Oil Spill Risk in Industry Sectors Regulated by Washington State Department of Ecology Spills Program For Oil Spill Prevention and Preparedness

Environmental Research Consulting

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Forward

In 2007 the legislature directed the Joint Legislative Audit and Review Committee (JLARC) to examine the funding mechanism for the oil spill prevention, preparedness, and response program. The purpose of the review was to provide options for a risk based approach to address a funding deficit in the Oil Spill Prevention Account (OSPA) starting in the 2007-2009 biennium.

The JLARC report looked at three key questions as the basis of the review:

1. What are the sources of oil spill risk effecting Washington waters?
2. Do the current revenue sources align with the sources of risk?
3. Are there alternative funding methods?

The 2009 JLARC report "Review of Oil Spill Risk and Comparison to Funding Mechanism" concludes that:

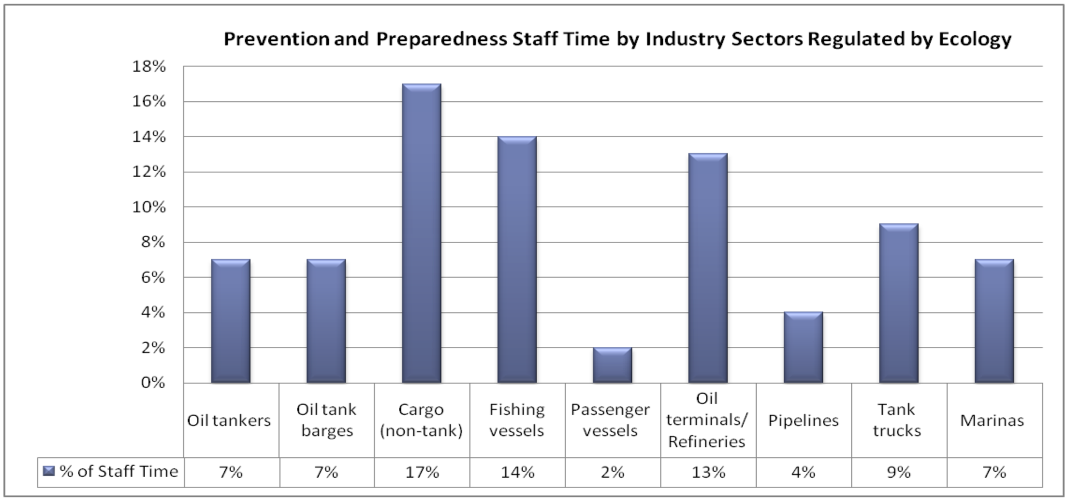
- There are many sources of oil spill risk occurring across the state.
- There is no alignment with the current revenue mechanism and the sources of risk.
- Other states have broader/different tax bases for funding oil spill prevention activities.

Although the JLARC report fulfills the legislative intent, the results examined a broader range of activities than those funded by the Oil Spill Prevention Account. For example, the report highlights many small spill sources including railroads and auto-repair shops that the Department of Ecology's Spills Program does not currently regulate. While the spill program's response unit oversees the cleanup of spills from all sources and volumes, the program's prevention and preparedness activities are focused on the industry sectors that pose the greater risk for major and catastrophic spills such as from oil tankers, cargo vessels, and oil refineries. The Legislature, recognized the significant environmental and economic impacts of a major spill like the *Exxon Valdez*, directed the Spills Program to focus its prevention and preparedness activities (see RCW 90.56 and 88.46) on the potential for a "worst-case discharge volume"[1].

After the JLARC report was completed, Ecology contracted with JLARC's consultant to further refine the risk analysis to *only* include industry sectors that are currently regulated by the Spills Program. This analysis used the same methodology as that of the JLARC report, with the additional consideration of the worst-case discharge volume. The following report is the result of that analysis.

In addition to this independent risk study, Ecology conducted an internal workload analysis to determine how much prevention and preparedness staff time was spent on each of the industry sectors (see the graph below). Notably, the greatest amount of staff time is spent with the *cargo vessels, fishing vessels, oil terminals, and refineries*.

[1] RCW 88.46.10 – Worst Case Discharge oil spill is defined as the complete loss of fuel and cargo (vessels) and complete loss of the largest tank (facility).



The current funding mechanism, the Oil Spill Administration Tax (commonly known as the barrel tax), is assessed on the first possession of oil imported into the state by a waterborne vessel (typically an oil tanker or barge). This activity is primarily associated with oil terminals /refineries that receive product from the vessel, thereby making the oil terminals/refineries the largest barrel tax payer. According to the JLARC report and this follow-on report, the oil terminals/refineries pose a risk of spills. However, a significantly higher risk is posed by oil tankers, cargo vessels and pipelines, but they do not pay the barrel tax.

Ecology's internal workload analysis offers the further conclusion that there is direct alignment between the legislative direction for the Spills Program's activities and the industry it regulates. However, like the JLARC report, the attached report also concludes there is not a strong alignment between the revenue mechanism and the industry sectors that pose the risk of major and catastrophic oil spills.

Oil spill risk analyses are often controversial and there are many approaches that can be taken. However, the JLARC report, this report, and the workload analysis conducted by Ecology, offer important information to inform the legislature and stakeholders about the relationship between funding and oil spill risk.

The legislature has determined that the greater risk of a major and catastrophic spill as those posed by oil tankers, cargo vessels, oil refineries and pipelines. The JLARC report confirmed that these industry sectors posed the highest risk. This report offers a narrower focus on the industry sectors that are within the current statutory authority of the Spills Program. If in the future, the legislature determines that the focus should be broaden to include other industry sectors such as railroads, these analyses could also be used to target new program activities.

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Executive Summary

Twenty years ago, on the 24th of March 1989, the tanker *Exxon Valdez* spilled 11 million gallons of crude oil into Prince William Sound. The devastating impact of that spill on the pristine waters and shorelines of Alaska and the far-reaching impacts to the natural and cultural resources of that state stunned the nation and the world. Yet, dramatic as it was, The Exxon Valdez spill was *not* a worst-case discharge from that tanker. Had *all* that fully-loaded tanker's cargo spilled, there would have been *six times as much oil* in the water. The urgent need for *effective spill prevention and preparedness measures* became clear.

Like Alaska, Washington State has unique invaluable natural and cultural resources that are vulnerable to impacts from spills from oil tankers and other sources. It is difficult to grasp that a worst-case discharge from a fully-loaded oil tanker in Washington waters would involve *several times the volume of oil released in the Exxon Valdez*. The Alaskan spill required $4.4 billion in spill response, and caused $341 million in natural resource damages and over $11 billion in third-party damages. A large oil spill, let alone a worst-case discharge, in Washington waters would likely to cause damages of at least this level. Though very large oil spills are relatively rare, the risk is real.

Spill "risk" is a combination of the likelihood of a spill occurring and the impact of that spill. Each spill is a unique event that varies *oil type* (e.g., diesel fuel, crude oil, or heavy fuel), *season* (e.g., periods of salmon spawning or bird migration), and *location* (e.g., Puget Sound or Columbia River). Oil types vary with regard to their toxicity, persistence in the environment, and propensity to coat fur and feathers, as well as shorelines and other resources. The seasonal timing and location of an oil spill will also determine the types of environmental and socioeconomic damages that occur. These factors, along with spill volume, determine the overall magnitude of impacts.

This study addresses oil spill risk of those industry sectors regulated by the Washington State Department of Ecology (Ecology) for *spill prevention and preparedness*, such as oil tankers, oil barges, large vessels, oil terminals, pipelines, and refineries. Spill *preparedness* programs and resources need to focus not only on the most common types of incidents (smaller spills), but must also address the *small but real* likelihood of a worst-case discharge spill (RCW 90.56 and 88.46). From the perspective of *prevention*, it is important to recognize that the fact that a particular source type (e.g., oil tankers) has not had a significant spill in recent history does not mean there is no risk from this source, but rather is reflective of the fact that prevention measures, such as vessel inspections and tug escorts, have been effectively administered on a continuing basis by regulatory authorities.

The analyses demonstrate that with regard to oil spill risk from the perspective of prevention and preparedness, oil tankers represent over 75 percent of the total worst-case discharge potential risk, followed by cargo vessels ("non-tank vessels") with 15 percent of the risk, and oil tank barges with six percent of the total risk. The relative risk will change slightly by 2015 with 57 percent of the worst-case discharge potential risk attributable to oil tankers and 32 percent of the risk attributable to cargo vessels.

During 1995 through 2008 there were over 1,000 near-miss vessel casualty incidents that did *not* result in spillage, and the rate of near-miss incidents has decreased by 80 percent since 2001. The fact that actual oil spill rates have been so low with oil tankers and other vessels is testament to the effectiveness of Ecology's spill prevention and preparedness programs. Funding for these spill prevention and preparedness programs should be commensurate with worst-case discharge potential risk.

