Appendix E

Rail Spill Risk Analysis

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Rail Spill Risk Analysis For EFSEC DEIS for Vancouver Energy

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Executive Summary

The overall approach to assessing the risk of spill from the crude-by-rail (CBR) traffic associated with the proposed Vancouver Energy facility in this report involves:

- Estimating the probability of spills of crude oil associated with accidents during the transport of crude oil to the Vancouver Energy facility and the probability of diesel fuel spills from locomotives transporting empty trains on return routes by:
  - Estimating the probability of derailment; and
  - Determining the probability that derailments would result in spillage of oil;
- Determining the potential volumes of spillage from tank car and locomotive derailments;
- Determining the probability distribution of spill volumes;
- Calculating spill volumes related to requirements for contingency planning (average most-probable, maximum most-probable, and worst-case discharges);
- Evaluating the potential impacts of spills of Bakken crude oil, diluted bitumen, and diesel fuel along the railroad corridors based on oil type and geographic location; and
- Evaluating potential impacts of risk mitigation measures to prevent railroad accidents and spills.

The general approach is shown in Figure 1.

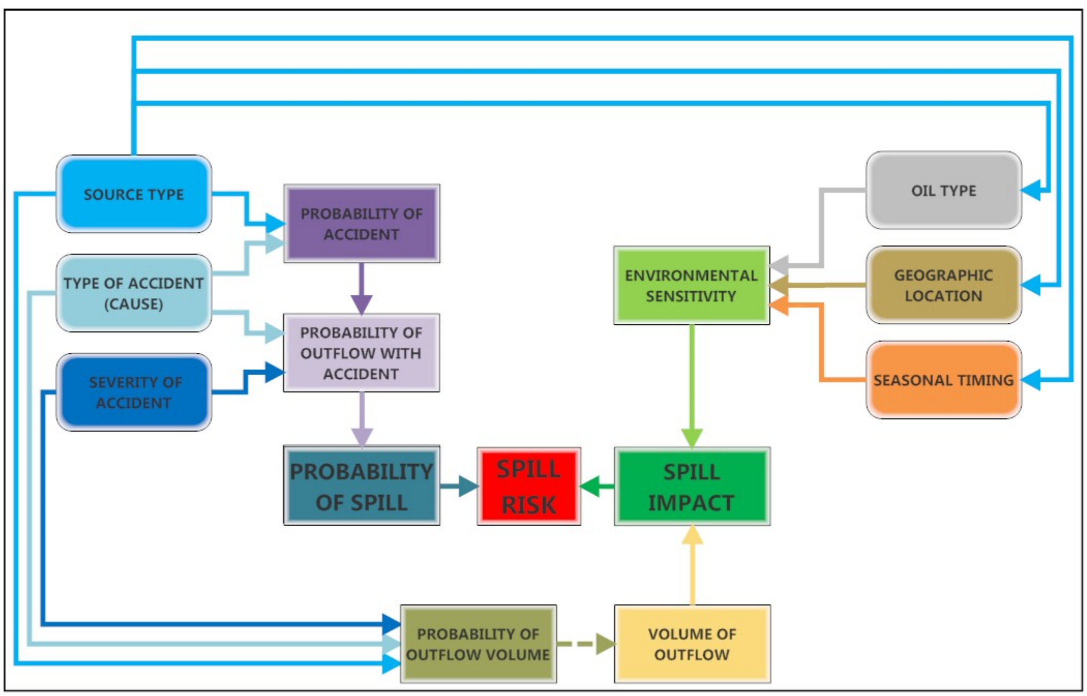

Figure 1: General Risk Analysis Approach

The general approach involves evaluating the two components of risk – probability and consequences or impacts. Determining the probability of a spill involves estimating the probability that there will be an accident that could potentially cause spillage, determining that the probability that the accident will actually result in spillage, and then determining the volume of the spill based on the severity and type of accident. The environmental impact of the spill will be determined by sensitivity of the receiving environment, which is, in turn determined by the oil type, location, and season.

CBR Train Routing Assumptions

The basic CBR routing assumptions for this study are:

- The rail routes that would generally be utilized by four CBR trains going to and from the Vancouver Energy facility daily are as shown in Figure 2;
- The route utilized to transport crude to the Vancouver Energy facility would be from Sand Point, Idaho (Kootenai-Spokane Subdivision), to Pasco (Lakeside Subdivision) to Vancouver (Fallbridge Subdivision);
- The route utilized to transport empty unloaded trains back to Sand Point would be the subdivisions from Vancouver to Auburn (Vancouver-Seattle Subdivision) to Ellensburg (Stampede Subdivision), Ellensburg to Pasco (Yakima Valley Subdivision), and then from Pasco to Sand Point via Spokane (Lakeside Subdivision, then (Kootenai-Spokane Subdivision); the overall Auburn to Pasco corridor is frequently referred to as "Stampede Pass"; [1]

[1] Stampede Pass was the assumed return route for the unloaded/empty trains as this is the route with the greatest length, which corresponds to the route selected for analysis in Vancouver Energy's SEPA Draft EIS. In addition, according to Etkin et al. 2015 (Washington State Marine and Rail Oil Transportation Study), "Empty unit bulk trains generated from north of Vancouver (Kalama, Longview, Centralia, Tacoma, Seattle and north) are destined to return to Pasco and to points east via the Stampede Pass at Auburn (between Seattle and Tacoma). Under this routing concept, train operations over Stampede Pass will be almost exclusively eastbound empty bulk trains. A small number of empty bulk trains from Everett north are routed over Stevens Pass when a 'slot' is available, but BNSF does not believe that intermodal growth will allow that to occur over the long run."

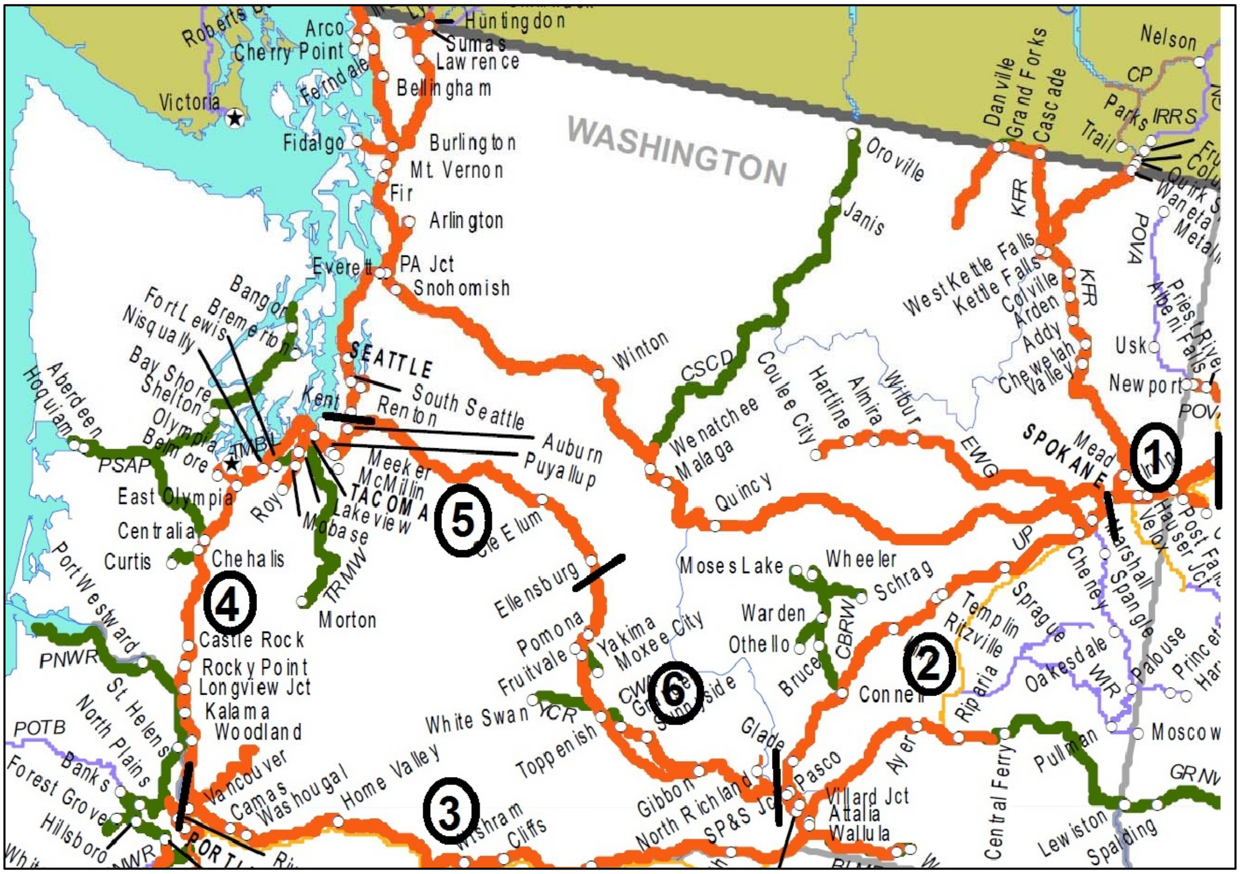

Figure 2: BNSF Routes in Washington Showing Subdivisions Assumed in Study

Segment 1: Sand Point, Idaho, to Spokane (Kootenai-Spokane Subdivision); Segment 2: Spokane to Pasco (Lakeside Subdivision); Segment 3: Pasco to Vancouver (Fallbridge Subdivision); Segment 4: Vancouver to Auburn (Vancouver-Seattle Subdivision); Segment 5: Auburn to Ellensburg (Stampede Subdivision); Segment 6: Ellensburg to Pasco (Yakima Valley Subdivision).

Definitions of Worst-Case Discharge

The analysis evaluates and references several different types of "worst-case discharges" (WCD):

***Theoretical* WCD:** This is volume based on a single derailment event (of a non-CBR freight train) in which all of the freight cars derailed. While this particular historical event did not result in the spillage from all of the freight cars, the volume of this "theoretical WCD" is based on the hypothetical assumption that the train had been a CBR train and all of the contents of the tank cars spilled all of their contents. This type of scenario is extremely unlikely based on the very low probability of all of the cars derailing and the very low probability that all of the cars would release oil.

***Effective* WCD:** This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents. Unlike for vessels, at this time, there is no regulatory definition of WCD for response planning purposes or to evaluate potential environmental impacts. This study proposes the use of the "effective

WCD" for the purposes of environmental impact analysis, and for response planning until a regulatory WCD volume is implemented.

Approach to Determining Potential Spill Volumes

The first step in the analysis addresses the overall probabilities of derailments and potential spillage across the entire rail corridor. This analysis goes through a series of steps as shown in Figure 3.

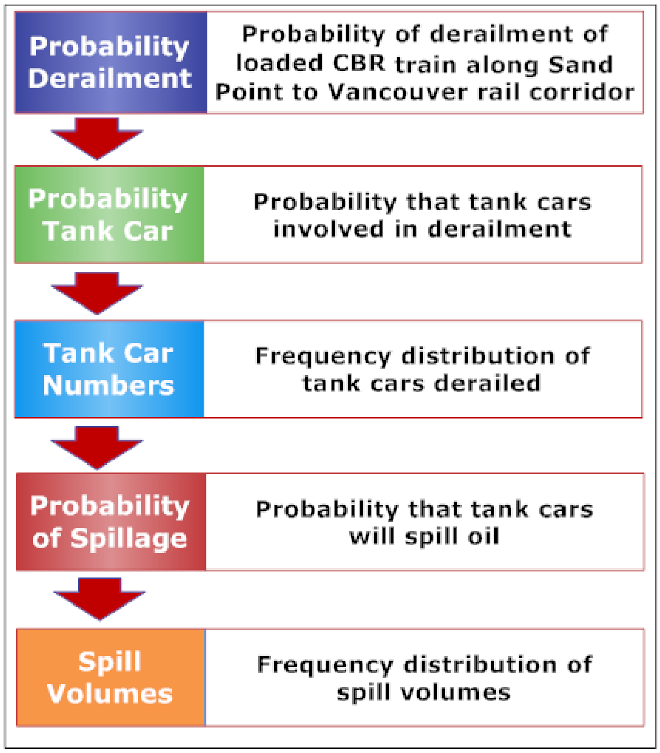

Figure 3: Steps to Derive Probability of Rail Spills and Distribution of Spill Volumes

Basic Assumptions on Vancouver Energy Facility Throughput

For this analysis (and the related analysis conducted for rail transport risk) the following basic assumptions have been applied:

- The overall annual throughput at the facility will average 360,000 barrels (bbl) per day across 365 days for a maximum annual throughput of 131.4 million bbl;
- Rail deliveries of crude oil to the facility will be limited to 120-car train length unit trains by the loading facilities and proposed rail infrastructure at Terminal 5;
- The maximum volume per rail tank car is assumed to be 750 bbl for air permitting purposes, though actual carloads are limited by cargo weight, which is affected by oil density, by tank car weight, which is affected by the design, and by vapor space requirements to allow for expansion of the oil and to control for buildup of volatiles;[2] and

[2] In actual practice, the tank cars often do not exceed 650 to 690 bbl of cargo loading.

- There would be four trains per day, with a possible fifth train infrequently on some days.

General Derailment Frequency

With an estimated average four loaded CBR trains per day expected at the Vancouver Energy facility and 435 miles of track along the loaded route, and 510 miles of track on the Stampede Pass (unloaded train) return route, the estimated numbers of derailments (not necessarily spills) are: 0.5 derailments of loaded trains annually (or about one derailment every two years), and 0.6 derailments of empty trains annually (or about one derailment every 20 months). This estimate is based on conservative (tending to overestimate) derailment frequencies for US freight trains of all types during 2000 – 2014.

