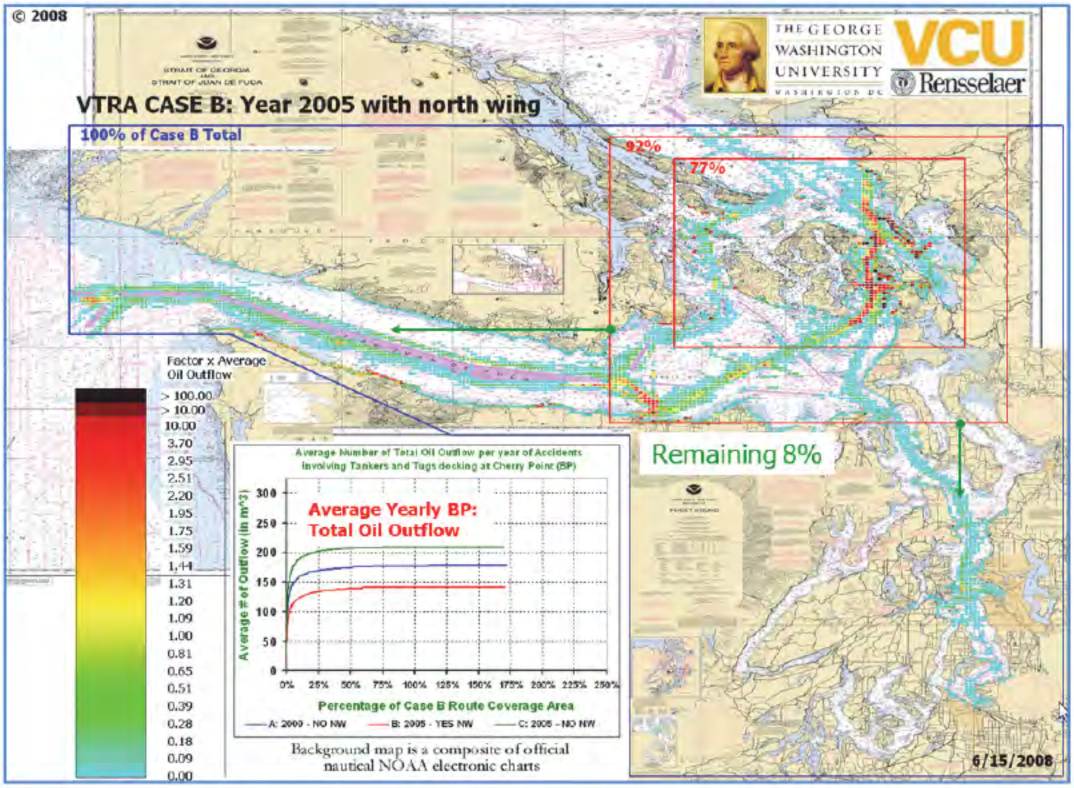
[8] The VTRA 2005 analysis in [11] was limited to vessel traffic risk evaluation associated with Tankers, ATB's and ITB's docking at the Cherry Point terminal.



Background map is a composite of official nautical NOAA electronic charts

Figure 18.An example of a geographic profile of oil spill risk (generated during the 2005 VTRA).

assessment of the distribution of the analysis results and thus provides for an understanding of system risk. For example, we immediately observe from Figure 18 larger risk levels in the areas of Rosario Strait, Haro-Strait Boundary Pass, Guemes Channel and at route convergence locations at Buoy J and Port Angeles. A visual comparison of a baseline scenario generated geographic profile and that of a What-If and risk mitigation scenario allows for a visual assessment of potential increases and decreases in risk and their location. The percentages in the top left corners of the red rectangles and blue border of the study area in Figure 18 allow for a more quantitative evaluation of system risk and its changes from a baseline scenario to What-If and RMM scenario analysis results. The fact that in Figure 18 the percentage in the top left of the blue border equals 100% implies that this is a baseline geographic profile. For a more detailed explain of geographic risk profile interpretation see [12].

Sensitivity and Uncertainty of Analysis Results

More data is being made available electronically over time allowing for an even more accurate representation of the movement of vessel traffic and modeling of the accident scenarios within an MTS simulation. As a result, the movement of traffic within the MTS simulation more resembles a replication of how vessels actually moved rather than simulating them. An example being that every vessel in the MTS simulation arrives and departs as per the VTOSS 2010 data while retaining its route segments and vessel characteristics, such as e.g. its own vessel name. No doubt, this added level of detail reduces model uncertainty to a great extent. The evaluation of model uncertainty is not accounted for in traditional sensitivity/uncertainty analysis approaches.

With the increased availability of this electronic data, however, the time to prepare it in an electronic format that can serve as input to an MTS simulation increases as well. Despite these advances, one should always bear in mind that any model is an abstraction of reality in which simplifying assumptions are often necessitated to maintain computational efficiency. The increase of computational complexity to reduce model uncertainty within the 2005 VTRA methodology, does unfortunately not allow for the application of traditional sensitivity/uncertainty analysis of output analysis results. We are pushing computational boundaries of existing computation platforms that the 2005 VTRA model runs on. As a result, we find that solely relative comparisons across accident types, across oil outflow categories and across risk intervention scenarios are particularly enlightening and informative and we concentrate less on the absolute values of the results in our analysis comparisons.

That being said, uncertainty of output analysis results for the 2005 VTRA methodology has been studied and funded by the National Science Foundation for smaller analysis context instances (See, [16], [17]). In these studies it was concluded that ranking of scenarios/alternatives are robust within our analysis methodology with respect to changes in vessel traffic. A small number of bench/mark sensitivity analyses in which traffic levels are varied may further serve as a guide to judge risk level changes as traffic levels change.