Introduction

The “risk” of an event is defined by risk analysts as the product of probability and consequences or impact. With oil spills, risk can be defined as the *probability* that a particular type of spill incident is likely to occur multiplied by the impacts of that particular type of spill scenario. Since the types of spills that occur vary by *spill source* (e.g., oil tankers, pipelines, or oil terminals), as well as by *spill volume* (e.g., 25 gallons or 200,000 gallons), *oil type* (e.g., diesel fuel, crude oil, or heavy fuel), *season* (e.g., periods of salmon spawning or bird migration), and *location* (e.g., Puget Sound or Columbia River), the probability dimension needs to take into account the broad spectrum of spill scenarios by all of these factors.

Oil types vary with regard to their toxicity, persistence in the environment, and propensity to coat fur and feathers, as well as shorelines and other resources. The seasonal timing and location of an oil spill will also determine the types of environmental and socioeconomic damages that occur. Since the environmental impacts of oil spills are dependent on spill volume, oil type, season, and location, these factors need to be incorporated into the consequences or impacts side of risk.

Determining the risk for different industry sectors as potential spill sources in the present time requires an analysis of historical spill trends (spill types and their impacts). At the same time, from the perspective of spill *prevention* and *preparedness*, the *potential* for worst-case spillage, even if not reflected in historical data, must also be taken into account. A worst-case discharge is defined as the largest possible release of oil from a particular source – e.g., all the oil in an oil tanker (oil tank ship) or all the oil in a storage tank at a facility.

Spill *preparedness* programs and resources need to focus not only on the most common types of incidents (smaller spills), but must also address the *small but real* likelihood of a worst-case discharge spill scenario. From the perspective of *prevention*, it is important to recognize that the fact that a particular source type (e.g., oil tankers) has not had a significant spill in recent history is reflective of the fact that prevention measures, such as vessel inspections, have been effectively administered on a continuing basis by regulatory authorities.

This study addresses oil spill risk of those industry sectors regulated by the Washington State Department of Ecology (Ecology) from the perspective of *spill prevention and preparedness*, but *not* spill response:

- Oil tankers (tank ships carrying oil as cargo)
- Oil tank barges (manned and unmanned barges carrying oil as cargo)
- Cargo vessels (non-tank vessels carrying oil as fuel only)
- Fishing vessels (>300 gross tons)
- Passenger vessels (>300 gross tons, excepting public vessels)
- Oil terminals
- Pipelines
- Refineries
- Tank trucks (only tank vehicles transferring oil to vessels over waters of the state)
- Marinas and other small fueling facilities (transferring to non-recreational vessels in quantities <10,500 gallons)

Each of these source types presents a different spill risk due to the volumes and types of oil handled or transported, the geographic zones in which these sources transit or are permanently located, the rate at which they handle oil, the nature of the oil handling and transit, and the effectiveness of spill prevention measures in place.

A previous study presented to the State of Washington Joint Legislative Audit & Review Committee (JLARC) in January 2009 addressed oil spill risk for the State, but focused on *all* spills to State waters, including spills from source types not under Ecology's regulatory jurisdiction, such as spills from smaller vessels and smaller inland facilities. In addition, since the JLARC study was mandated for the purpose of quantifying risk for funding mechanisms for all types of programs, including spill response, the methodology and results are not directly applicable for the analysis of oil spill risk from the perspective of spill preparedness and prevention measures for Ecology's more narrow regulatory jurisdiction.

The analyses of oil spill risk from Ecology-regulated industry sectors builds on the previous JLARC study and applies a narrower focus. This study from the perspective of oil spill preparedness and prevention programs revealed that while the *actual* spillage during 1995 – 2008 showed pipelines to be the greatest risk, the *potential* worst-case discharge (WCD) spillage risk is greatest with oil tankers (oil tank ships) followed by cargo vessels. By 2015, the risk will still be highest with oil tankers but more risk will shift to cargo vessels.

Analyses of the spill data (119 spills and 1,035 near-miss vessel casualties in Washington waters) showed that the largest actual spill event involved 277,200 gallons of gasoline that spilled from a pipeline in Bellingham in June 1999. This incident tragically killed three people, though that impact is not captured in the impact rating score assigned to this type of incident. This particular pipeline spill had a WCD potential of 3.4 million gallons. But, oil tankers would have a WCD potential of over 33 to 83 million gallons, i.e., at least ten times the volume of the Bellingham pipeline spill and *three to seven times the size of the Exxon Valdez spill.*

Findings

Tankers

There were only 14 oil spills from tankers during 1995 to 2008, with a total of 13,709 gallons of oil spilled. During the same time period, however, there were an additional 132 near-miss casualty incidents. The total WCD potential for all of these 146 incidents was nearly 2.7 *billion* gallons. This WCD potential is expected to be reduced by 50 percent by 2015 with the full implementation of double hulls and other preventive measures. Yet, even at a reduced level in 2015, the risk from oil tankers will still be 316 times higher than that of pipelines.

The fact that oil tankers have historically represented less than four percent of the total spill risk while having had a WCD potential risk of over 75 percent is clearly reflective of the fact that spill prevention measures at both the national and federal levels have been enforced with great efficacy. National tanker spill rates have been shown to have decreased since 1990[2] due in large part to the implementation of various parts of the federal Oil Pollution Act of 1990 (OPA 90) and in some cases from coastal state

[2] Etkin (2003)

regulatory programs, which include mandated double hulls for tankers[3], increased liability limits for spill response, inclusion of natural resource damage assessments, and increased requirements for financial responsibility. Overall, a higher class of tankers transits US waters than other parts of the world.

At the same time, Washington State has distinguished itself within the US with regard to spill prevention from tankers and other vessels. Spill rates from vessels in Washington waters are significantly lower than in other key port states and in the US as a whole[4]. The lower spillage rates in Washington waters can be attributed to mandated and voluntary best-achievable-practice (BAP) programs for vessel owners and operators in the State, and the continuous efforts of Department of Ecology in such activities as inspecting vessels, monitoring vessel response and spill preparedness plans, implementing pre-booming regulations for oil transfer operations, tug escort programs, and conducting spill response drills and exercises.

During 1995 to 2008 there were over 1,000 near-miss vessel casualty incidents that did *not* result in spillage. It is noteworthy that the incidence of near-misses has decreased by 80 percent since 2001 (Figure 1).

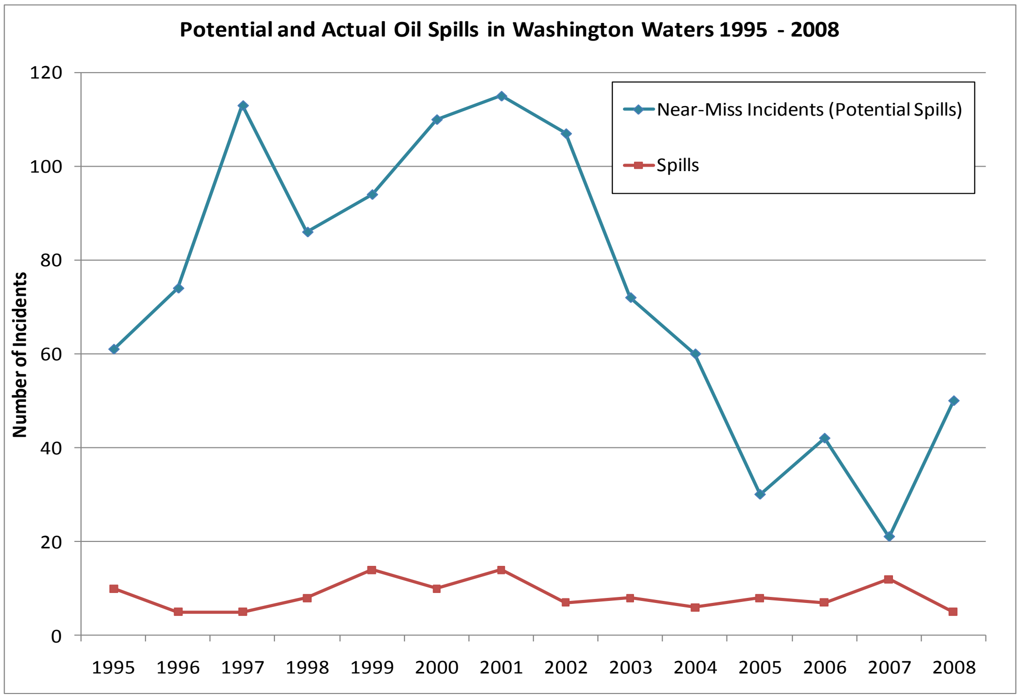

Figure 1: Actual spills (25 gallons or more) and potential spills (from near-miss vessel casualties) in Washington waters 1995 – 2008.