The derailment analyses for federal and Washington are based on all varieties of freight trains, not necessarily crude by rail (CBR) trains. The reasoning behind this approach is that are not enough data on CBR train derailments alone to allow for a statistically-valid analysis. CBR traffic has been underway at a large scale only in the last few years. In addition, derailments occur regardless of the cargo content of the freight cars. Track conditions, rail operating procedures, and other factors unrelated to cargo content are the factors that determine derailment frequencies and locations.

The estimates of the number of CBR derailments, which do not necessarily lead to spills, can be roughly estimated by the number of train miles or the number of transits expected for the Vancouver Energy facility on both the loaded and unloaded (return) routes.

With an estimated four loaded CBR trains per day expected at the Vancouver Energy facility and 435 miles of track along the loaded route[3] and 510 miles on the Stampede Pass (unloaded train) return route , the estimated numbers of derailments (not necessarily spills) are as shown in Table 1.[4] This analysis assumes four trains per day arriving at the Vancouver Energy facility and that trains would return on the Stampede Pass route. A per-train mile derailment frequency of 0.00000078 was conservatively applied.

Table 1: Estimated Derailment Frequency along Vancouver Energy-Related CBR Routes

Route	Rail Subdivision	Track Miles	Annual Train Miles[5]	Derailment Frequency (per year)		Derailment Return Years	
				Loaded	Empty	Loaded	Empty
Loaded	Sand Point ID-Spokane (Kootenai/Spokane)	68.5	100,010	0.078	n/a	12.8	n/a
	Spokane-Pasco (Lakeside)	146.4	213,744	0.167	n/a	6.0	n/a
	Pasco-Vancouver (Fallbridge)	219.8	320,908	0.250	n/a	4.0	n/a
	Total Loaded	**434.7**	**634,662**	**0.495**	**n/a**	**2.0**	**n/a**
Return	Vancouver-Seattle (partial)	68.0	99,280	n/a	0.078	n/a	12.8

[3] Sand Point ID-Spokane (Kootenai/Spokane Subdivision), Spokane-Pasco (Lakeside Subdivision), and Pasco-Vancouver (Fallbridge Subdivision).

[4] Based on track mileage in *BNSF Railway Timetable No. 4*, 2009, as presented in Etkin et al. 2015.

[5] Assumes four CBR trains per day.

Table 1: Estimated Derailment Frequency along Vancouver Energy-Related CBR Routes							
Route	**Rail Subdivision**	**Track Miles**	**Annual Train Miles[5]**	**Derailment Frequency (per year)**		**Derailment Return Years**	
				Loaded	**Empty**	**Loaded**	**Empty**
Stampede Pass	**Ellensburg-Stampede/Auburn (Stampede)**	102.6	149,796	n/a	0.116	n/a	8.6
	Pasco-Ellensburg (Yakima Valley)	124.1	181,186	n/a	0.142	n/a	7.0
	Spokane-Pasco (Lakeside)	146.4	213,744	n/a	0.167	n/a	6.0
	Sand Point ID-Spokane (Kootenai/Spokane)	68.5	100,010	n/a	0.078	n/a	12.8
	Total Return Stampede Pass	**509.6**	**744,016**	**n/a**	**0.581**	**n/a**	**1.7**
	TOTAL	**944.3**	**1,378,678**	**0.495**	**0.581**	**2.0**	**1.7**

Spillage with Derailments

When a freight train derailment occurs, the average number of cars that derails has averaged about eight cars in the US as a whole and about six cars considering Washington incidents only during the last fifteen years. Percentile values of car derailment numbers are shown in Table 2. In the US as a whole, the median incident involves five cars and four cars for the US and Washington, respectively. The worst-case in Washington has been 74 cars, while in the US there was an incident involving 122 cars.

Table 2: Percentile Values of Cars Derailed per Incident		
Statistic	**US**	**Washington Only**
% Incidents with No Cargo Car Derailment	2.60%	59.18%
Average	7.7 cars	6.1 cars
25th Percentile (75% Higher)	2 cars	1 car
50th Percentile (Median) (50% Higher)	5 cars	4 cars
75th Percentile (25% Higher)	10 cars	8 cars
90th Percentile (10% Higher)	17 cars	14 cars
95th Percentile (5% Higher)	23 cars	19 cars
99th Percentile (1% Larger)	37 cars	30 cars
Actual Worst Case	122 cars	74 cars

Of the derailed cars carrying hazardous materials (hazmat), 16.7% released cargo. The rate was lower at 9.2% in the last 15 years (Table 3).

Table 3: Average Percentage of Derailed Hazmat Cars with Release		
Time Period	**% Derailed Hazmat Cars with Release**	
	US 4,383 derailments with Hazmat Cars	**Washington 63 derailments with Hazmat Cars**
1975 – 1999	19.4%	16.0%

2000 – 2014	9.2%	10.0%
1975 – 2014	16.7%	14.5%

Given that there is a derailment of tank cars, the distribution of potential spill volumes is as shown in Table 4.

Table 4: Preliminary Estimated Spill Volumes from CBR Unit Trains

Statistic	**Number of Derailed Cars**	**Less Conservative Approach (9.2% Release Rate)**		**More Conservative Approach (16.7% Release Rate)**	
		Number of Cars with Spillage	**Total Volume of Spillage (bbl)**	**Number of Cars with Spillage**	**Total Volume of Spillage (bbl)**
25th Percentile	2 cars	0.2	131	0.33	238
50th Percentile (Median)	5 cars	0.5	328	0.84	596
75th Percentile	10 cars	0.9	657	1.67	1,192
90th Percentile	17 cars	1.6	1,117	2.84	2,027
95th Percentile	23 cars	2.1	1,511	3.84	2,742
99th Percentile	37 cars	3.4	2,430	6.18	4,412
Actual Worst Case	122 cars	11.2	8,014	20.37	14,547

This incorporates the distribution of numbers of derailed cars in a single derailment incident and the probability that if these cars were to be CBR tank cars in a unit train, they would release oil, and the volume of that release.

This analysis assumes that freight cars are proxies for CBR tank cars and that the distribution of derailed cars in a unit train would be analogous to those of a manifest train (i.e., one with a variety of cargo in freight cars). There are not enough data on CBR derailments and spills to do a comprehensive analysis.

This analysis also assumes that if there were to be a release from a CBR tank car, the tank car is full for a total of 30,000 gallons (714 bbl). The US distribution of derailed cars was used as this would represent a more conservative approach.

Based on this analysis and a comparison with recent CBR incidents, the recommended discharge volumes for analysis are shown in Table 5. The most credible worst case discharge volume is based on a volume that is 10% larger than the largest incident to date. It is approximately the 99th percentile with respect to derailed cars assuming all of the cars release oil.

The theoretical worst case discharge is presented for information purposes. This event is extremely unlikely. Only one derailment of any freight train in 40 years of US history has ever involved that many derailed cars. It is also highly unlikely that if this many cars were to derail that all of the cars would release oil.

For spills from empty trains in which only locomotives could spill fuel, the maximum spillage would be from up to five locomotives each carrying 131 bbl of diesel for a total of 655 bbl.[6] This volume of spillage would constitute a theoretical worst-case discharge from an empty train. This event would require that both

[6] The largest locomotives have fuel tanks with capacities of 5,500 gallons (about 131 bbl).

of the locomotives would derail and spill all of their fuel oil content. Note that there would also be the possibility that diesel fuel would spill in a derailment of a loaded CBR train, but since this volume would be less than even a median spill volume for a loaded train, it is not considered as significant in the analysis of loaded CBR train potential spillage. There are also smaller quantities of other types of oil (e.g., lubricants) in the locomotive that are also not considered as significant factors in this analysis.

Table 5: Spill Volumes from Loaded CBR Unit Trains for Analysis

Spill Category	Volume[7]	Approximate Tank Cars
Small Spill (Analogous to Average Most Probable Discharge)[8]	100 bbl[9]	0.1
Median (50th Percentile)	700 bbl	1
Large Spill (Analogous to Maximum Most Probable Discharge)	2,200 bbl[10]	3
Effective Worst Case Discharge	20,000 bbl[11]	28
Theoretical Worst Case Discharge	85,680 bbl	120[12]

Probability of Spillage from Loaded CBR Trains

The probabilities that there will be spills of various volumes from derailed loaded CBR trains associated with the Vancouver Energy project are summarized in Table 6 using a more conservative (higher estimate) approach of a 16.7% release rate, and a less conservative approach of a 9.2% release rate.

Table 6: Estimated Spill Frequencies for Vancouver Energy CBR Loaded Trains

Spill Probability Estimate Type	Derailments		Spills (Return Years)				
	Frequency per Year	Return Years	Any Spill	100 bbl Spill	700 bbl Spill	2,200 bbl Spill	20,000 bbl Spill
More Conservative 16.7% Release	0.495	2.00	12.1	16	27	121	12,097
Less Conservative	0.495	2.00	22.0	29	49	220	21,959

[7] The values in this table are rounded to the nearest hundred based on an approximate value of 714 bbl/tank car. Tank cars often contain only about 700 bbl to allow for a small degree (2%) expansion of the cargo. The actual tank capacity is 714 bbl. The theoretical WCD assumes 120 tank cars with 714 bbl each.

[8] There is no regulatory definition of Average Most-Probable or Maximum Most-Probable Discharge for railroads as there is for vessels and facilities. These categories are included here solely for the purpose of the environmental analysis conducted in other parts of this study to coincide with the concepts of AMPD and MMPD volumes for vessels and facilities.

[9] This volume represents spillage of a portion of a tank car (approximately 10%) that might spill as part of a leakage event or other minor incident.

[10] Based on 90th percentile rounded to an even number of tank cars (based on Table 17).

[11] This represents approximately the 99th percentile with respect to derailed cars assuming all of the cars release oil. This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents. It also coincides with the volume that is about 20% larger than the largest incident to date (16,422 bbl spilled in the November 2013 Aliceville, Alabama, incident as shown in Table 18).

[12] 120 tank cars is the longest CBR train that has been reported to date. Typically, the CBR unit trains (trains that contain only CBR tank cars) may be 100 to 120 tank cars long.

9.2% Release							

Return years (or return period in years) is the amount of time that would be expected to pass for one incident to occur. For example, a 100-year flood is something that is expected to occur once in 100 years. The return period is calculated by the formula:

$$R_{yrs} = \frac{1}{frequency\ /\ year}$$

Probability of Spillage from Empty CBR Trains

In the study conducted for JLARC,[13] rail spills in Washington were analyzed, showing that the probability distribution of spill volumes was such that the median spill volume was 2 bbl, the 90th percentile spill was 48 bbl, and the 99th percentile spill was 120 bbl. Only one spill in 170 spills (over the course of 13 years) involved the spillage of 262 bbl of oil.

There are no specific data on the rate of locomotive derailments and spillage. If one conservatively assumes that, in the event of a derailment incident involving an empty CBR train, each of the two contiguous locomotives has a 5% likelihood of derailing (as opposed to one of the other cars) and the fuel tanks would release oil based on the probability distribution of spill volumes from the JLARC railroad incident data,[14] the spill frequencies for locomotives would be as shown in Table 7. Since the each of the two locomotives make up approximately 1% of the total number of cars on a 120-tank car unit train, this assumes that a locomotive is five times more likely to derail and spill than a tank car. It would be reasonable to assume that the locomotives pulling a freight train are the first to hit any track irregularity.

Table 7: Estimated Spill Frequencies for Vancouver Energy CBR Empty Trains

Spill Probability Estimate Type	Empty Train Derailments		Locomotive Spills (Return Years)				
	Frequency per Year	Return Years	Any Spill	2 bbl Spill	48 bbl Spill	120 bbl Spill	262 bbl Spill
Assuming 5% Probability Locomotive(s) Derailing and Spilling	0.581[15]	1.72	17.2	34	172	1,720	17,200

Approach in Geographic Analysis

Given that spill risk is the probability of a spill incident occurring multiplied by the consequences of that spill, based on volume and oil type, and the fact that both spill location (derailments) and impacts are

[13] Etkin 2009; Etkin et al. 2009; French-McCay et al. 2008, 2009; State of Washington JLARC 2009.

[14] Railroad spill data for Washington State for 1995 – 2007. Etkin 2009; Etkin et al. 2009; French-McCay et al. 2008, 2009; State of Washington JLARC 2009.

[15] Based on empty train derailment frequency from Table 1.

geographically-based, a geographic analysis was performed. The geographic analysis included the steps shown in Figure 4.

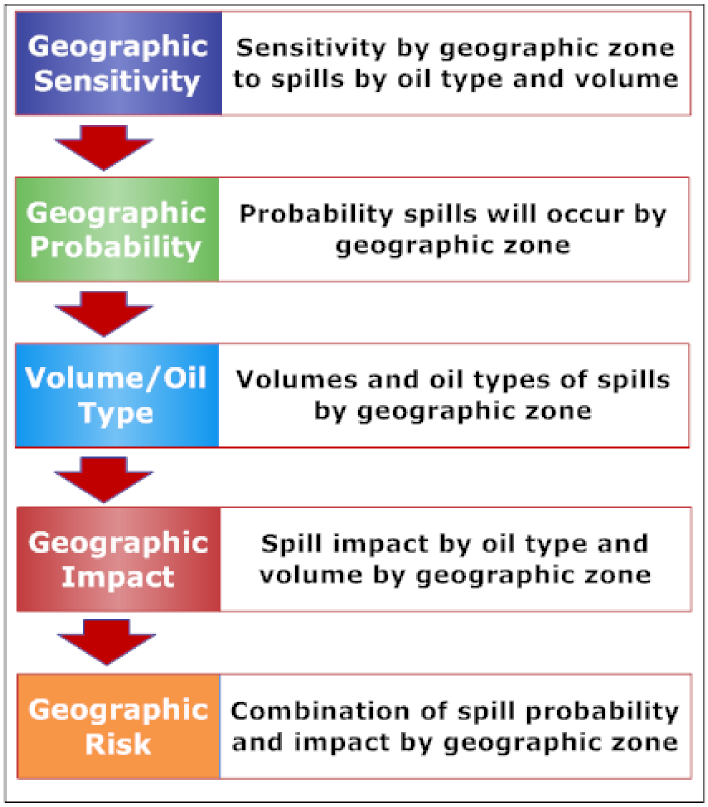

Figure 4: Approach to Geographic Analysis

Geographic Analysis of Potential Spill Impacts

The relative ranking of spill scenarios based on impact of credible worst-case discharges are shown in Table 8). In this table, the impact scores were normalized so that the lowest number (other than zero) was given a rank of 1.0 and the other scores were divided by that raw impact score. This means that the highest-ranked scenario – a WCD spill from a train loaded with diluted bitumen spill in the Klickitat WRIA (30) would have an impact that is 274 times as high as a diesel spill from locomotives in the Lower Snake WRIA (33). The WRIA zones refer to the areas depicted in Figure 5.

Table 8: Ranked and Normalized Impact Scores for Rail WCDs by Oil Type and Zone

WRIA #	Zone	Oil Type	Impact Score	Normalized Score
30	**Klickitat**	Diluted Bitumen	559,600	274.18
34	**Palouse**	Diluted Bitumen	524,000	256.74
-	**Western Columbia River**	Diluted Bitumen	513,000	251.35
28	**Salmon-Washougal**	Diluted Bitumen	505,600	247.72
36	**Esquatzel Coulee**	Diluted Bitumen	461,000	225.87
29	**Wind-White Salmon**	Diluted Bitumen	453,800	222.34
56	**Hangman**	Diluted Bitumen	403,200	197.55

Table 8: Ranked and Normalized Impact Scores for Rail WCDs by Oil Type and Zone

WRIA #	Zone	Oil Type	Impact Score	Normalized Score
32	**Walla Walla**	Diluted Bitumen	362,800	177.76
30	**Klickitat**	Bakken	341,200	167.17
34	**Palouse**	Bakken	319,400	156.49
57	**Middle Spokane**	Diluted Bitumen	316,400	155.02
-	**Western Columbia River**	Bakken	312,800	153.26
28	**Salmon-Washougal**	Bakken	308,400	151.10
36	**Esquatzel Coulee**	Bakken	281,200	137.78
29	**Wind-White Salmon**	Bakken	276,800	135.62
31	**Rock-Glade**	Diluted Bitumen	259,000	126.90
33	**Lower Snake**	Diluted Bitumen	255,400	125.13
56	**Hangman**	Bakken	245,800	120.43
32	**Walla Walla**	Bakken	221,200	108.38
57	**Middle Spokane**	Bakken	193,000	94.56
31	**Rock-Glade**	Bakken	158,000	77.41
33	**Lower Snake**	Bakken	155,800	76.34
23	**Upper Chehalis**	Diesel	4,795	2.35
11	**Nisqually**	Diesel	4,336	2.12
37	**Lower Yakima**	Diesel	4,307	2.11
27	**Lewis**	Diesel	4,197	2.06
34	**Palouse**	Diesel	4,184	2.05
26	**Cowlitz**	Diesel	4,182	2.05
9	**Duwamish-Green**	Diesel	4,090	2.00
13	**Deschutes**	Diesel	3,943	1.93
-	**Southern Puget Sound**	Diesel	3,838	1.88
36	**Esquatzel Coulee**	Diesel	3,684	1.80
39	**Upper Yakima**	Diesel	3,540	1.73
56	**Hangman**	Diesel	3,220	1.58
-	**Central Puget Sound**	Diesel	3,026	1.48
32	**Walla Walla**	Diesel	2,898	1.42
12	**Chambers-Clover**	Diesel	2,547	1.25
57	**Middle Spokane**	Diesel	2,528	1.24
33	**Lower Snake**	Diesel	2,041	1.00

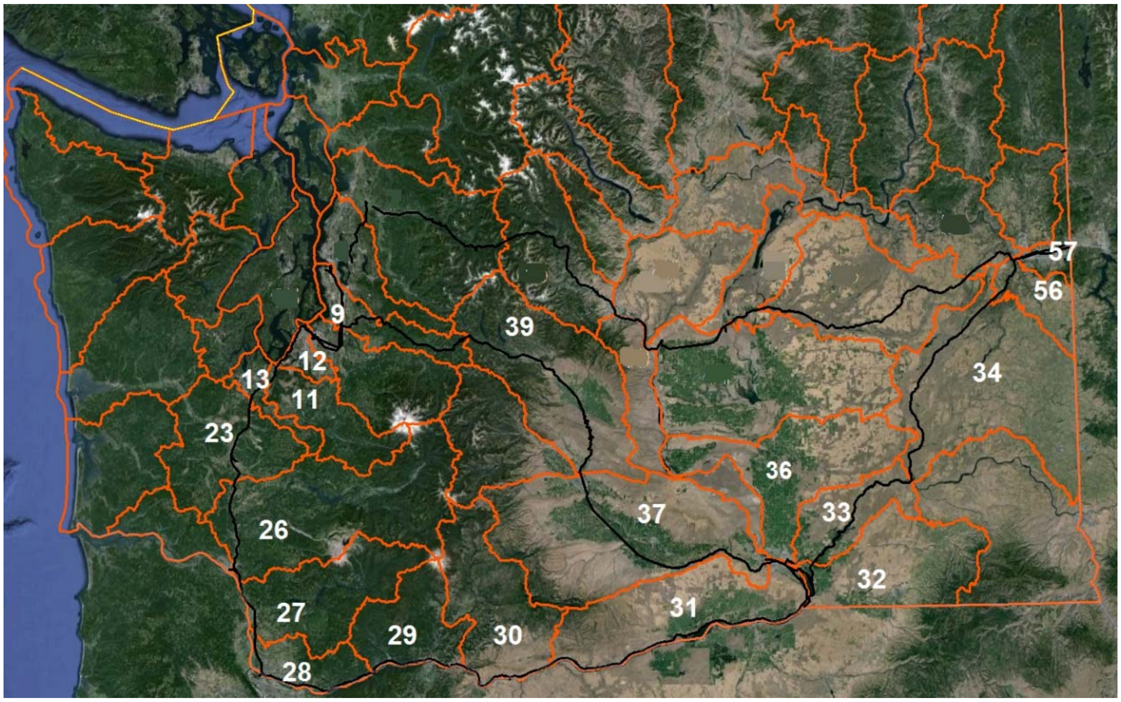

Figure 5: Inland Zones Potentially Impacted by CBR Spills[16]

Geographic Analysis of Probability of Derailments and Spills

The track conditions throughout the rail corridors that would be utilized for the CBR traffic to and from the Vancouver Energy facility would determine the relative likelihood of a derailment and potential subsequent spill in different geographic zones. Five BNSF Subdivisions were reviewed for this study.

The characteristics of the rail subdivisions are summarized in Table 9.

Table 9: Derailment Factors of BNSF Rail Subdivisions

Feature	Subdivision[17]				
	Kootenai/ Spokane	Lakeside	Fallbridge	Stampede	Yakima Valley
Curves ≥7°30'	None	None	None	85	16
Flash Flood Warning Areas	3	7	9	14	12
Average Wayside Detector Spacing	4.18 miles	5.05 miles	8.2 miles	4.9 miles	9.57 miles
Wayside Detectors Longest Gap	7.7 miles	8.2 miles	25 miles	16.4 miles	30.2 miles
Maximum Freight Train Speed	60 mph	60 mph	60 mph	49 mph	49 mph

[16] The inland zones are based on Water Resource Inventory Areas (WRIAs). Mainline rails are shown in black.
[17] MP = milepost.

The derailment factors were given relative scores in Table 10. The relative scores were derived by assigning a five-point scale (lowest, low, medium, high, highest) to the values for the factors shown in Table 9. Five point scoring scale used lowest to highest with 1 point for lowest and 5 points for highest. Curvature was given the highest weight (0.40), followed by the two wayside detector factors (0.15 and 0.15 each), and then flash flood areas (0.25), and maximum train speed (0.05). These weighting factors were based on expert judgement of the degree to which these factors would contribute to derailment probability. The total scores were derived by adding the weighted point scores for each subdivision. These scores were then normalized to derive a relative probability by adding the total number of points for all the subdivisions (15.85) and dividing each subdivision by the grand total. The final result is a relative probability, so that, for example, it could be expected that 21% of derailments would occur in the Lakeside Subdivision and 10% would occur in the Koontenai/Spokane Subdivision.

Table 10: Scores for Derailment Probability by BNSF Rail Subdivision

Feature	Subdivision				
	Kootenai/ Spokane	**Lakeside**	**Fallbridge**	**Stampede**	**Yakima Valley**
Curves ≥7°30’	Lowest (1 pt.)	High (4 pts.)[18]	Lowest (1 pt.)	Highest (5 pts.)	Medium (3 pts.)
Flash Flood Warning Areas	Low (2 pts.)	Medium (3 pts.)	Medium (3 pts.)	Highest (5 pts.)	Highest (5 pts.)
Average Wayside Detector Spacing	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	Medium (3 pts.)	High (4 pts.)
Wayside Detectors Longest Gap	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	High (4 pts.)	Highest (5 pts.)
Maximum Freight Train Speed	Medium (3 pts.)	Medium (3 pts.)	Medium (3 pts.)	Low (2 pts.)	Low (2 pts.)
Total Score	**1.65**	**3.4**	**2.5**	**4.4**	**3.9**
Relative Probability	**0.10**	**0.21**	**0.16**	**0.28**	**0.25**

Geographic Analysis of Risk from CBR Spills

The geographically-based oil spill impact was based on the application of a methodology developed for the Washington State Joint Legislative Audit and Review Committee (JLARC) and Washington Department of Ecology.[19] This methodology involves analyzing the impacts of different types of oil by season and geographic location to assign a per-unit spill volume impact value. The value is roughly based on the Washington State Compensation Formula, which is used to assess environmental damages by the state in spill cases. While the Compensation Formula is based on a per-gallon dollar value (up to $50) that can be assessed to the spiller, in the JLARC study this was used as a dimensionless relative value to determine impacts of different spill types. It was applied in the same manner in the current study.

[18] Risk score increased due to most conspicuous area of curvature over the entire route. The area features multiple reverse curves but track speed is generally limited to 35 mph to 50 mph. In addition, the track in the area crosses a dry wash in a number of locations.

[19] French-McCay et al. 2008; French-McCay et al. 2009; Etkin 2009; Etkin et al. 2009; State of Washington JLARC 2009.

The geographic zones, determined by marine or estuarine zone or by Water Resource Inventory Area (WRIA) zone for inland areas, were assigned per-unit impact values by oil type as described in greater detail in the Appendix.

The relative (normalized) risk scores for CBR worst-case discharge (WCD) spills in each of the geographic zones are presented in Table 11. These scores combine the relative probability that a derailment incident (and spill) will occur in that location with the impact score based on location, oil type, and potential WCD volume. Based on this analysis, the highest risk based on probability and environmental impacts is to the Columbia River with a worst-case discharge diluted bitumen spill.[20]

Table 11: Ranked and Normalized Risk Scores for Rail WCDs by Oil Type and Zone

WRIA #	Zone	Oil Type	Normalized Impact Score	Normalized Relative Frequency	Normalized Risk Score
	Western Columbia River	**Diluted Bitumen**	251.35	0.69	**173.43**
34	**Palouse**	**Diluted Bitumen**	256.74	0.54	**138.64**
57	**Middle Spokane**	**Diluted Bitumen**	155.02	0.86	**133.32**
33	**Lower Snake**	**Diluted Bitumen**	125.13	1	**125.13**
	Western Columbia River	**Bakken**	153.26	0.69	**105.75**
34	**Palouse**	**Bakken**	156.49	0.54	**84.50**
57	**Middle Spokane**	**Bakken**	94.56	0.86	**81.32**
33	**Lower Snake**	**Bakken**	76.34	1	**76.34**
30	**Klickitat**	**Diluted Bitumen**	274.18	0.14	**38.39**
31	**Rock Glade**	**Diluted Bitumen**	126.9	0.28	**35.53**
28	**Salmon-Washougal**	**Diluted Bitumen**	247.72	0.14	**34.68**
29	**Wind-White Salmon**	**Diluted Bitumen**	222.34	0.14	**31.13**
56	**Hangman**	**Diluted Bitumen**	197.55	0.14	**27.66**
30	**Klickitat**	**Bakken**	167.17	0.14	**23.40**
56	**Hangman**	**Bakken**	120.43	0.18	**21.68**
31	**Rock Glade**	**Bakken**	77.41	0.28	**21.67**
28	**Salmon-Washougal**	**Bakken**	151.1	0.14	**21.15**
29	**Wind-White Salmon**	**Bakken**	135.62	0.14	**18.99**
32	**Walla Walla**	**Diluted Bitumen**	177.76	0.09	**16.00**
32	**Walla Walla**	**Bakken**	108.38	0.09	**9.75**
39	**Upper Yakima**	**Diesel**	1.73	0.78	**1.35**
37	**Lower Yakima**	**Diesel**	2.11	0.57	**1.20**
23	**Upper Chehalis**	**Diesel**	2.35	0.32	**0.75**
34	**Palouse**	**Diesel**	2.05	0.36	**0.74**
57	**Middle Spokane**	**Diesel**	1.24	0.57	**0.71**
33	**Lower Snake**	**Diesel**	1	0.66	**0.66**

[20] The probability of a Bakken crude spill versus a diluted bitumen spill will depend on the relative volumes of the two crude oil types that are handled by the Vancouver Energy facility and are thus transported by rail. In this analysis, it is assumed that it is equally likely that there will be a Bakken crude spill as a diluted bitumen spill.