Cargo Vessels

Historically, cargo vessels presented the second highest risk from both actual and WCD perspectives. The relative risk from cargo vessels in 2015 will be higher since there will no significant prevention measures in place and incidents are expected to rise about 10 percent.

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[3] While full implementation of this regulation will not be realized until 2015, there has been a steady shift of tanker fleets from single-hulls to double-hulls over the last decade.

[4] Etkin and Neel (2001)

Pipelines

Overall, historically, pipelines represent nearly 79 percent of the total risk, cargo vessels 10 percent, and oil tankers less than 4 percent (Figure 2). At the same time, historically, oil tankers represent over 75 percent of the total WCD potential spill risk, followed by cargo vessels at over 15 percent, and oil tank barges at six percent (Figure 3).

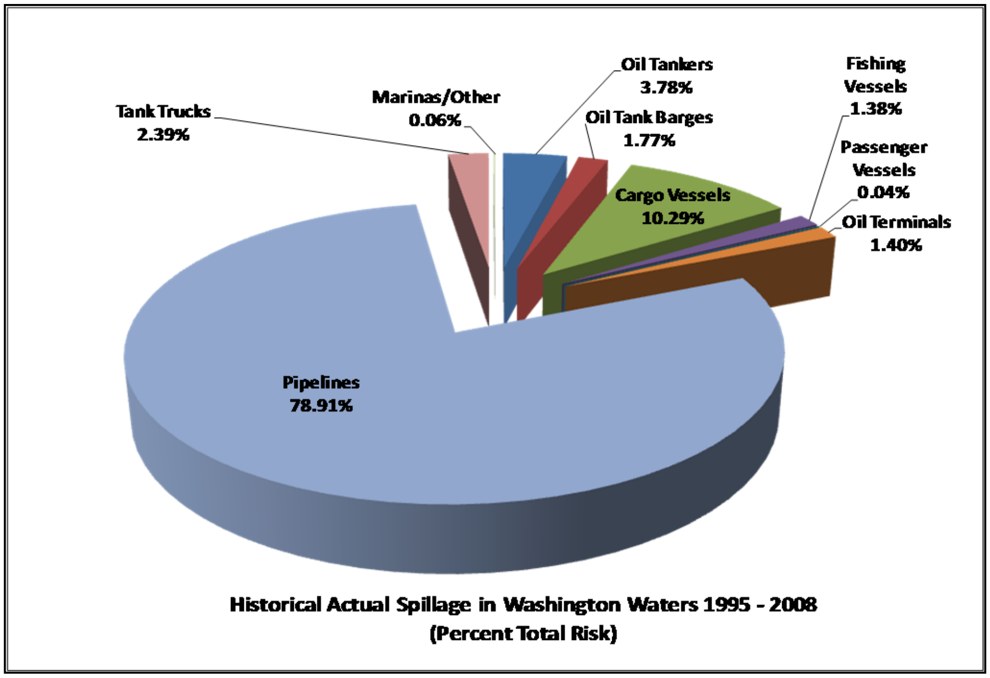

Figure 2: Percent total risk 1995 – 2008 by industry sector for historical actual spillage

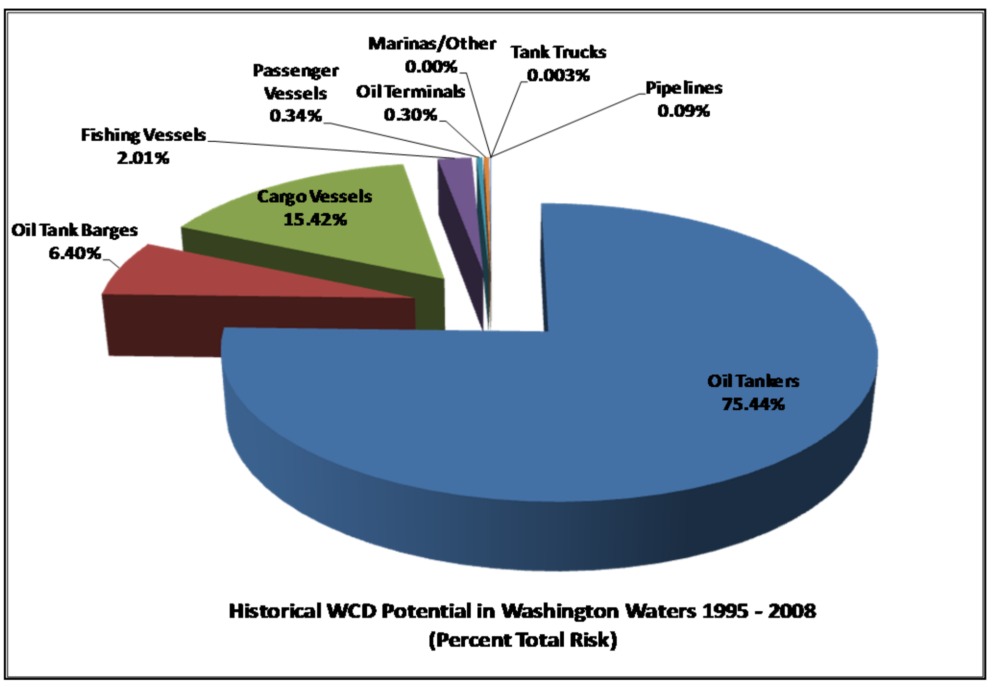

Figure 3: Percent total risk 1995 – 2008 by industry sector for historical WCD spillage potential

Oil Terminals

Similarly, the potential spillage from oil terminals and refineries is high, but spill rates have been kept at a very low level, again because of the vigilance of Ecology's prevention programs. Again, the need for spill preparedness needs to be commensurate with the potential for large spills from these sources.

Future Projections

Projecting to the year 2015, the relative WCD potential risk picture changes somewhat with oil tankers representing less than 57 percent of the total risk, cargo vessels having a higher relative risk than previously at 32 percent, and oil tank barges with a relative risk of six percent. Fishing vessels represent four percent of risk much higher than pipelines, which represent under 0.2 percent of the risk (Figure 4).

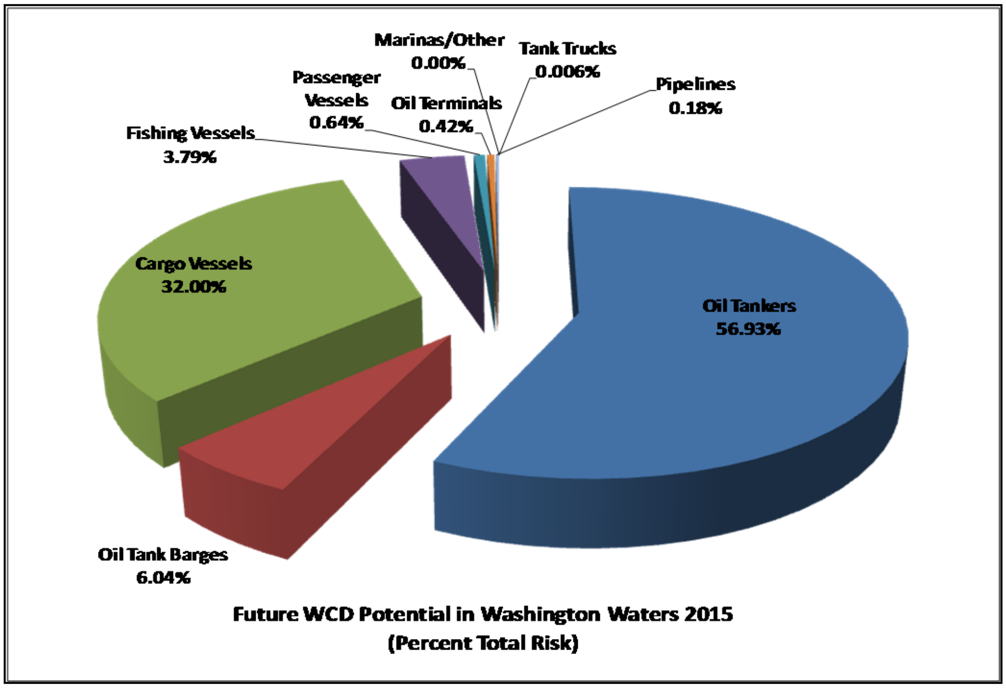

Figure 4: Percent total risk in 2015 by industry sector for WCD spillage potential

Implementing the very successful spill prevention measures and maintaining a level of spill preparedness *commensurate with the risk of potential WCD scenarios* requires considerable resources and effort on the part of the state's Department of Ecology Spills Program. These resources and efforts need to be maintained in order to keep spill rates and impacts low while being prepared for larger spills and possible WCD scenarios now and in the future.