Table 11: Ranked and Normalized Risk Scores for Rail WCDs by Oil Type and Zone					
WRIA #	**Zone**	**Oil Type**	**Normalized Impact Score**	**Normalized Relative Frequency**	**Normalized Risk Score**
26	**Cowlitz**	**Diesel**	2.05	0.32	**0.66**
27	**Lewis**	**Diesel**	2.06	0.24	**0.49**
9	**Duwamish-Green**	**Diesel**	2	0.24	**0.48**
	Southern Puget	**Diesel**	1.88	0.16	**0.30**
56	**Hangman**	**Diesel**	1.58	0.12	**0.19**
11	**Nisqually**	**Diesel**	2.12	0.08	**0.17**
13	**Deschutes**	**Diesel**	1.93	0.08	**0.15**
36	**Esquatzel Coulee**	**Diesel**	1.8	0.07	**0.13**
	Central Puget	**Diesel**	1.48	0.08	**0.12**
12	**Chambers-Clover**	**Diesel**	1.25	0.08	**0.10**
32	**Walla Walla**	**Diesel**	1.42	0.06	**0.09**

Approach to Rail Spill Risk Analysis

This report addresses the risks from rail transport of crude oil associated with the proposed Vancouver Energy facility. The analysis briefly addresses:

- The probability of spills of crude oil associated with accidents during the transport of crude oil to the Vancouver Energy facility and the probability of diesel fuel spills from locomotives transporting empty trains on return routes;
- The potential volumes of spillage from tank car and locomotive derailments;
- The probability distribution of spill volumes;
- Spill volumes related to requirements for contingency planning (average most-probable, maximum most-probable, and worst-case discharges);
- The potential impacts of spills of Bakken crude oil, diluted bitumen, and diesel fuel along the railroad corridors based on oil type and geographic location; and
- The potential impacts of risk mitigation measures to prevent railroad accidents and spills.

The general approach is shown in Figure 6. The general approach involves evaluating the two components of risk – probability and consequences or impacts. Determining the probability of a spill involves estimating the probability that there will be an accident that could potentially cause spillage, determining that the probability that the accident will actually result in spillage, and then determining the volume of the spill based on the severity and type of accident.

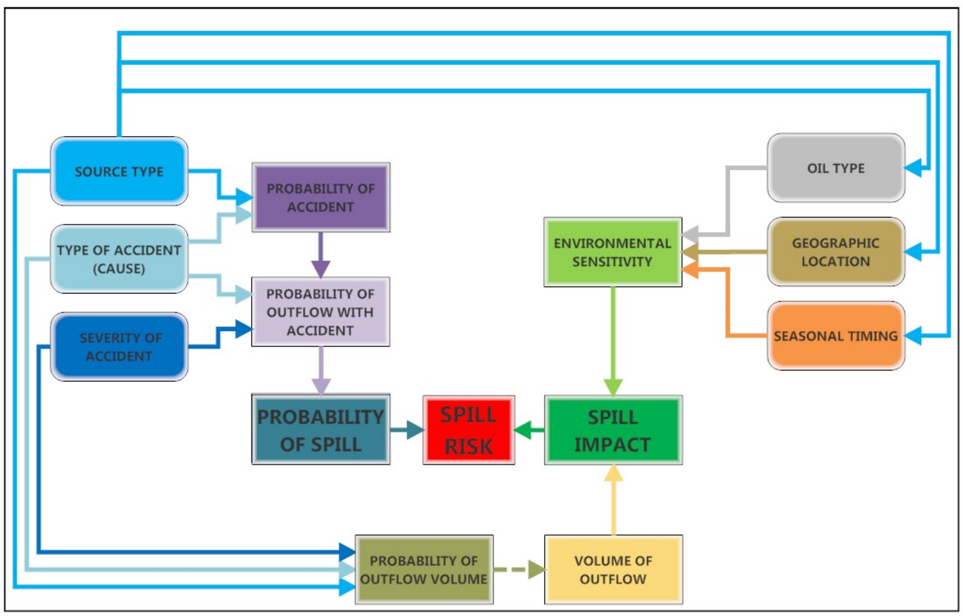

Figure 6: General Risk Analysis Approach

The environmental impact of the spill will be determined by sensitivity of the receiving environment, which is, in turn determined by the oil type, location, and season. Since the seasonality of the CBR train traffic is not known and assumed to be equally spread across all seasons, this factor is not applied in this analysis.

Basic Assumptions on Vancouver Energy Facility Throughput

For this analysis (and the related analysis conducted for rail transport risk) the following basic assumptions have been applied:

- The overall annual throughput at the facility will average 360,000 barrels (bbl) per day across 365 days for a maximum annual throughput of 131.4 million bbl;
- Rail deliveries of crude oil to the facility will be limited to 120-car train length unit trains by the loading facilities and proposed rail infrastructure at Terminal 5;
- The maximum volume per rail tank car is assumed to be 750 bbl for air permitting purposes, though actual carloads are limited by cargo weight, which is affected by oil density, by tank car weight, which is affected by the design, and by vapor space requirements to allow for expansion of the oil and to control for buildup of volatiles;[21] and
- There would be four trains per day, with a possible fifth train infrequently on some days.

CBR Train Routing Assumptions

The basic CBR routing assumptions for this study are:

- The rail routes that would generally be utilized by four CBR trains going to and from the Vancouver Energy facility daily are as shown in Figure 7;
- The route utilized to transport crude to the Vancouver Energy facility would be from Sand Point, Idaho (Kootenai-Spokane Subdivision), to Pasco (117 Subdivision) to Vancouver (Fallbridge Subdivision);
- The route utilized to transport empty unloaded trains back to Sand Point would be the subdivisions from Vancouver to Auburn (Vancouver-Seattle Subdivision) to Ellensburg (Stampede Subdivision), Ellensburg to Pasco (Yakima Valley Subdivision), and then from Pasco to Sand Point via Spokane (Lakeside Subdivision, then (Kootenai-Spokane Subdivision); the overall Auburn to Pasco corridor is frequently referred to as "Stampede Pass"; [22]

[21] In actual practice, the tank cars often do not exceed 650 to 690 bbl of cargo loading.

[22] Stampede Pass was the assumed return route for the unloaded/empty trains as this is the route with the greatest length, which corresponds to the route selected for analysis in Vancouver Energy's SEPA Draft EIS. In addition, according to Etkin et al. 2015 (Washington State Marine and Rail Oil Transportation Study), "Empty unit bulk trains generated from north of Vancouver (Kalama, Longview, Centralia, Tacoma, Seattle and north) are destined to return to Pasco and to points east via the Stampede Pass at Auburn (between Seattle and Tacoma). Under this routing concept, train operations over Stampede Pass will be almost exclusively eastbound empty bulk trains. A small number of empty bulk trains from Everett north are routed over Stevens Pass when a 'slot' is available, but BNSF does not believe that intermodal growth will allow that to occur over the long run."

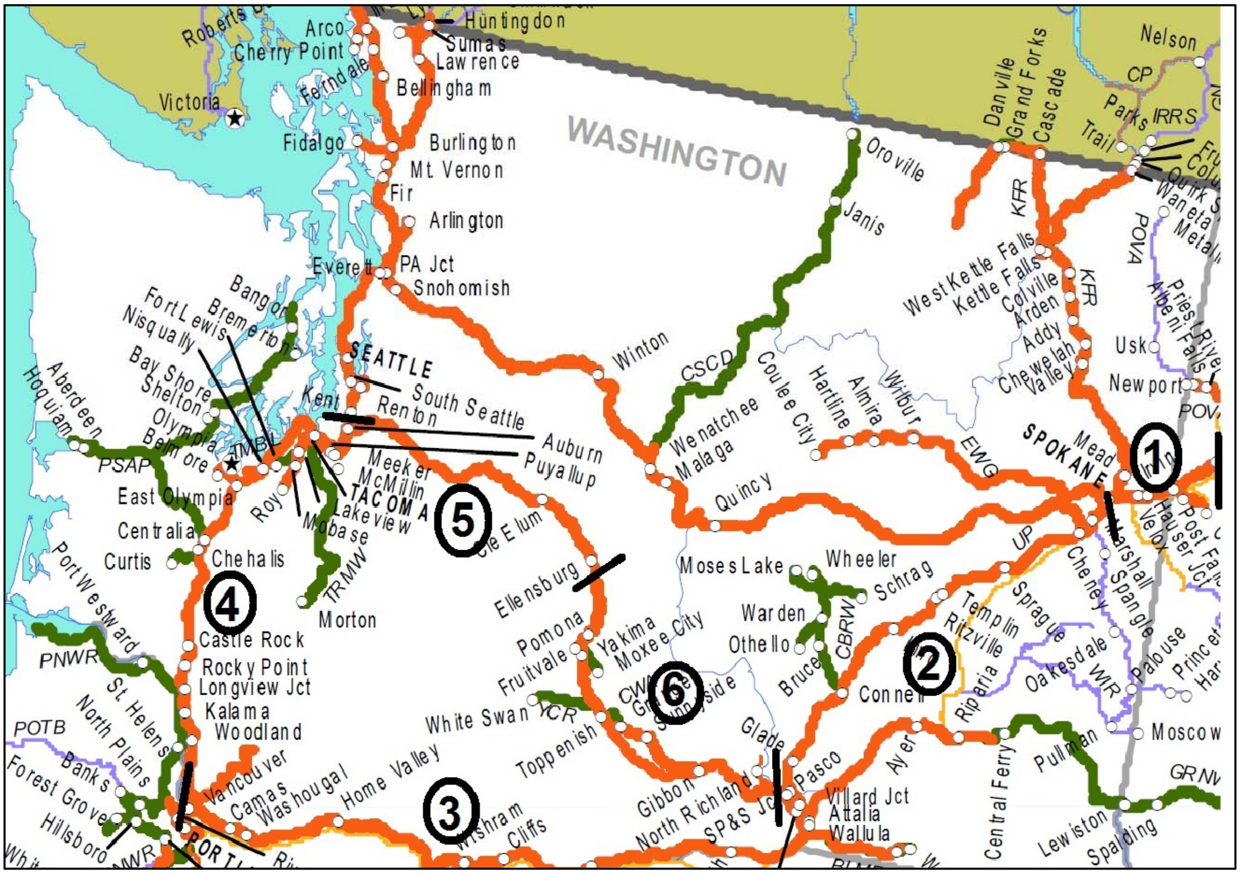

Figure 7: BNSF Routes in Washington Showing Subdivisions Assumed in Study

Segment 1: Sand Point, Idaho, to Spokane (Kootenai-Spokane Subdivision); Segment 2: Spokane to Pasco (Lakeside Subdivision); Segment 3: Pasco to Vancouver (Fallbridge Subdivision); Segment 4: Vancouver to Auburn (Vancouver-Seattle Subdivision); Segment 5: Auburn to Ellensburg (Stampede Subdivision); Segment 6: Ellensburg to Pasco (Yakima Valley Subdivision).

Definitions of Worst-Case Discharge

The analysis evaluates and references several different types of "worst-case discharges" (WCD):

***Theoretical* WCD:** This is volume based on a single derailment event (of a non-CBR freight train) in which all of the freight cars derailed. While this particular historical event did not result in the spillage from all of the freight cars, the volume of this "theoretical WCD" is based on the hypothetical assumption that the train had been a CBR train and all of the contents of the tank cars spilled all of their contents. This type of scenario is extremely unlikely based on the very low probability of all of the cars derailing and the very low probability that all of the cars would release oil.

***Effective* WCD:** This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents. Unlike for vessels, at this time, there is no regulatory definition of WCD for response planning purposes or to evaluate potential environmental impacts. This study proposes the use of the "effective

WCD" for the purposes of environmental impact analysis, and for response planning until a regulatory WCD volume is implemented.

General Probabilities of Derailment and Spillage

This analysis addresses the overall probabilities of derailments and potential spillage across the entire rail corridor. This analysis goes through a series of steps as shown in Figure 8. The geographic-specific analysis is addressed in a subsequent section.

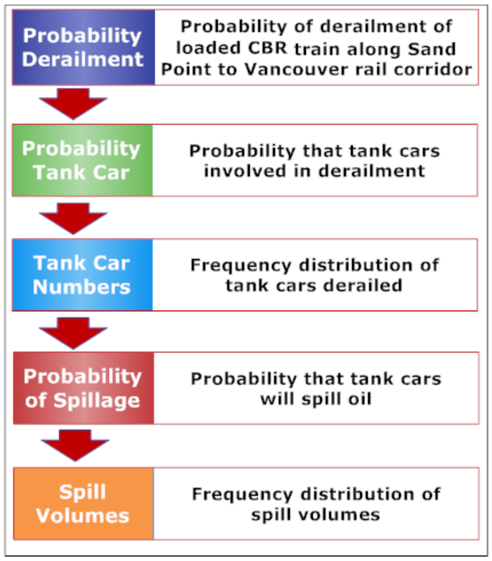

Figure 8: Steps to Derive Probability of Rail Spills and Distribution of Spill Volumes

The analysis is largely based on Federal Railroad Administration (FRA) data[23] for the years 1975 – 2014 (40 years). The derailment data analyzed included only freight trains (i.e., no passenger trains) on main line tracks (i.e., excluding yard, siding, and industry tracks). Freight trains of all kinds were included with the assumption that derailments with crude-by rail (CBR) unit trains would have similar outcomes. There are not enough CBR-specific data to conduct a robust analysis with respect to estimating spill volumes from tank car outflows. Unless otherwise specified the data are for the US as a whole. Washington-specific data were analyzed in some instances to determine whether the derailment rates were significantly different.

Derailment Frequencies

The frequency of derailment incidents has decreased significantly since the late 1970s (Figure 9) and even in the last fifteen years (Figure 10). Washington shows a similar decrease, though there is greater variability in annual rates. The average derailment rate for Washington is slightly lower in both time periods (Table 12).

The frequencies of derailment depicted in these graphs are based on estimates of track miles (i.e., the miles traveled by trains). With changes in track miles, especially with an increase in CBR traffic, the frequencies and probabilities of future derailments will change. In addition, the geographic distribution of derailments

[23] http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx

is not evenly spaced across the rail corridors. These factors are analyzed in a separate section of this study. This analysis demonstrates that the frequency of derailments has decreased significantly and that more recent time periods are more appropriate for analysis of derailment frequencies.

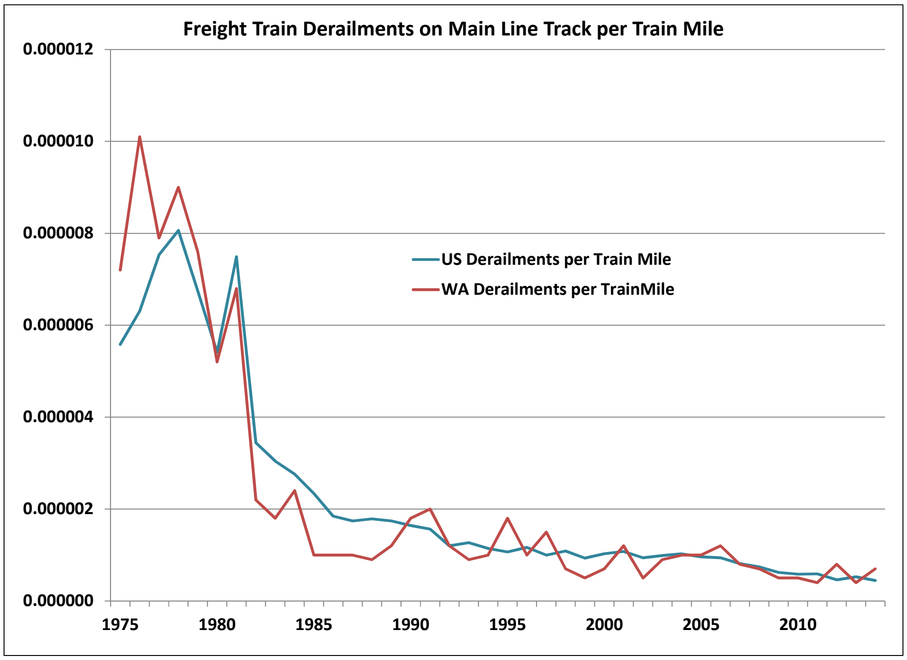

Figure 9: Freight Train Derailments on Main Line Track per Train Mile (1975 – 2014)

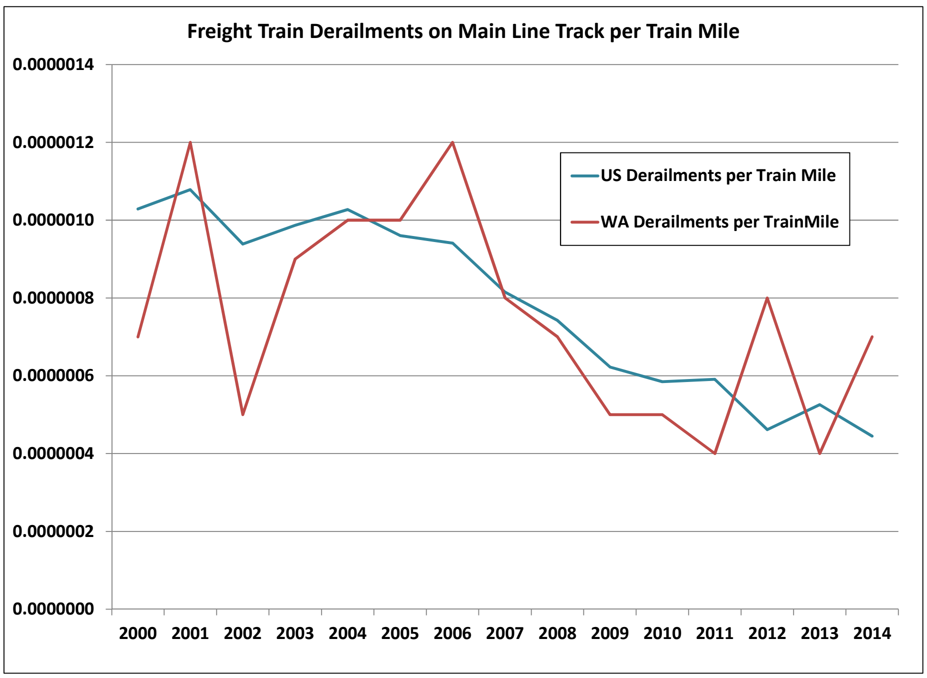

Figure 10: Freight Train Derailments on Main Line Track per Train Mile (2000 – 2014)

Table 12: Derailment Frequency for Freight Trains				
Time Period	**US Derailment Rate**		**Washington Derailment Rate**	
	Average Derailments per Train Mile	**Average Train Miles per Derailment**	**Average Derailments per Train Mile**	**Average Train Miles per Derailment**
1975 – 1984	0.00000564	177,362	0.00000602	166,113
1985 – 1994	0.00000163	614,602	0.00000120	833,333
1995 – 2004	0.00000103	969,480	0.00000098	1,020,408
2005 – 2014	0.00000067	1,494,877	0.00000070	1,428,571
2010 – 2014	0.00000052	1,917,029	0.00000055	1,818,182
2000 – 2014	0.00000078	1,276,644	0.00000075	1,327,434
1975 – 2014	0.00000224	446,145	0.00000223	449,438

Derailment Frequencies for Vancouver Energy CBR Traffic

The derailment analyses for federal and Washington are based on all varieties of freight trains, not necessarily crude by rail (CBR) trains. The reasoning behind this approach is that are not enough data on CBR train derailments alone to allow for a statistically-valid analysis. CBR traffic has been underway at a large scale only in the last few years. In addition, derailments occur regardless of the cargo content of the freight cars. Track conditions, rail operating procedures, and other factors unrelated to cargo content are the factors that determine derailment frequencies and locations.

The estimates of the number of CBR derailments, which do not necessarily lead to spills, can be roughly estimated by the number of train miles or the number of transits expected for the Vancouver Energy facility on both the loaded and unloaded (return) routes.

With an estimated four loaded CBR trains per day expected at the Vancouver Energy facility and 435 miles of track along the loaded route[24] and 510 miles on the Stampede Pass (unloaded train) return route , the estimated numbers of derailments (not necessarily spills) are as shown in Table 13.[25] This analysis assumes four trains per day arriving at the Vancouver Energy facility and that the trains would return on the Stampede Pass route. The per-train mile derailment frequency of 0.00000078 (from Table 12) has been conservatively applied. [A geographic analysis of derailment probability is presented in a subsequent section.]

This analysis indicates that with four daily CBR trains, it is expected that a derailment incident might occur once every two years with a loaded train, and once 20 months with an empty train. *Note that this does not mean that these derailments would result in spillage.*

[24] Sand Point ID-Spokane (Kootenai/Spokane Subdivision), Spokane-Pasco (Lakeside Subdivision), and Pasco-Vancouver (Fallbridge Subdivision).

[25] Based on track mileage in *BNSF Railway Timetable No. 4*, 2009, as presented in Etkin et al. 2015.

Table 13: Estimated Derailment Frequency along Vancouver Energy-Related CBR Routes							
Route	**Rail Subdivision**	**Track Miles**	**Annual Train Miles[26]**	**Derailment Frequency (per year)**		**Derailment Return Years**	
				Loaded	**Empty**	**Loaded**	**Empty**
Loaded	**Sand Point ID-Spokane (Kootenai/Spokane)**	68.5	100,010	0.078	n/a	12.8	n/a
	Spokane-Pasco (Lakeside)	146.4	213,744	0.167	n/a	6.0	n/a
	Pasco-Vancouver (Fallbridge)	219.8	320,908	0.250	n/a	4.0	n/a
	Total Loaded	**434.7**	**634,662**	**0.495**	**n/a**	**2.0**	**n/a**
Return Stampede Pass	**Vancouver-Seattle (partial)**	68.0	99,280	n/a	0.078	n/a	12.8
	Ellensburg-Stampede/Auburn (Stampede)	102.6	149,796	n/a	0.116	n/a	8.6
	Pasco-Ellensburg (Yakima Valley)	124.1	181,186	n/a	0.142	n/a	7.0
	Spokane-Pasco (Lakeside)	146.4	213,744	n/a	0.167	n/a	6.0
	Sand Point ID-Spokane (Kootenai/Spokane)	68.5	100,010	n/a	0.078	n/a	12.8
	Total Return Stampede Pass	**509.6**	**744,016**	**n/a**	**0.581**	**n/a**	**1.7**
	TOTAL	**944.3**	**1,378,678**	**0.495**	**0.581**	**2.0**	**1.7**

Volume of Spillage from CBR Derailments

When derailments occur, there is the potential for spillage based on the characteristics of the accident and the numbers of cars involved.

Number of Cars Derailed per Incident

When derailments occur, varying numbers of cars and/or locomotives are involved. The average numbers of cars involved in derailments are shown in Table 14. (This includes factoring in "zero" for incidents involving only locomotives.) The number of cars derailed per incident is somewhat lower in Washington than in the US as a whole, particularly in the last 15 years.

Table 14: Average Number of Cars per Derailment		
Time Period	**US**	**Washington Only**
1975 – 1999	7.7	7.1
2000 – 2014	8.0	4.9
1975 – 2014	7.5	6.0

[26] Assumes four CBR trains per day.

The distributions of derailed car per incident are shown in Figure 11 and Figure 12. The cumulative probability distribution functions with percentile values are shown in Figure 13 and Figure 14. These data include factoring in “zero” for incidents involving only locomotives.

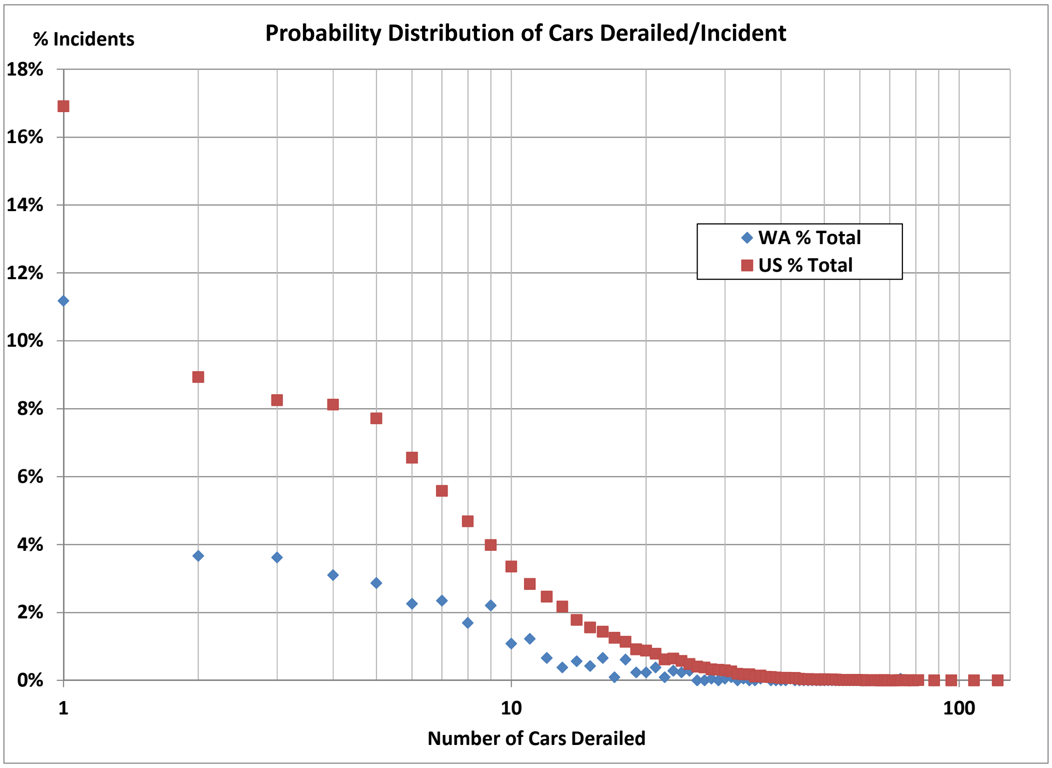

Figure 11: Probability Distribution of Cars Derailed per Incident (Logarithmic)