Natural and Socioeconomic Values

Washington State has unique invaluable natural and cultural resources at stake. A worst-case discharge from a fully-loaded oil tanker or large oil terminal would involve several *times the volume of oil released in the Exxon Valdez* two decades ago. That spill required $4.4 billion in spill response[5], and caused $341 million in natural resource damages and over $11 billion in third-party damages. The impacts of a large

[5] All costs in 2008 dollars from ERC Spill Cost Database.

oil spill, let alone a worst-case discharge, in Washington waters is likely to cause damages of at least this level[6].

Basis of Spill Prevention and Preparedness Programs

Maintaining and enforcing spill prevention and preparedness requires continuous vigilance and resources and should clearly be based on the level of worst-case discharge potential risk presented by the industry sectors that are transporting and handling large quantities of oil.

According to the risk analyses conducted herein, the greatest risk lies with oil tankers (75.4 percent total risk), cargo vessels (15.4 percent total risk), oil tank barges (6.4 percent total risk), and fishing vessels (2.0 percent total risk). Lesser risks are attributable to passenger vessels, oil terminals (and refineries), pipelines, tank trucks transferring oil over water, and marinas and other small marine fueling facilities.

By 2015, this worst-case discharge risk picture will change to some degree with somewhat less risk from oil tankers (down to 57 percent total risk) and considerably more risk from cargo vessels (up to 32 percent total risk).

Conclusion

In conclusion, these analyses demonstrate that with regard to oil spill risk from the perspective of prevention and preparedness, oil tankers represent just over 75 percent of the total worst-case discharge potential risk, followed by cargo vessels (also called “non-tank vessels”) with 15 percent of the risk, and oil tank barges with six percent of the total risk. The relative risk will change slightly by 2015 with 57 percent of the worst-case discharge potential risk attributable to oil tankers and 32 percent of the risk attributable to cargo vessels.

During 1995 through 2008 there were over 1,000 near-miss vessel casualty incidents that did not result in spillage, and the rate of near-miss incidents has decreased by 80 percent since 2001. The fact that actual oil spill rates have been so low with oil tankers and other vessels is testament to the effectiveness of Ecology’s spill prevention and preparedness programs. Funding for these spill prevention and preparedness programs should be commensurate with worst-case discharge potential risk rather than be based on risk as measured by actual historical spill data.

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[6] Etkin (2004a, 2004b, 2004c, 2005); Etkin et al. (2005a, 2005b); French-McCay et al. (2004, 2005a, 2005b).

Appendix: Methodology and Results

Historical Data Analysis

The historical data analyzed in this study were provided to Environmental Research Consulting (ERC) by the Ecology Spills Program and included only spill and near-miss incidents from those sectors of direct concern to Ecology. The 119 spill incidents included in the study involved spillage of 25 or more gallons to State waters[7] from one of the regulated source types during 1995 through 2008. In addition, 1,035 near-miss vessel casualties[8] were included in the data set, as these incidents further reflected *potential* spillage (Figure A-1 and Table A-1). Actual spillage represented only 0.01 percent of potential worst-case spillage[9].

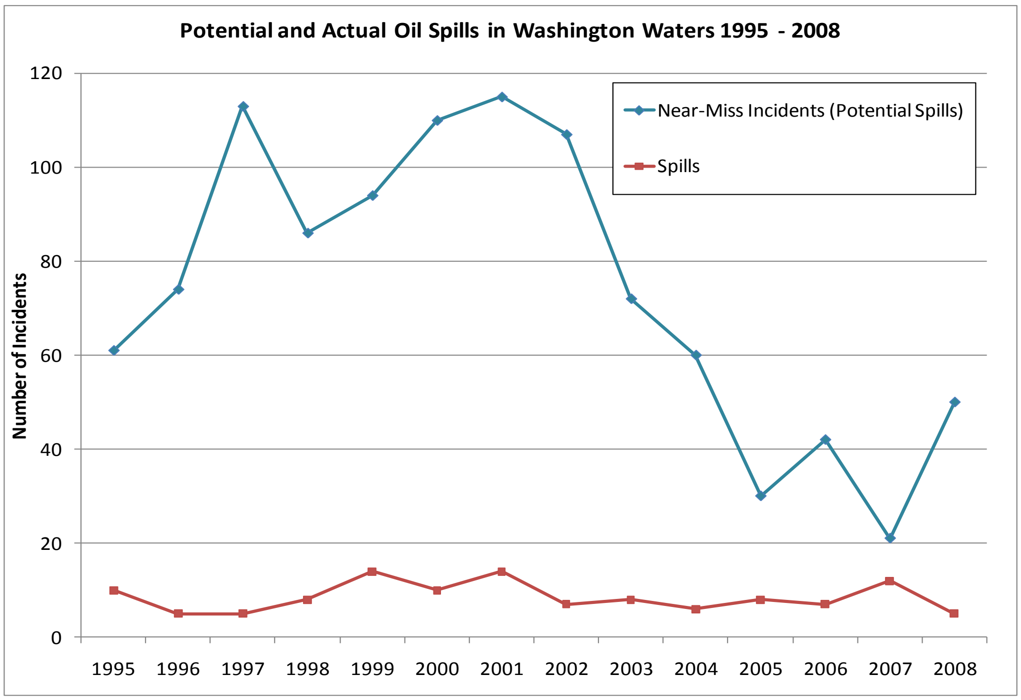

Figure A-1: Actual spills (25 gallons or more) and potential spills (from near-miss vessel casualties) in Washington waters 1995 – 2008.

Table A-1: Actual and Potential Oil Spillage in Washington Waters 1995 – 2008

Year	Near-Miss Incidents	Spills (25 gallons or more)	Actual Volume (gallons)	Potential Volume (gallons)	% Potential Volume
1995	61	10	3,405	224,248,824	0.0015%
1996	74	5	970	153,254,320	0.0006%
1997	113	5	705	230,911,174	0.0003%
1998	86	8	16,115	168,559,792	0.0096%
1999	94	14	280,255	348,490,042	0.0804%

[7] Spills that originated in Oregon or British Columbia waters that impacted Washington waters were not included.
[8] Near-miss casualty incidents or "potential" spills were specifically excluded from the JLARC study.
[9] Worst-case discharge volumes were provided by industry sectors to Washington Department of Ecology for the purpose of state contingency planning requirements.

Table A-1: Actual and Potential Oil Spillage in Washington Waters 1995 – 2008					
Year	**Near-Miss Incidents**	**Spills (25 gallons or more)**	**Actual Volume (gallons)**	**Potential Volume (gallons)**	**% Potential Volume**
2000	110	10	2,991	298,488,692	0.0010%
2001	115	14	7,575	626,593,614	0.0012%
2002	107	7	5,144	363,872,784	0.0014%
2003	72	8	9,362	151,541,774	0.0062%
2004	60	6	8,312	161,526,155	0.0051%
2005	30	8	974	85,812,870	0.0011%
2006	42	7	374	122,042,676	0.0003%
2007	21	12	3,230	190,337,330	0.0017%
2008	50	5	856	235,458,284	0.0004%
TOTAL	**1,035**	**119**	**340,268**	**3,361,138,331**	**0.0101%**

It is noteworthy that the incidence of near-misses has decreased by 80 percent since 2001.

Geographic Zones

Spill and casualty incidents were grouped into geographic zones[10], as described above, as well as considered for the State as a whole. The marine and estuarine geographic zones include (Figure A-2):

- Central Puget Sound
- South Puget Sound
- Hood Canal
- Whidbey Basin
- North Puget Sound
- Strait of Juan de Fuca
- Inner Straits
- Rosario Strait and Vicinity
- Grays Harbor
- Willapa Bay
- West Columbia River (downstream of Bonneville Dam)
- Outer Coast

The inland geographic zones include (Figure A-3):

- East Columbia River (including Snake River upstream of Bonneville Dam)
- Lake Union/Washington (including Ship Canal)
- Olympic Peninsula
- West of Cascades
- East of Cascades

[10] The same geographic zones were used in the JLARC study.