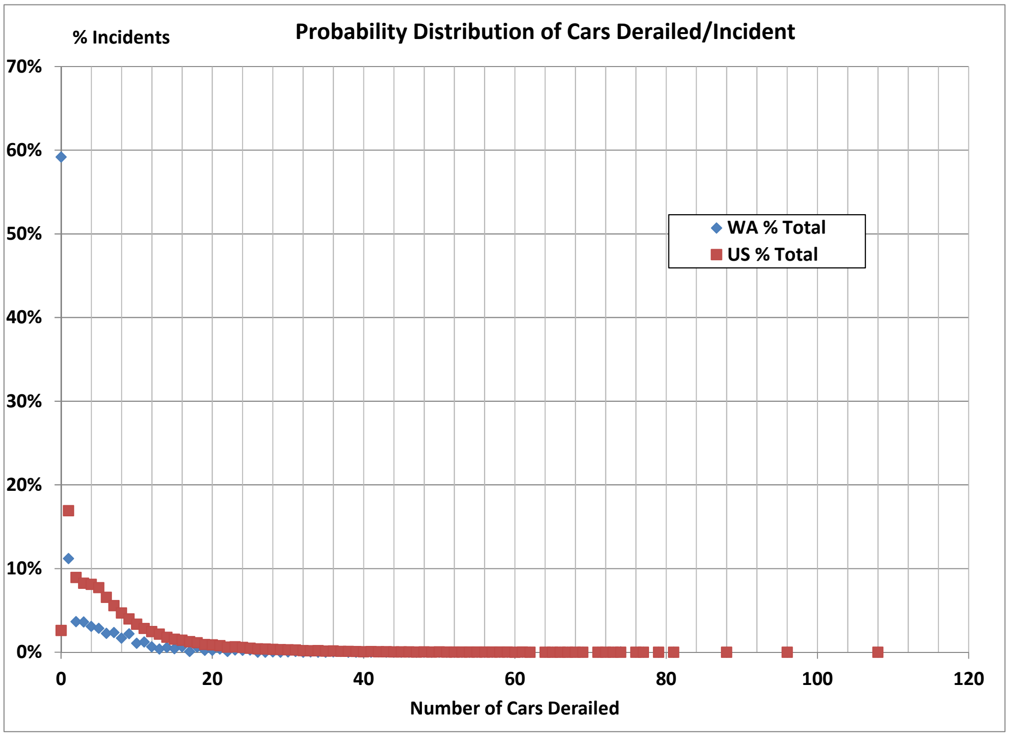

Figure 12: Probability Distribution of Cars Derailed per Incident

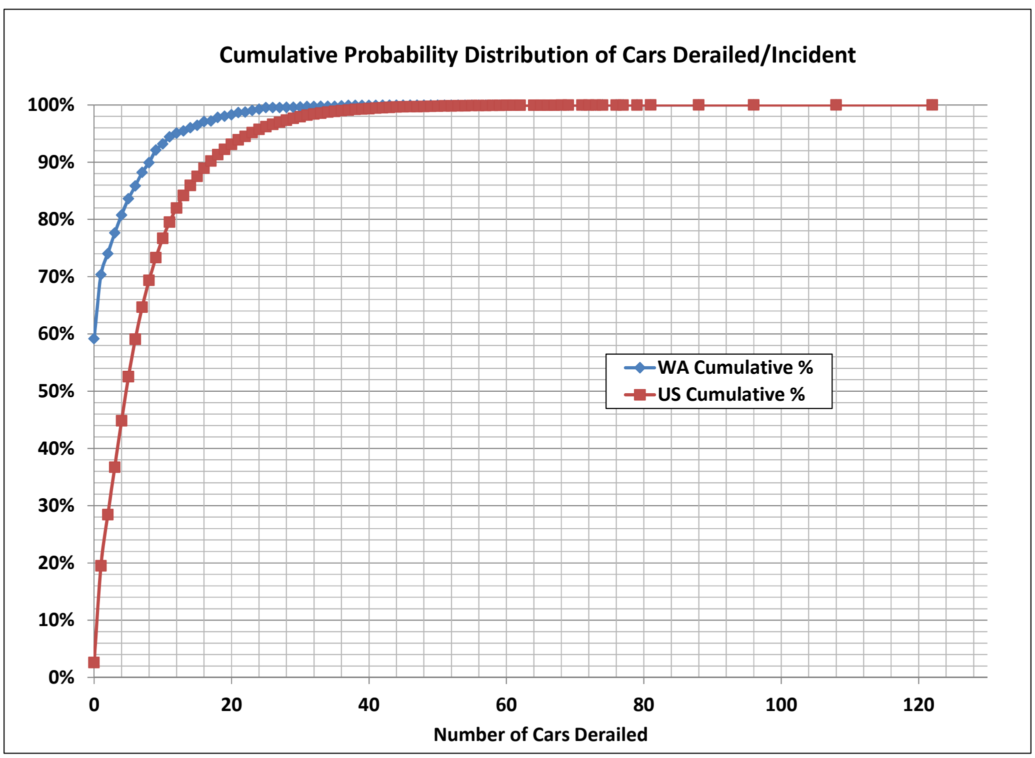

Figure 13: Cumulative Probability Distribution of Cars Derailed/Incident

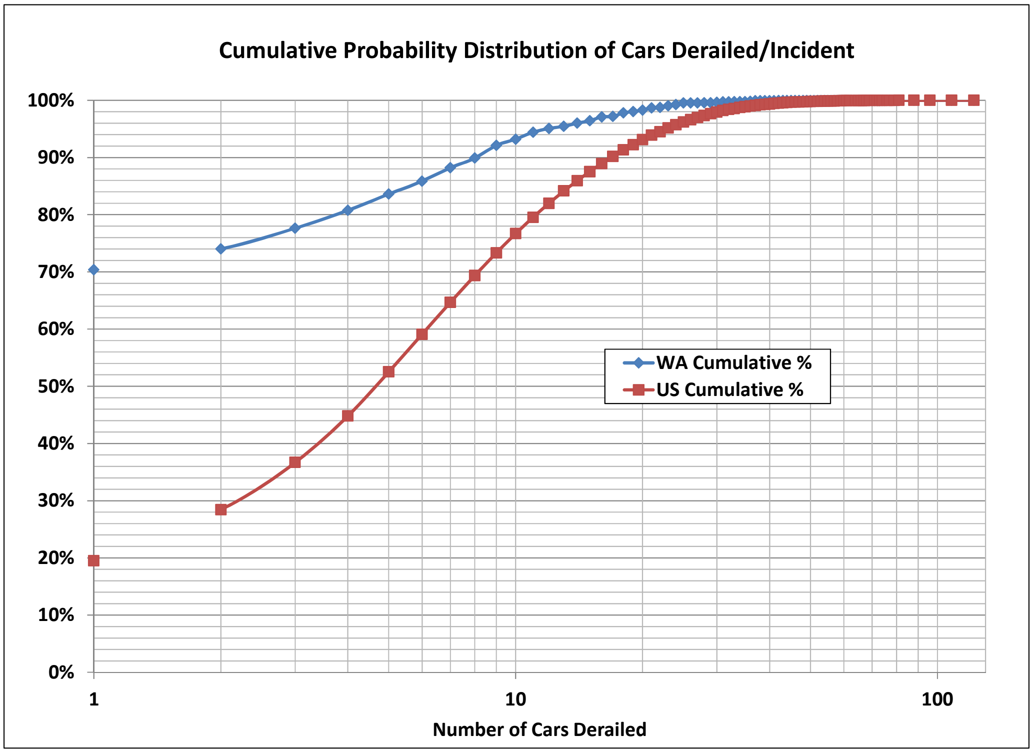

Figure 14: Cumulative Probability Distribution of Cars Derailed/Incident (Logarithmic)

Table 15 shows the percentile numbers of cars involved in derailments assuming that there is involvement of cars that could potentially have cargo spillage rather than just locomotives. The Washington distribution shows a generally lower number of cars derailed per incident and a much higher percentage of derailment incidents in which no freight cars derail (i.e., only locomotives are involved).

Table 15: Percentile Values of Cars Derailed per Incident

Statistic	US	Washington Only
% Incidents with No Cargo Car Derailment	2.60%	59.18%
Average	7.7 cars	6.1 cars
25th Percentile (75% Higher)	2 cars	1 car
50th Percentile (Median) (50% Higher)	5 cars	4 cars
75th Percentile (25% Higher)	10 cars	8 cars
90th Percentile (10% Higher)	17 cars	14 cars
95th Percentile (5% Higher)	23 cars	19 cars
99th Percentile (1% Larger)	37 cars	30 cars
Actual Worst Case	122 cars	74 cars

Probability of Hazardous Material Release from a Derailed Car

A freight car derailment means that there is a potential for spillage, though not all derailed freight cars spill cargo. The distribution of percentages of hazardous material tank cars that released their cargo contents in derailments was analyzed. For all derailed tank cars over 1975 – 2014, 16.7% had spillage.[27] For the data for the years 2000 – 2014, 9.2% of derailed tank cars had spillage. There was no significant relationship between the number of cars that derailed and the percentage of cars that released cargo. These rates of spillage from derailed cars were applied as the probability that given a derailment there will be a release of hazardous materials. The data differ between time periods as shown in Table 16.

Table 16: Average Percentage of Derailed Hazmat Cars with Release

Time Period	% Derailed Hazmat Cars with Release	
	US 4,383 derailments with Hazmat Cars	Washington 63 derailments with Hazmat Cars
1975 – 1999	19.4%	16.0%
2000 – 2014	9.2%	10.0%
1975 – 2014	16.7%	14.5%

Given that in the last 15 years, there was a significant reduction in the percentage of derailed hazmat cars that release hazardous materials in a derailment, the 9.2% value was applied in determining the potential volume of release for a "less conservative" approach and 16.7% was applied for a "more conservative" approach.

For each train derailment incident in the larger data set of 4,383 derailment incidents for the years 1975 – 2014, there are varying numbers and percentages of derailed tank cars that release oil. While there are no specific analyses on this issue, it is assumed that the probability that a particular derailed tank car spills oil is based on a large number of factors, including those related to the particular circumstances of the derailment accident (e.g., train speed, track curvature). However, in this analysis, it is assumed that the most important factor in determining the probability of spillage is the structural integrity of the tank car itself. [In fact, this is the basis for the proposed regulatory changes regarding tank car design.] For this reason, applying the overall percentage of derailed tank cars that have spilled oil across all incidents is applied. The less conservative approach of taking the lowered percentage of release for the more recent derailment incidents is based on the significant reduction in the release rate (by about 50%) over the last 15 years. This reduction may be attributed to changes in train operations and changes in tank car design.

Estimated Spill Volume Probability Distribution from Derailed Tank Cars

Given that there is a derailment of tank cars, the distribution of potential spill volumes is as shown in Table 17.

Table 17: Preliminary Estimated Spill Volumes from CBR Unit Trains

Statistic	Number of Derailed Cars	Less Conservative Approach (9.2% Release Rate)		More Conservative Approach (16.7% Release Rate)	
		Number of Cars with Spillage	Total Volume of Spillage (bbl)	Number of Cars with Spillage	Total Volume of Spillage (bbl)
25th Percentile	2 cars	0.2	131	0.33	238
50th Percentile (Median)	5 cars	0.5	328	0.84	596

[27] These data take into account the 74% of incidents in which no cargo was released.

75th Percentile	10 cars	0.9	657	1.67	1,192
90th Percentile	17 cars	1.6	1,117	2.84	2,027
95th Percentile	23 cars	2.1	1,511	3.84	2,742
99th Percentile	37 cars	3.4	2,430	6.18	4,412
Worst Case	122 cars	11.2	8,014	20.37	14,547

This incorporates the distribution of numbers of derailed cars in a single derailment incident and the probability that if these cars were to be CBR tank cars in a unit train, they would release oil, and the volume of that release.

This analysis assumes that freight cars are proxies for CBR tank cars and that the distribution of derailed cars in a unit train would be analogous to those of a manifest train (i.e., one with a variety of cargo in freight cars). There are not enough data on CBR derailments and spills to do a comprehensive analysis.

This analysis also assumes that if there were to be a release from a CBR tank car, the tank car is full for a total of 30,000 gallons (714 bbl). The US distribution of derailed cars was used as this would represent a more conservative approach.

Comparison with Anecdotal Data from Recent CBR Accidents

These values were compared with anecdotal data from CBR accidents that have occurred in the last three years (Table 18 and Table 19).

Table 18: Recent Accidents Involving Crude by Rail Trains

Location/Date Incident Type	Railroad	Fire	Spill (Bbl)	Details
Boomer Bottom, WV[28] February 16, 2015 Derailment	CSX	Yes	Unknown	26 cars derailed; 14 caught fire; some oil entered creek. One injury.
LaSalle, CO[29] May 9, 2014 Derailment	Union Pacific	No	155	6 cars of a 100-car crude oil train derailed, causing leakage from one car. Leakage was at rate of 20-50 gallons/minute. Spill contained in ditch. No injuries.
Lynchburg, VA[30] April 30, 2014 Derailment	CSX	Yes	<1,190	15 cars in crude oil train derailed in downtown area of city. 3 cars caught fire, and some cars derailed into river along tracks. Immediate area surrounding derailment evacuated. No injuries were reported.
Vandergrift, PA[31] Feb 13, 2014 Derailment	Norfolk Southern	No	108	21 tank cars of 120-car train derailed outside Pittsburgh. 19 derailed cars carrying crude oil from western Canada; 4 released product. No fire or injuries.
Philadelphia, PA January 20, 2014 Derailment	CSX	No	None	7 cars of 101-car CSX train, including 6 carrying crude oil, derailed on bridge over Schuylkill River. No injuries and no leakage were reported, but 2 cars, one tanker, leaning over river.