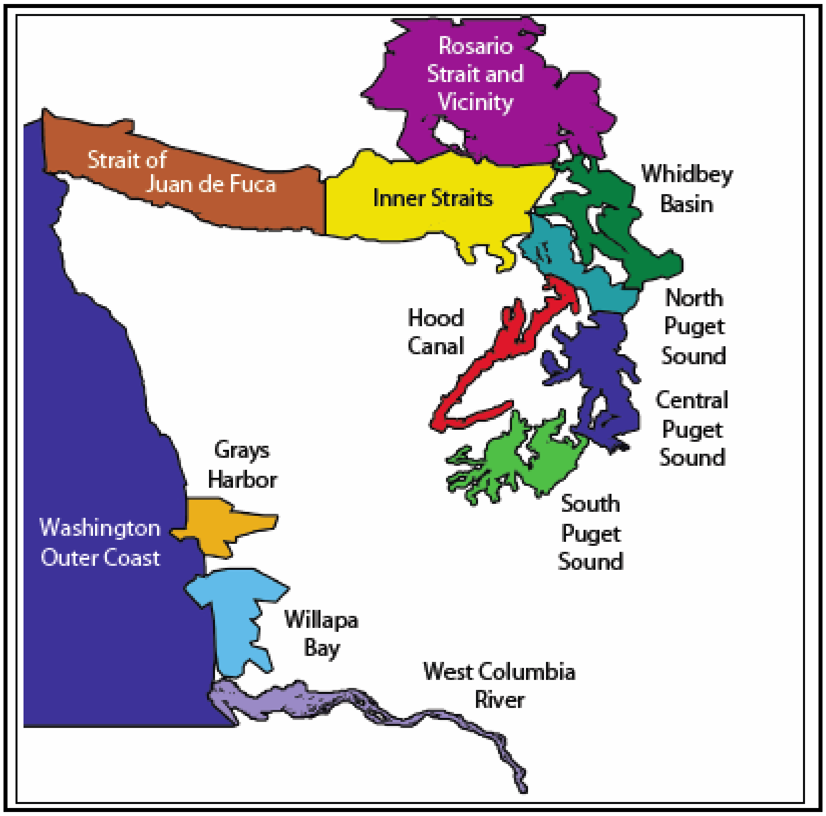

Figure A-2: Marine/ estuarine geographic zones (JLARC 2009; French-McCay et al. 2008)

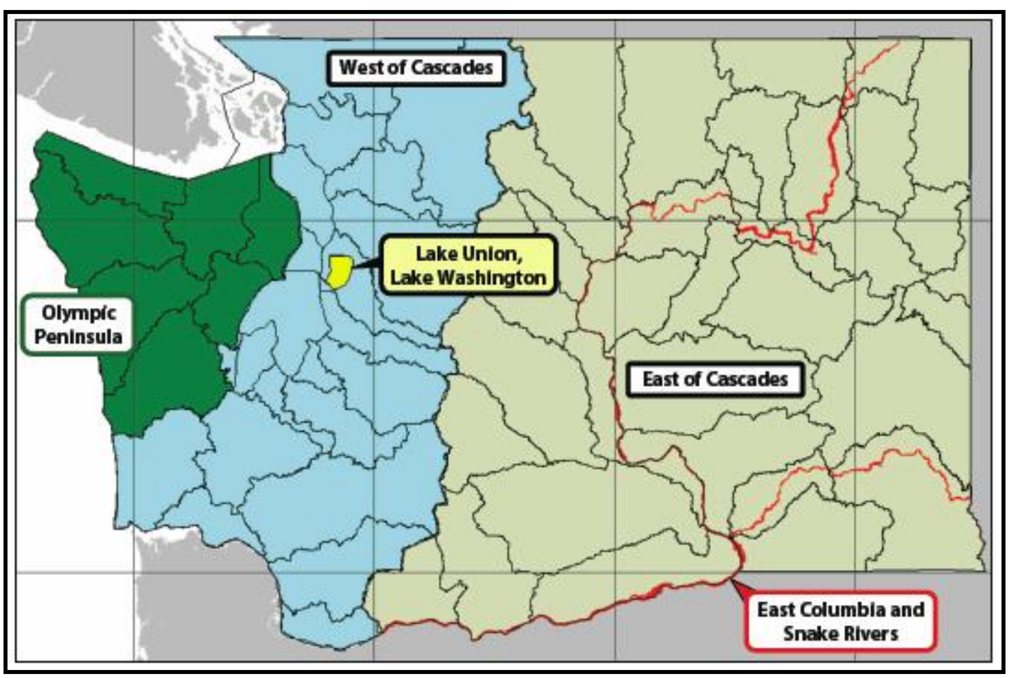

Figure A-3: Inland geographic zones (JLARC 2009; French-McCay et al. 2008)

Probability Analysis

Probability distributions of spill types were developed based on the historical spill data and casualty incidents to reflect *actual* spillage and *potential worst-case discharge (WCD)* spillage at the current time (based on historical spillage) and projected to the year 2015. The actual spillage analyses (historical and future) were based on actual reported spill volumes, while the potential WCD spillage analyses[11] (historical and future) were based on worst-case discharge volumes for each of the industry sectors.

Adjustments with regard to future spillage applied the same methodology as used in the JLARC (2009) study[12]. Actual and potential WCD oil spillages by industry sector are presented in Table A-2.

Table A-2: Oil Spills into Washington Waters from Ecology-Regulated Sectors (1995 – 2008)

Industry Sector	Historical Incident Numbers		Historical Spillage (Gallons)		Future (2015) Spillage (Gallons)	
	Actual[13]	Potential[14]	Actual	WCD[15]	Actual	WCD
Oil Tankers	14	131	13,709	2,655,486,963	10,967	2,655,511,784
Oil Tank Barges	14	88	7,002	236,777,610	7,002	236,791,716
Cargo Vessels	30	427	23,051	400,340,146	25,356	400,389,010
Fishing Vessels	40	233	5,746	43,407,306	5,746	43,419,071
Passenger Vessels	2	156	173	12,951,750	173	12,952,254
Oil Terminals	6	0	5,670	10,227,378	4,253	7,670,534
Pipelines	1	0	277,200	3,402,000	277,200	3,956,401
Tank Trucks	8	0	7,517	108,000	7,517	123,042
Marinas/Other	4	0	200	16,000	150	16,354
Total	**119**	**1,035**	**340,268**	**3,362,717,153**	**338,364**	**3,360,830,166**

The geographic distribution of historical spillage (actual and WCD) is shown in Tables A-3 and A-4. (*Note that Table A-4 is presented in thousands of gallons*.) The same results for future (2015) spillage are shown in Tables A-5 and A-6. Only four percent of historical actual spillage can be attributed to oil tankers, whereas for potential WCD spillage, 79 percent would be attributable to oil tankers.

Actual spillage is highest in the Rosario Straits zone, largely attributed to the largest recorded spill of 277,200 gallons from the 1999 Bellingham pipeline spill. For WCD spillage, however, the North Puget Sound zone has the highest potential spillage. The difference between actual spillage and WCD spillage is dramatic. While less than 14,000 gallons spilled from oil tankers in 14 years, this represents a potential

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[11] This methodology differs significantly from the approach employed in the JLARC study for which potential spillage was considered in a probabilistic manner. In other words, worst-case discharge (WCD) scenarios were included with regard to their spill impact, but the *probability* that these events would occur was determined by the rate of WCD for different source types across the US for most source types, and internationally for oil tankers. The international component was added to the oil tanker analyses based on the fact that there has not been a WCD from an oil tanker in the US. (Note that the T/V Exxon Valdez spill, while extremely large with wide-reaching impacts, was *not* a WCD. Less than 20% of the tanker's cargo spilled.)

[12] These adjustments included: reduction of probability of tanker spillage by 20%; no change in tank barge spillage; increase of spillage for cargo vessels by 10%; reduction of probability of facility spillage by 25%. WCD for oil tankers, tank barges, and cargo vessels decreased by 50% in 2015. (Based on French-McCay et al. 2008).

[13] Only includes incidents in which oil actually spilled.

[14] Includes only near-miss casualty incidents for vessels as reported to ERC by Ecology.

[15] WCD for all incidents in which oil actually spilled as well as WCD for near-miss casualty incidents.

WCD spillage of nearly 2.7 *billion* gallons. The actual and WCD volumes from tankers should decrease by 2015 when mandated double-hulls are fully implemented.