[28] Preliminary data.
[29] http://www.greeleytribune.com/news/11353788-113/crude-car-cars-davis.
[30] http://www.latimes.com/nation/nationnow/la-na-nn-lynchburg-virginia-train-derailment-20140430-story.html
[31] http://triblive.com/neighborhoods/yourallekiskivalley/yourallekiskivalleymore/5596923-74/railroad-oil-norfolk#axzz37qQHJGGf.

Table 18: Recent Accidents Involving Crude by Rail Trains				
Location/Date Incident Type	**Railroad**	**Fire**	**Spill (Bbl)**	**Details**
Wisconsin/Minnesota[32] Feb 3, 2014 Leak	Canadian Pacific	No	286	Valve or cap mishap caused spill of 12,000 gallons from one tank car while en route between Winona and Red Wing. Train traveling at low speed.
Plaster Rock, New Brunswick, Canada[33] Jan 7, 2014 Derailment	Canadian National	Yes	Unknown	17 cars of mixed train hauling crude oil, propane, and other goods derailed likely due to sudden wheel/axle failure. 5 tank cars carrying crude oil caught fire and exploded. Train delivering crude from Manitoba and Alberta to Irving Oil refinery in St. John, New Brunswick. 45 homes evacuated; no injuries reported.
Casselton, ND[34] Dec 30, 2013 Derailment and Collision	BNSF	Yes	>9,524	Eastbound train hauling 106 tank cars of crude oil struck westbound train carrying grain that shortly before had derailed onto eastbound track. Some 34 cars from both trains derailed, including 20 cars carrying crude that exploded and burned for over 24 hours. About 1,400 residents of Casselton were evacuated but no injuries were reported. Cause of derailments and subsequent fire under investigation.
Aliceville, AL[35, 36] Nov 8, 2013 Derailment	Genesee & Wyoming	Yes	16,422[37]	Train hauling 90 cars of crude oil from North Dakota to refinery near Mobile, AL, derailed on section of track through wetland near Aliceville, AL. 30 tank cars derailed and some dozen burned. No one was injured or killed. The derailment occurred on a shortline railroad's track that had been inspected few days earlier. Train was travelling under speed limit for this track. Cause of derailment under investigation. 25 cars derailed, 23 were breached. Actual spill volume unknown.
Gainford, Alberta, Canada[38] Oct 19, 2013 Derailment	Canadian National	Yes	Unknown	9 tank cars of propane and four tank cars of crude oil from Canada derailed as train was entering siding at 22 mph. About 100 residents evacuated. 3 propane cars burned, but tank cars carrying oil were pushed away and did not burn. No one injured or killed. Derailment cause under investigation. 9 propane, 4 crude; 3 propane cars burned.

[32] http://www.winonadailynews.com/news/local/gallons-of-crude-oil-spilled-between-winona-and-red-wing/article_850d10d2-a702-5fc8-b97e-f822d0c5c30b.html.

[33] http://dot111.info/category/recent-derailments/.

[34] https://www.ntsb.gov/doclib/reports/2014/Casselton_ND_Preliminary.pdf.

[35] http://dot111.info/category/disasters/aliceville-al/.

[36] http://www.nrt.org/production/nrt/RRTHomeResources.nsf/resources/RRT4Feb2014Meeting/$File/aliceville_derailment_Cash.pdf

[37] Reported spill volume was "less than 18,295 bbl". Based on the known number of tank cars breached (23), the spill was estimated to be 16,422 bbl.

[38] http://www.edmontonsun.com/2013/10/23/evacuation-lifted-after-train-derailment-in-gainford-alberta.

Table 18: Recent Accidents Involving Crude by Rail Trains				
Location/Date Incident Type	**Railroad**	**Fire**	**Spill (Bbl)**	**Details**
Lac-Mégantic, Quebec, Canada[39] July 5, 2013 Derailment	Montreal, Main & Atlantic	Yes	>869	Train with 72 loaded tank cars of crude oil from North Dakota moving from Montreal, Quebec, to St. John, New Brunswick, stopped at Nantes, Quebec, at 11:00 pm. Operator and sole railroad employee aboard train secured it and departed, leaving train on short line track with descending grade of 1.2%. At about 1:00 am, train began rolling down descending grade toward own of Lac-Mégantic, about 30 miles from U.S. border. Near center of town, 63 tank cars derailed, resulting in multiple explosions and subsequent fires. 47 fatalities and extensive damage to town. 2,000 people evacuated. Initial determination was that braking force applied to train insufficient to hold it on 1.2% grade and that crude oil released was more volatile than expected.
White River, Calgary, Alberta[40]	Canadian Pacific	Yes	640	A broken wheel and emergency brake application caused a derailment. Two of seven cars carrying crude oil spilled. There was a fire that was put out by local firefighters.
Parkers Prairie, MN[41] Mar 27, 2013 Derailment	Canadian Pacific	No	2,142	14 cars on 94-car crude oil train derailed; up to 3 cars ruptured.

Table 19: Crude by Rail Derailments with Spillage: Tank Car Numbers (2013–2015)						
Location	**Derailed Tank Cars**	**Tank Cars with Spillage**	**Total Tank Cars**	**Percent Derailed**	**Percent Spilled from Total Train**	**Percent Derailed Tank Cars with Release**
LaSalle, Colorado	6	1	100	6%	1%	17%
Vandergraft, Pennsylvania	19	1	120	16%	1%	5%
Plaster Rock, New Brunswick	17	5	n/a	n/a	n/a	29%
Lac-Mégantic, Quebec	63	5	72	88%	7%	8%
Aliceville, Alabama	25	23	90	28%	26%	92%
Casselton, North Dakota	20	20	106	19%	19%	100%
Lynchburg, Virginia	17	3	105	16%	3%	18%
Gainford, Alberta	4	0	n/a	n/a	n/a	0%
Parkers Prairie, Minnesota	14	3	94	15%	8%	21%
Boomer Bottom, West Virginia	26	14	109	24%	13%	54%

39 Runaway Train, Oil Change International. http://priceofoil.org/content/uploads/2014/05/OCI_Runaway_Train_Single_reduce.pdf.

40 http://www.saultstar.com/2014/12/15/wheel-caused-white-river-derailment

41 http://usnews.nbcnews.com/_news/2013/03/28/17501526-train-hauling-oil-derails-spilling-30000-gallons-of-crude-in-minnesota.

For the recent incidents in which oil spilled, the lowest volume was 108 bbl and the highest was 18,295 bbl. The lowest volume is lower than the 25th percentile and the largest volume is 26% larger than the calculated worst-case discharge using the more conservative release percentage (based on Table 17).

Rail Discharge Volumes for Impact Analysis

The recommended discharge volumes for analysis are shown in Table 20. The effective worst case discharge (WCD) volume is based on a volume that is 20% larger than the largest incident to date, the spill of an estimated 16,422 bbl in Aliceville, Alabama (see Table 18). It is approximately the 99th percentile with respect to derailed cars assuming all of the cars release oil. This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents.[42] Each tank car contains about 700 to 714 bbl. The numbers are rounded.

The theoretical worst case discharge is presented for information purposes. This event, which involves 120 tank cars spilling all of their contents, is extremely unlikely. Only one derailment of any freight train in 40 years of US history has ever involved that many derailed cars, a rate of about 0.000021.[43] It is also highly unlikely that if this many cars were to derail that all of the cars would release oil.

Table 20: Spill Volumes from Loaded CBR Unit Trains for Analysis

Spill Category	Volume[44]	Approximate Tank Cars with Spillage
Small Spill (Analogous to Average Most Probable Discharge)[45]	100 bbl[46]	0.1
Median (50th Percentile)	700 bbl	1
Large Spill (Analogous to Maximum Most Probable Discharge)	2,200 bbl[47]	3
Effective Worst Case Discharge	20,000 bbl[48]	28

[42] Unlike for vessels, at this time, there is no regulatory definition of WCD for response planning purposes or to evaluate potential environmental impacts. This study proposes the use of the "effective WCD" for the purposes of environmental impact analysis, and for response planning until a regulatory WCD volume is implemented.

[43] One incident out of 48,449 derailments nationwide.

[44] The values in this table are rounded to the nearest hundred based on an approximate value of 714 bbl/tank car. Tank cars often contain only about 700 bbl to allow for a small degree (2%) expansion of the cargo. The actual tank capacity is 714 bbl. The theoretical WCD assumes 120 tank cars with 714 bbl each.

[45] There is no regulatory definition of Average Most-Probable or Maximum Most-Probable Discharge as for vessels and facilities. These categories are included here solely for the purpose of the environmental analysis conducted in other parts of this study to coincide with the concepts of AMPD and MMPD volumes for vessels and facilities.

[46] This volume represents spillage of a portion of a tank car (approximately 10%) that might spill as part of a leakage event or other minor incident.

[47] Based on 90th percentile rounded to an even number of tank cars (based on Table 17).

[48] This represents approximately the 99th percentile with respect to derailed cars assuming all of the cars release oil. This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents. It also coincides with the volume that is about 20% larger than the largest incident to date (16,422 bbl spilled in the November 2013 Aliceville, Alabama, incident as shown in Table 18).

Theoretical Worst Case Discharge	85,680 bbl	120[49]

For spills from empty trains in which only locomotives could spill fuel, the maximum spillage would be from up to five locomotives each carrying 131 bbl of diesel for a total of 655 bbl.[50] This volume of spillage would constitute a theoretical worst-case discharge from an empty train. This event would require that both of the locomotives would derail and spill all of their fuel oil content. Note that there would also be the possibility that diesel fuel would spill in a derailment of a loaded CBR train, but since this volume would be less than even a median spill volume for a loaded train, it is not considered as significant in the analysis of loaded CBR train potential spillage. There are also smaller quantities of other types of oil (e.g., lubricants) in the locomotive that are also not considered as significant factors in this analysis.

Overall Probability of Spills from Vancouver Energy CBR Traffic

The probability that there will be a spill due to Vancouver Energy-related CBR traffic depends on the probability of derailment and the probability that that derailment will result in spillage. The volume of spillage will depend on the number of cars that derail and release oil, as previously analyzed.

Probability of Spillage from Loaded CBR Trains

The probabilities that there will be spills of various volumes from derailed loaded CBR trains associated with the Vancouver Energy project are summarized in Table 21 using a more conservative (higher estimate) approach of a 16.7% release rate, and a less conservative approach of a 9.2% release rate (based on Table 17).

Table 21: Estimated Spill Frequencies for Vancouver Energy CBR Loaded Trains

Spill Probability Estimate Type	Derailments		Spills (Return Years)				
	Frequency per Year	Return Years	Any Spill	100 bbl Spill	700 bbl Spill	2,200 bbl Spill	20,000 bbl Spill
More Conservative 16.7% Release	0.495	2.00	12.1	16	27	121	12,097
Less Conservative 9.2% Release	0.495	2.00	22.0	29	49	220	21,959

Return years (or return period in years) is the amount of time that would be expected to pass for one incident to occur. For example, a 100-year flood is something that is expected to occur once in 100 years. The return period is calculated by the formula:

$$R_{yrs} = \frac{1}{frequency / year}$$

[49] 120 tank cars is the longest CBR train that has been reported to date. Typically, the CBR unit trains (trains that contain only CBR tank cars) may be 100 to 120 tank cars long.

[50] The largest locomotives have fuel tanks with capacities of 5,500 gallons (about 131 bbl).

Probability of Spillage from Empty CBR Trains

For locomotive spills, the potential volume of spillage can be very conservatively estimated to be one or two locomotive fuel capacities – either 131 bbl or 262 bbl. This assumes that a derailment of an empty train necessarily involves one or both locomotives and that the total fuel capacity of one or both engines would be released. Since a CBR unit train includes about 100 to 120 cars and up to five locomotives spread out across the train (sometime at the front and back of the train), the probability that one or both locomotives derail and spill oil needs to take into account the probability that the locomotives derail and that spillage occurs. There are no reliable data on which to base this analysis.

In the study conducted for JLARC,[51] rail spills in Washington were analyzed, showing that the probability distribution of spill volumes was such that the median spill volume was 2 bbl, the 90th percentile spill was 48 bbl, and the 99th percentile spill was 120 bbl. Only one spill in 170 spills (over the course of 13 years) involved the spillage of 262 bbl of oil.

There are no specific data on the rate of locomotive derailments and spillage. If one conservatively assumes that, in the event of a derailment incident involving an empty CBR train, each of the two contiguous locomotives has a 5% likelihood of derailing (as opposed to one of the other cars) and the fuel tanks would release oil based on the probability distribution of spill volumes from the JLARC railroad incident data,[52] the spill frequencies for locomotives would be as shown in Table 22. Since the each of the two locomotives make up approximately 1% of the total number of cars on a 120-tank car unit train, this assumes that a locomotive is five times more likely to derail and spill than a tank car. It would be reasonable to assume that the locomotives pulling a freight train are the first to hit any track irregularity.

Table 22: Estimated Spill Frequencies for Vancouver Energy CBR Empty Trains

Spill Probability Estimate Type	Empty Train Derailments		Locomotive Spills (Return Years)				
	Frequency per Year	Return Years	Any Spill	2 bbl Spill	48 bbl Spill	120 bbl Spill	262 bbl Spill
Assuming 5% Probability Locomotive(s) Derailing and Spilling	0.581[53]	1.72	17.2	34	172	1,720	17,200

Factors Determining the Impacts of CBR Spills

As with all oil spills, the impacts that occur will be determined by the oil type, volume of spillage, location, and timing (e.g., season). CBR spills may occur anywhere along the rail lines employed by these trains, which includes all types of inland areas, populated cities and towns, along rivers, and streams, and even along some marine and estuarine waters. As such, CBR-related spills are not unlike many of the oil spills that occur from pipelines, facilities, tanker trucks, or smaller vessels. As with pipeline spills, rail spills may

[51] Etkin 2009; Etkin et al. 2009; French-McCay et al. 2008, 2009; State of Washington JLARC 2009.