Table A-3: Geographic Distribution of Actual Spillage into Washington Waters from Ecology-Regulated Industry Sectors (1995 – 2008)

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	0	0	0	0	0	0	0	0	0	**0**
Grays Harbor	0	0	0	0	0	0	0	50	0	**50**
Willapa Bay	0	0	0	0	0	0	0	1,296	0	**1,296**
Juan de Fuca	0	0	0	0	0	0	0	0	0	**0**
Inner Straits	1,650	40	0	95	0	235	0	0	0	**2,020**
Rosario Strait	3,586	465	0	0	0	0	277,200	0	70	**281,321**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	570	1,625	3,135	1,318	0	0	0	0	0	**6,648**
C. Puget	0	4,737	1,609	1,362	120	2,136	0	0	30	**9,994**
S. Puget	7,334	60	15,656	1,476	0	2,576	0	0	50	**27,152**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	569	50	2,651	0	53	723	0	693	0	**4,739**
Lake Union	0	25	0	1,495	0	0	0	0	50	**1,570**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	2,356	0	**2,356**
W. Cascades	0	0	0	0	0	0	0	3,122	0	**3,122**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**13,709**	**7,002**	**23,051**	**5,746**	**173**	**5,670**	**277,200**	**7,517**	**200**	**340,268**

Table A-4: Geographic Distribution of WCD Spillage (Thousands of Gallons) into Washington Waters from Ecology-Regulated Industry Sectors (1995 – 2008)

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	53,008	4,194	2,474	0	0	0	0	0	0	**59,676**
Grays Harbor	0	0	0	0	0	0	0	14	0	**14**
Willapa Bay	0	0	0	0	0	0	0	14	0	**14**
Juan de Fuca	624,228	18,503	57,505	1,655	1,627	0	0	0	0	**703,518**
Inner Straits	162,066	987	850	1,233	330	4,223	0	0	0	**169,689**
Rosario Strait	237,364	25,889	4,394	0	694	0	3,402	0	4	**271,747**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	1,004,308	64,084	53,635	4,198	3,820	0	0	0	0	**1,130,045**
C. Puget	149,105	80,867	142,954	25,576	5,350	3,360	0	0	4	**407,216**
S. Puget	112,066	23,038	35,417	2,068	64	101	0	0	4	**172,758**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	289,449	17,872	102,260	0	995	2,644	0	14	0	**413,234**
Lake Union	23,893	1,343	851	8,677	71	0	0	0	4	**34,839**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	27	0	**27**
W. Cascades	0	0	0	0	0	0	0	41	0	**41**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**2,655,487**	**236,777**	**400,340**	**43,407**	**12,951**	**10,328**	**3,402**	**110**	**16**	**3,362,818**

Table A-5: Geographic Distribution of Future (2015) Actual Spillage into Washington Waters from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	0	0	0	0	0	0	0	0	0	**0**
Grays Harbor	0	0	0	0	0	0	0	50	0	**50**
Willapa Bay	0	0	0	0	0	0	0	1,296	0	**1,296**
Juan de Fuca	0	0	0	0	0	0	0	0	0	**0**
Inner Straits	660	20	0	95	0	176	0	0	0	**951**
Rosario Strait	1,434	233	0	0	0	0	277,200	0	53	**278,919**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	228	813	3,449	1,318	0	0	0	0	0	**5,807**
C. Puget	0	2,369	1,770	1,362	120	1,602	0	0	23	**7,245**
S. Puget	2,934	30	17,222	1,476	0	1,932	0	0	38	**23,631**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	228	25	2,916	0	53	542	0	693	0	**4,457**
Lake Union	0	13	0	1,495	0	0	0	0	38	**1,545**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	2,356	0	**2,356**
W. Cascades	0	0	0	0	0	0	0	3,122	0	**3,122**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**5,484**	**3,501**	**25,356**	**5,746**	**173**	**4,253**	**277,200**	**7,517**	**150**	**329,379**

Table A-6: Geographic Distribution of Future (2015) WCD Spillage into Washington Waters from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	21,203	2,097	2,722	0	0	0	0	0	0	**26,022**
Grays Hbr	0	0	0	0	0	0	0	14	0	**14**
Willapa Bay	0	0	0	0	0	0	0	14	0	**14**
Juan de Fuca	249,691	9,252	63,255	1,655	1,627	0	0	0	0	**325,480**
Inner Straits	64,826	494	935	1,233	330	3,167	0	0	0	**70,985**
Rosario Str	94,946	12,944	4,834	0	694	0	3,402	0	3	**116,823**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	401,723	32,042	58,998	4,198	3,820	0	0	0	0	**500,781**
C. Puget	59,642	40,433	157,250	25,576	5,350	2,520	0	0	3	**290,774**
S. Puget	44,826	11,519	38,958	2,068	64	76	0	0	3	**97,514**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	115,780	8,936	112,486	0	995	1,983	0	14	0	**240,194**
Lake Union	9,557	671	936	8,677	71	0	0	0	3	**19,915**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	27	0	**27**
W. Cascades	0	0	0	0	0	0	0	41	0	**41**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**1,062,194**	**118,388**	**440,374**	**43,407**	**12,951**	**7,746**	**3,402**	**110**	**12**	**1,688,584**

Impact Analysis

The impact of spilled oil varies considerably by oil type, location, and season, as well as by volume. Each of the actual or potential WCD spills needed to be evaluated with regard to environmental impacts for that particular type and amount of oil in that particular location in that season. The methodology employed for the impact analysis was the same as the one developed for and applied in the JLARC (2009) study.

The impact assessments[16] in that study, as applied in the historical analysis, were based on the Washington Compensation Schedule (WCS) qualitative rating system with some modifications based on expert opinion. Potential impacts were rated on a numerical scale from low to high, considering oil toxicity, persistence, and the vulnerability of the State's marine and aquatic resources at particular locations and times of year. Each of the impact categories (e.g., shorelines, biota, socioeconomic, etc.) were assigned a relative impact rating based on the modified WCS model.

For estuarine and marine waters of the state, the WCS ratings were developed for each oil type and season; averaged by geographical sub-regions of varying sensitivity, as defined in WAC 173-183; and then averaged over each of the geographic zones covering those waters.

For inland waters, a rating system was developed based on the approach in WAC 173-183, using recent land use data, hydrologic maps, locations and heights of fish barriers, fish run health ratings, and stream water quality data. The inland ratings were developed for each oil type and by each of the 62 watersheds (WRIAs) in the state, and averaged by geographic zone.

The seasonal variation of impact risk is relatively small. However, the scores are higher in the spring and summer than in the autumn and winter. The seasonal highs for some resources are balanced by different seasonal patterns for other resources, such that the composite score has only small variation by season.

When considering the impact scores averaged over the four seasons, the impact risk is highest for the heavy fuels, followed by crude oil, and lower for light oils and gasoline, which is similar for a given zone. The lowest scores were for jet fuel and non-petroleum oils. This trend is related to the higher persistence and mechanical injury[17] scores of the heavier oils, which therefore have more impact on birds, marine mammals, habitats, and recreation than non-persistent oils. This trend is in agreement with spill impact observations and modeling, in general.

It is important to note that the WCS does not take into account direct human fatalities or injuries, nor significant socioeconomic impacts into account in its measures of spill impacts. While the largest spill in Washington's spill history since 1995, the 277,200-gallon spill of gasoline from a pipeline in Bellingham in June 1999, killed three people, the per-gallon impact score for gasoline in this location is less than the average impact score. Scores range from 4.178 for spills of jet fuel and non-petroleum oils in Lake Union/Lake Washington to 32.819 for spills of heavy oils in the Inner Straits. The per-gallon impact scores[18] applied to the spills in the analysis are shown in Tables A-7 and A-8.

[16] Described in detail in French-McCay et al. (2008).

[17] Measuring propensity to coat and foul organisms.

[18] Because the impact scores are on a per-gallon basis, the final risk quotient is highly dependent on the volume of actual or potential spillage applied. Theoretically, this means that each gallon of oil of a particular type in a

Table A-7: Per-Gallon Marine/Estuarine Impact Scores from Modified WCS					
Geographic Zone	**Oil Type**	**Spring**	**Summer**	**Fall**	**Winter**
Outer Coast	**Crude**	19.906	18.815	16.561	16.665
	Heavy oil	26.712	24.635	21.949	22.156
	Light oil	16.071	14.981	13.159	13.160
	Gasoline	16.057	14.967	13.145	13.146
	Jet Fuel	10.251	9.641	8.326	8.326
	Non-Petroleum	10.251	9.641	8.326	8.326
Grays Harbor	**Crude**	21.219	18.862	17.557	18.560
	Heavy oil	27.518	24.573	22.593	24.216
	Light oil	16.597	14.917	13.601	14.599
	Gasoline	15.614	13.993	12.694	13.638
	Jet Fuel	10.618	9.035	8.619	8.979
	Non-Petroleum	10.618	9.035	8.619	8.979
Willapa Bay	**Crude**	23.829	22.392	20.930	20.301
	Heavy oil	30.886	29.352	27.178	26.619
	Light oil	18.464	17.842	16.389	15.951
	Gasoline	17.553	16.511	15.566	14.952
	Jet Fuel	11.915	10.953	10.072	9.940
	Non-Petroleum	11.915	10.953	10.072	9.940
Strait of Juan de Fuca	**Crude**	13.355	13.295	13.240	13.243
	Heavy oil	17.464	17.382	17.324	17.330
	Light oil	10.289	10.240	10.209	10.214
	Gasoline	9.292	9.242	9.211	9.212
	Jet Fuel	6.183	6.152	6.145	6.146
	Non-Petroleum	6.183	6.152	6.145	6.146
Inner Straits	**Crude**	25.083	24.050	23.051	22.138
	Heavy oil	32.819	30.853	30.683	28.897
	Light oil	20.212	19.197	19.091	17.335
	Gasoline	19.246	18.264	18.137	17.230
	Jet Fuel	12.529	12.451	11.517	10.620
	Non-Petroleum	12.529	12.451	11.517	10.620
Rosario Strait	**Crude**	21.191	18.929	17.477	18.392
	Heavy oil	27.879	24.677	22.910	24.013
	Light oil	17.031	15.074	13.813	14.607
	Gasoline	16.272	14.668	13.480	13.992
	Jet Fuel	10.670	9.508	8.831	9.222
	Non-Petroleum	10.670	9.508	8.831	9.222
Whidbey Basin	**Crude**	21.817	20.556	18.915	18.530
	Heavy oil	28.717	26.943	24.669	24.016
	Light oil	17.531	16.367	14.783	14.696
	Gasoline	16.551	15.376	14.231	13.950
	Jet Fuel	11.121	10.351	9.289	9.284
	Non-Petroleum	11.121	10.351	9.289	9.284
North Puget Sound	**Crude**	23.198	22.557	20.510	20.453
	Heavy oil	30.505	29.473	26.497	26.395
	Light oil	18.676	18.037	16.158	16.250
	Gasoline	17.639	17.090	15.524	15.387
	Jet Fuel	11.770	11.326	10.236	10.310
	Non-Petroleum	11.770	11.326	10.236	10.310

particular location would have the same impact, and that a 10,000-gallon spill would cause ten times the damage of a 1,000-gallon spill. In reality, the impacts are not directly linearly related to spill volume.

Table A-7: Per-Gallon Marine/Estuarine Impact Scores from Modified WCS					
Geographic Zone	**Oil Type**	**Spring**	**Summer**	**Fall**	**Winter**
Central Puget Sound	**Crude**	16.062	15.002	14.226	14.185
	Heavy oil	21.018	19.836	18.665	18.654
	Light oil	12.583	11.821	10.944	10.869
	Gasoline	11.742	11.258	10.503	10.433
	Jet Fuel	7.980	7.351	6.966	6.911
	Non-Petroleum	7.980	7.351	6.966	6.911
South Puget Sound	**Crude**	21.017	18.132	17.231	18.491
	Heavy oil	27.697	23.777	22.151	24.006
	Light oil	16.522	14.342	13.352	14.397
	Gasoline	15.810	13.668	12.893	13.881
	Jet Fuel	10.370	9.063	8.542	9.227
	Non-Petroleum	10.370	9.063	8.542	9.227
Hood Canal	**Crude**	15.882	15.020	14.458	14.827
	Heavy oil	20.747	19.569	18.999	19.598
	Light oil	12.210	11.682	11.432	11.712
	Gasoline	11.606	11.102	10.664	10.903
	Jet Fuel	7.611	7.134	7.128	7.263
	Non-Petroleum	7.611	7.134	7.128	7.263
West Columbia River	**Crude**	20.705	20.705	18.992	18.823
	Heavy oil	26.807	26.807	24.590	24.371
	Light oil	16.346	16.346	14.994	14.860
	Gasoline	15.256	15.256	13.994	13.869
	Jet Fuel	10.461	10.461	9.596	9.511
	Non-Petroleum	10.461	10.461	9.596	9.511

Table A-8: Per-Gallon Inland Impact Scores from Modified WCS						
Geographic Zone	**Crude**	**Heavy Oil**	**Light Oil**	**Gasoline**	**Jet Fuel**	**Non-Petroleum**
Lake Union / Washington	8.269	10.706	6.528	6.093	4.178	4.178
East Columbia River	10.288	13.320	8.122	7.581	5.198	5.198
Olympic Peninsula	22.112	28.630	17.457	16.293	11.173	11.173
West of Cascades	20.266	26.239	15.999	14.933	10.239	10.239
East of Cascades	15.854	20.527	12.516	11.682	8.010	8.010

Risk Calculations

For each spill or casualty incident, the per-gallon impact score appropriate to the location, oil type, and season was multiplied by the actual and WCD spill volumes to calculate the actual and WCD "risk quotients". The total risk quotient scores for each industry sector (source type) were derived from adding the individual risk quotients for all incidents in that sector. The probability distributions of future (2015) spillage were also treated in this manner.

The risk quotients, while based on the WCS method, which calculates a *monetary* value[19], should in this analysis be considered *relative* values. The risk quotients for historical actual spillage and WCD spillage are shown by geographic zone and industry sector in Tables A-9 and A-10. The risk quotients for future (2015) actual spillage and WCD spillage are shown by geographic zone and industry sector in Tables A-11 and A-12.

[19] The risk quotients are essentially the value that would have been calculated by an application of a modified version of the Washington Compensation Schedule (WCS) prior to any adjustments proposed in 2009.

Table A-9: Risk Quotients for Actual Spillage into Washington Waters (in thousands) from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	0	0	0	0	0	0	0	0	0	**0**
Grays Harbor	0	0	0	0	0	0	0	1	0	**1**
Willapa Bay	0	0	0	0	0	0	0	21	0	**21**
Juan de Fuca	0	0	0	0	0	0	0	0	0	**0**
Inner Straits	0	1	0	2	0	4	0	0	0	**7**
Rosario Strait	67	8	0	0	0	0	4,066	0	1	**4,142**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	14	29	65	22	0	0	0	0	0	**130**
C. Puget	0	51	28	16	1	23	0	0	1	**120**
S. Puget	99	1	372	21	0	34	0	0	1	**528**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	15	1	65	0	1	11	0	10	0	**103**
Lake Union	0	0	0	10	0	0	0	0	0	**10**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	41	0	**41**
W. Cascades	0	0	0	0	0	0	0	50	0	**50**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**195**	**91**	**530**	**71**	**2**	**72**	**4,066**	**123**	**3**	**5,152**

Table A-10: Risk Quotients for Potential WCD Spillage into Washington Waters (in thousands) from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	908,147	55,159	58,242	0	0	0	0	0	0	**1,021,548**
Grays Hbr	0	0	0	0	0	0	0	211	0	**211**
Willapa Bay	0	0	0	0	0	0	0	223	0	**223**
Juan de Fuca	6,963,452	153,501	985,460	16,983	16,675	0	0	0	0	**8,136,071**
Inner Straits	0	32,392	27,882	23,341	6,242	80,623	0	0	0	**170,480**
Rosario Str	3,602,580	356,261	117,118	0	10,592	0	49,901	0	66	**4,136,518**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	19,780,294	1,166,320	1,439,431	74,432	68,157	0	0	0	0	**22,528,634**
C. Puget	1,787,928	953,001	2,309,502	299,326	61,419	36,772	0	0	59	**5,448,007**
S. Puget	1,718,966	389,639	725,311	30,511	892	1,351	0	0	26	**2,866,696**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	4,952,424	266,819	2,486,025	0	16,198	37,906	0	201	0	**7,759,573**
Lake Union	155,971	8,649	0	615,901	464	0	0	0	75	**781,060**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	456	0	**456**
W. Cascades	0	0	0	0	0	0	0	648	0	**648**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**39,869,762**	**3,381,741**	**8,148,971**	**1,060,494**	**180,639**	**156,652**	**49,901**	**1,739**	**226**	**52,850,125**

Table A-11: Risk Quotients for Future (2015) Actual Spillage into Washington Waters (in thousands) from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	0	0	0	0	0	0	0	0	0	**0**
Grays Harbor	0	0	0	0	0	0	0	1	0	**1**
Willapa Bay	0	0	0	0	0	0	0	21	0	**21**
Juan de Fuca	0	0	0	0	0	0	0	0	0	**0**
Inner Straits	0	1	0	2	0	3	0	0	0	**6**
Rosario Strait	54	8	0	0	0	0	4,066	0	1	**4,129**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	11	29	72	22	0	0	0	0	0	**134**
C. Puget	0	51	31	16	1	17	0	0	1	**117**
S. Puget	79	1	409	21	0	26	0	0	1	**537**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	12	1	72	0	1	8	0	10	0	**104**
Lake Union	0	0	0	10	0	0	0	0	0	**10**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	41	0	**41**
W. Cascades	0	0	0	0	0	0	0	50	0	**50**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**156**	**91**	**583**	**71**	**2**	**54**	**4,066**	**123**	**2**	**5,148**

Table A-12: Risk Quotients for Future (2015) WCD Spillage into Washington Waters (in thousands) from Ecology-Regulated Industry Sectors (1995 – 2008)										
Geographic Zone	**Oil Tankers**	**Tank Barges**	**Cargo Vessels**	**Fish Vessels**	**Pass Vessels**	**Terminals**	**Pipelines**	**Tank Trucks**	**Marinas**	**Total**
Outer Coast	363,259	27,580	64,066	0	0	0	0	0	0	**454,905**
Grays Hbr	0	0	0	0	0	0	0	211	0	**211**
Willapa Bay	0	0	0	0	0	0	0	223	0	**223**
Juan de Fuca	2,785,381	76,751	1,084,006	16,983	16,675	0	0	0	0	**3,979,796**
Inner Straits	0	16,196	30,670	23,341	6,242	60,467	0	0	0	**136,916**
Rosario Str	1,441,032	178,131	128,830	0	10,592	0	49,901	0	50	**1,808,536**
Whidbey	0	0	0	0	0	0	0	0	0	**0**
N. Puget	7,912,118	583,160	1,583,374	74,432	68,157	0	0	0	0	**10,221,241**
C. Puget	715,171	476,501	2,540,452	299,326	61,419	27,579	0	0	44	**4,120,492**
S. Puget	687,586	194,820	797,842	30,511	892	1,013	0	0	20	**1,712,684**
Hood Canal	0	0	0	0	0	0	0	0	0	**0**
W. Columbia	1,980,970	133,410	2,734,628	0	16,198	28,430	0	201	0	**4,893,837**
Lake Union	62,388	4,325	0	615,901	464	0	0	0	56	**683,134**
E. Columbia	0	0	0	0	0	0	0	0	0	**0**
Olympic Pen	0	0	0	0	0	0	0	456	0	**456**
W. Cascades	0	0	0	0	0	0	0	648	0	**648**
E. Cascades	0	0	0	0	0	0	0	0	0	**0**
Total	**15,947,905**	**1,690,874**	**8,963,868**	**1,060,494**	**180,639**	**117,489**	**49,901**	**1,739**	**170**	**28,013,079**

The risk quotients in the four analyses (historical actual, historical WCD, future actual, future WCD) were then normalized to a 100-point (or percentage) scale of risk scores within each analysis, as shown in Tables A13 – A16. Relative risk should be considered *within* each analysis (i.e., within each column). The color scheme shows red as the highest risk and green as the lowest risk, with yellow as moderate risk.

Table A-13: Risk Scores for Actual Spillage from Ecology-Regulated Industry Sectors

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Grays Harbor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	**0.02**
Willapa Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	**0.41**
Juan de Fuca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Inner Straits	0.00	0.02	0.00	0.04	0.00	0.08	0.00	0.00	0.00	**0.14**
Rosario Strait	1.30	0.16	0.00	0.00	0.00	0.00	78.92	0.00	0.02	**80.40**
Whidbey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
N. Puget	0.27	0.56	1.26	0.43	0.00	0.00	0.00	0.00	0.00	**2.52**
C. Puget	0.00	0.99	0.54	0.31	0.02	0.45	0.00	0.00	0.02	**2.33**
S. Puget	1.92	0.02	7.22	0.41	0.00	0.66	0.00	0.00	0.02	**10.25**
Hood Canal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Columbia	0.29	0.02	1.26	0.00	0.02	0.21	0.00	0.19	0.00	**2.00**
Lake Union	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	**0.19**
E. Columbia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Olympic Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	**0.80**
W. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	**0.97**
E. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**3.78**	**1.77**	**10.29**	**1.38**	**0.04**	**1.40**	**78.92**	**2.39**	**0.06**	**100.00**

Table A-14: WCD Risk Scores from Ecology-Regulated Industry Sectors (1995 – 2008)

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	1.72	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00	**1.93**
Grays Harbor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Willapa Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Juan de Fuca	13.18	0.29	1.86	0.03	0.03	0.00	0.00	0.00	0.00	**15.39**
Inner Straits	0.00	0.06	0.05	0.04	0.01	0.15	0.00	0.00	0.00	**0.32**
Rosario Strait	6.82	0.67	0.22	0.00	0.02	0.00	0.09	0.00	0.00	**7.83**
Whidbey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
N. Puget	37.43	2.21	2.72	0.14	0.13	0.00	0.00	0.00	0.00	**42.63**
C. Puget	3.38	1.80	4.37	0.57	0.12	0.07	0.00	0.00	0.00	**10.31**
S. Puget	3.25	0.74	1.37	0.06	0.00	0.00	0.00	0.00	0.00	**5.42**
Hood Canal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Columbia	9.37	0.50	4.70	0.00	0.03	0.07	0.00	0.00	0.00	**14.68**
Lake Union	0.30	0.02	0.00	1.17	0.00	0.00	0.00	0.00	0.00	**1.48**
E. Columbia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Olympic Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
E. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**75.44**	**6.40**	**15.42**	**2.01**	**0.34**	**0.30**	**0.09**	**0.00**	**0.00**	**100.00**

Table A-15: Risk Scores for Actual Future Spillage from Ecology-Regulated Industry Sectors (1995 – 2008)

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Grays Harbor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	**0.02**
Willapa Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	**0.41**
Juan de Fuca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Inner Straits	0.00	0.02	0.00	0.04	0.00	0.06	0.00	0.00	0.00	**0.12**
Rosario Strait	1.05	0.16	0.00	0.00	0.00	0.00	78.98	0.00	0.02	**80.21**
Whidbey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
N. Puget	0.21	0.56	1.40	0.43	0.00	0.00	0.00	0.00	0.00	**2.60**
C. Puget	0.00	0.99	0.60	0.31	0.02	0.33	0.00	0.00	0.02	**2.27**
S. Puget	1.53	0.02	7.94	0.41	0.00	0.51	0.00	0.00	0.02	**10.43**
Hood Canal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Columbia	0.23	0.02	1.40	0.00	0.02	0.16	0.00	0.19	0.00	**2.02**
Lake Union	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	**0.19**
E. Columbia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Olympic Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	**0.80**
W. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	**0.97**
E. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**3.03**	**1.77**	**11.32**	**1.38**	**0.04**	**1.05**	**78.98**	**2.39**	**0.04**	**100.00**

Table A-16: Risk Scores for Future WCD Spillage from Ecology-Regulated Industry Sectors (1995 – 2008)

Geographic Zone	Oil Tankers	Tank Barges	Cargo Vessels	Fish Vessels	Pass Vessels	Terminals	Pipelines	Tank Trucks	Marinas	Total
Outer Coast	1.30	0.10	0.23	0.00	0.00	0.00	0.00	0.00	0.00	**1.62**
Grays Harbor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Willapa Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Juan de Fuca	9.94	0.27	3.87	0.06	0.06	0.00	0.00	0.00	0.00	**14.21**
Inner Straits	0.00	0.06	0.11	0.08	0.02	0.22	0.00	0.00	0.00	**0.49**
Rosario Strait	5.14	0.64	0.46	0.00	0.04	0.00	0.18	0.00	0.00	**6.46**
Whidbey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
N. Puget	28.24	2.08	5.65	0.27	0.24	0.00	0.00	0.00	0.00	**36.49**
C. Puget	2.55	1.70	9.07	1.07	0.22	0.10	0.00	0.00	0.00	**14.71**
S. Puget	2.45	0.70	2.85	0.11	0.00	0.00	0.00	0.00	0.00	**6.11**
Hood Canal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Columbia	7.07	0.48	9.76	0.00	0.06	0.10	0.00	0.00	0.00	**17.47**
Lake Union	0.22	0.02	0.00	2.20	0.00	0.00	0.00	0.00	0.00	**2.44**
E. Columbia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Olympic Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
W. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
E. Cascades	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**56.93**	**6.04**	**32.00**	**3.79**	**0.64**	**0.42**	**0.18**	**0.01**	**0.00**	**100.00**

The overall risk matrices for the industry sectors are summarized in Table A-17. The highest risk for actual spillage historically is with pipelines, but shifts to oil tankers followed distantly by cargo vessels for WCD. In future the WCD shifts more risk to cargo vessels and less to oil tankers for WCD.

Table A-17: Oil Spill Risk Matrix for Industry Sectors Regulated by Ecology Spills Program for Oil Spill Preparedness and Prevention

Industry Sector	Historical Spillage Analyses		Future (2015) Analyses	
	Actual Spillage	WCD Spillage	Actual Spillage	WCD Spillage
Oil Tankers	3.78	75.44	3.03	56.93
Oil Tank Barges	1.77	6.40	1.77	6.04
Cargo Vessels	10.29	15.42	11.32	32.00
Fishing Vessels	1.38	2.01	1.38	3.79
Passenger Vessels	0.04	0.34	0.04	0.64
Oil Terminals	1.40	0.30	1.05	0.42
Pipelines	78.92	0.09	78.98	0.18
Tank Trucks	2.39	0.00	2.39	0.01
Marinas/Other	0.06	0.00	0.04	0.00
Total	**100.00**	**100.00**	**100.00**	**100.00**

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[20] D. French-McCay, CJ Beegle-Krause, and J. Rowe are with Applied Science Associates, Inc., South Kingston, RI; D.S. Etkin is with Environmental Research Consulting, Cortlandt Manor, NY; and C. Moore and K. Michel are with Herbert Engineering Corp., Alameda, CA. This study was conducted under contract to Washington JLARC. The study findings are summarized in the 2009 JLARC report.