[52] Railroad spill data for Washington State for 1995 – 2007. Etkin 2009; Etkin et al. 2009; French-McCay et al. 2008, 2009; State of Washington JLARC 2009.

[53] Based on empty train derailment frequency from Table 13.

occur in remote, inaccessible areas, and have impacts on sensitive environments adjacent to the rail lines and affect aquifers.

The major difference with CBR spills is the nature of the oil that is being transported in many cases and the fact that fires and explosions are a possibility.

Market factors and technological advances in drilling will largely determine the types and quantities of oil being transported by rail. The two major types of crude oil that are currently being transported by rail in the US (and in Canada) are shale oil, primarily Bakken crude, and various types of diluted bitumen blends from oil sands. These are also the oil types expected to be transported to the Vancouver Energy facility.

The characteristics of these oils with respect to their volatility, toxicity, persistence, and, in the case of bitumen blends, their potential for becoming submerged in water under some circumstances, will determine the impacts of spills and the challenges for response.

Bakken Crude Incidents

The property of greatest concern for Bakken crude is its volatility. Concern about the volatility of Bakken crude followed the Lac-Mégantic incident in which a train derailed near the center of a town causing an explosion that resulted in the deaths of 47 people. Measuring volatility and classifying crude oils with respect to potential for flammability is not straightforward. The Reid Vapor Pressure (RVP), which is often used to measure volatility, or how quickly a petroleum product or fuel evaporates, varies from one sample to another. RVP is defined as the absolute vapor pressure exerted by a liquid at 100°F as determined by the test method ASTM D-323. According to ASTM D-323, an RVP of less than 26 psi is considered "low volatility". In five different samples of North Dakota sweet crude taken on five different dates roughly one year apart, the RVP varied from 5.94 psia to a high of 9.70 psia, a difference of nearly 39%. Other properties, such as density (°API) varied by less than 0.5% between sampling dates. In Capline Pipeline tests of a large number of crudes, RVP varied from a low of 0.623 psia for UK Foinaven crude to a high of 10.0 psia for Nigerian Forcados/Oco Condensate Blend. Bakken crude (North Dakota sweet) falls into the middle.

The presence of increasing amounts of dissolved gases and other light ends (methane, ethane, propane, butanes, and pentanes) increases the crude oil's vapor pressure, lowering its flashpoint and lowering its initial boiling point. According to an American Fuel & Petrochemical Manufacturers (AFPM) study[54], Bakken crude oil is within the norm with respect to the hazard characteristics of a light crude oil. The AFPM study showed maximum RVPs of 15.4 psia, considerably higher than those in the Capline testing.

American Petroleum Institute (API) analyzed more than 200 samples of Bakken and other types of crude, primarily West Texas Intermediate (WTI) crude and concluded that Bakken crude oil is "very similar to other light crudes." The API analyses indicate that Bakken crude is a Class 3 flammable liquid, which means that it has a flash point of not more than 60°C. The average flash point of light crudes is 38.9°C, whereas the flash point for Bakken crude is somewhat lower at 33.3°C.

[54] AFPM 2014.

The analyses indicate also that Bakken crude is classified as Packing Group I (PG I), except at the minimum measurements for those samples for which the initial boiling point is 66°C. Other light crudes are classified as Packing Group II (PG II), except for those that have a maximum initial boiling point of 28.6°C. The PG I classification encompasses substances that pose a high hazard level; PG II encompasses substances that have a medium hazard level.

API maintains that Reid Vapor Pressure (RVP) is not a good indicator of flammability based on preliminary analyses of simulations using the Fire Effects on Tank Cars (AFFTAC) Model.[55] The API Crude Oil Physical Properties Ad Hoc Group is considering if other crude oil properties are more appropriate in the selection of rail tank cars for transport (e.g., ignitability, flammability, light-end volumetric percent).

A more reliable and accurate measure of volatility is the analysis of distillation assays.[56] According to this type of assay, Bakken crude has twice as much volatile light-end components as WTI, and 1.7 times as much as Louisiana Light Sweet.

Diluted Bitumen Incidents

The greatest public concern for the various bitumen blends is the possibility that the oil will become submerged if spilled into water. This concern is largely based on the experiences with the response to the July 2010 pipeline spill in the Kalamazoo River, Michigan, USA.

The greatest concern for diluted bitumen blend spills is the possibility that some of the oil may become submerged. The public concerns about "sinking" oil are, for the most part, exaggerated and based on misconceptions about the properties of these oils. Bitumen blends vary considerably depending on the source, blending procedures, and diluent used. The latter two factors are seasonal. But, overall, these oils are not in and of themselves heavier than freshwater.

According to laboratory and mesoscale weathering experiments, diluted bitumen products have physical properties much aligned with a range of intermediate fuel oils and other heavy crude oils. Generally, depending on the initial blend and state of weathering, diluted bitumen products are not characterized as non-floating oils.[57] Even Group III and IV oils can become neutrally or negatively buoyant (i.e., sink) in freshwater or saltwater through various mechanisms, especially if the oil comes in contact with sediment in a high-energy setting (i.e., in nearshore surf zone areas).[58]

Diluted bitumen's potential for sinking after weathering – i.e., losing its light fractions to evaporation – was the impetus for a series of tank test studies on the behavior of diluted bitumen when spilled into freshwater[59]

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[55] API 2014.
[56] Hill 2011.
[57] Polaris Applied Sciences 2013.
[58] National Research Council 1999.
[59] SL Ross 2010.

or brackish marine waters.[60] Mesoscale weathering experiments done in Gainford, Alberta,[61] showed that Cold Lake and Access Western Blend diluted bitumen blends exhibited properties typical of a heavy, "conventional" crude oil as they weathered but in no instance was any oil observed to have sunk after 10 days of weathering on 20 ppt brackish water under varied physical conditions. The physical properties of weathering oil measured during those tests showed that diluted bitumen spilled into fresh, brackish, or saltwater will stay on the water surface for days unless another mechanism mixes it into the water column, as would be the case for most Group III and IV oils. Only after extensive weathering, or mixing with suspended particulate material, may some portion of weathered dilbit become submerged or sink.

In another series of studies conducted by the Government of Canada[62] on two diluted bitumen products that represented the highest volume transported by pipeline in Canada during 2012–2013 – Access Western Blend and Cold Lake Blend, the researchers concluded:

- Like conventional crude oil, both diluted bitumen products floated on saltwater (free of sediment), even after evaporation and exposure to light and mixing with water;
- When fine sediments were suspended in the saltwater, high-energy wave action mixed the sediments with the diluted bitumen, causing the mixture to sink or be dispersed as floating tarballs;
- Under conditions simulating breaking waves, where chemical dispersants have proven effective with conventional crude oils, a commercial chemical dispersant (Corexit 9500) had quite limited effectiveness in dispersing diluted bitumen (dilbit);
- Application of fine sediments to floating diluted bitumen was not effective in helping to disperse the products; and
- The two diluted bitumen products display some of the same behaviors as conventional petroleum products (i.e. fuel oils and conventional crude oils), but also some key differences, notably for the rate and extent of evaporation.

The four major factors that have a bearing on whether spilled oil, including diluted bitumen, will float, become neutrally buoyant (suspended in the water column), or sink are:

- Density of the oil, which may change with weathering (evaporation);
- Salinity of the water (i.e., density of the water relative to the oil);
- Amount of sediment in the water; and
- Turbidity of the water (stirring up sediment and breaking oil into smaller droplets).

[60] Witt O'Brien's et al. 2013.
[61] Witt O'Brien's et al. 2013.
[62] Government of Canada 2013.

As long as the oil is less dense than the water, it will float. It may temporarily become submerged in the water column if broken into smaller droplet in turbulent water, but in those cases it will refloat under more calm water conditions. If the oil becomes heavier than the water, either by becoming attached to sediment particles, or, less commonly, by having enough of the lighter ends evaporate to increase the density, it will become neutrally buoyant or sink. Since salt and brackish water is heavier than freshwater, it takes more of an increase in density to cause oil to sink in salt or brackish water than in freshwater, where the density of water is 999.97 kg/m^3 – or essentially 1,000 kg/m^3 or 1.0 g/ml. Seawater is denser than freshwater and has an average density of 1.025 g/m^3, though it may be as high as 1.028 g/m^3. Brackish water in estuaries varies in density between 1.0 to 1.025 g/m^3. For this reason, a heavy oil with a density of 1.01 g/m^3 would float in seawater but sink in a freshwater lake, or in an estuary.

When oil mixes with sediment particles (e.g., sand in the surf zone of a beach), the oil-mineral aggregates (OMA) can become heavier than water and cause sinking. OMA sinking is more likely to occur in freshwater than salt or brackish water because of the greater likelihood that the density of the OMA will be higher than the water density. The OMA density has to be somewhat higher to sink in salt or brackish water. OMA formation is more likely to occur in the following situations:

- The oil is in fine droplets;
- There is a large sediment load in the water column; and/or
- There is a lot of turbulence in the water, which increases the number of smaller oil droplets, stirs up sediment from the bottom, and increases the likelihood of contact between the oil droplets and sediment particles.

There is also potential for diluted bitumen to cause flammability issues, depending on the diluent type and proportion, especially when the diluent reaches 30% content.

Railroad Spill Spread

An additional factor to consider for railroad-source oil spills is that many spills, particularly smaller ones, will be confined to the track ballast, the sub-ballast, and ditch that is often alongside the ballast (Figure 15). Even along the Columbia River rail corridor (Lakeside Subdivision), the track bed is generally flat with relatively low angles (grades). In the event of a derailment and spill that occurred along tracks that were not on raised trestles or bridges, much of the oil would spill onto ballast and collect in the ditches before spilling onto surrounding land or waterways. If the derailment causes cars to move significantly off the tracks, as might occur if a number of cars derail, the spill may spread outside the ballast. In addition if a large volume is spilled or the incident occurs on a bridge or trestle, there may be wider spread of oil.

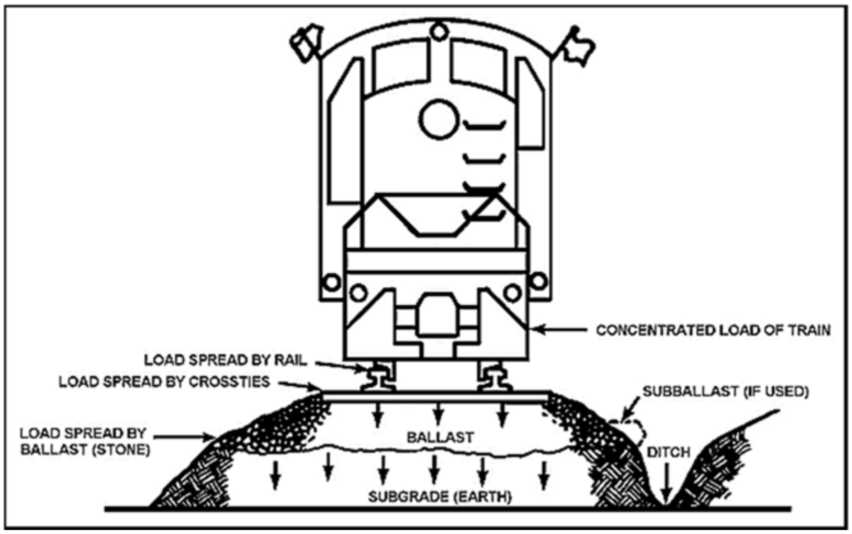

Figure 15: Railroad Track Components[63]

Overall Geographic Analysis Approach

Given that spill risk is the probability of a spill incident occurring multiplied by the consequences of that spill, based on volume and oil type, and the fact that both spill location (derailments) and impacts are geographically-based, a geographic analysis was performed. The geographic analysis included the steps shown in Figure 16.

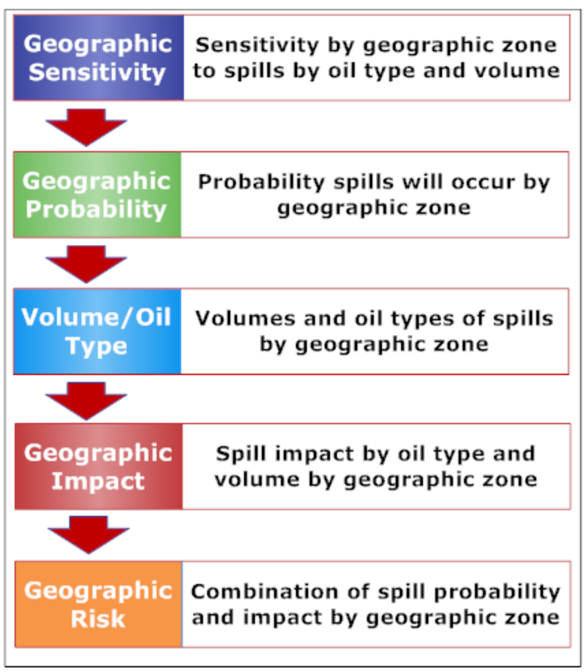

Figure 16: Approach to Geographic Analysis

[63] http://www.globalsecurity.org/military/library/policy/army/fm/55-20/ch7.htm

Geographic Analysis for CBR Spills: Incident Locations

The previous PDEIS study conducted by the Vancouver Energy facility applicant,[64] the authors concluded: "There is nothing inherently more or less risky in the Washington/Idaho Border to Port BNSF corridor than in any other BNSF corridor across the national BNSF network, and using the national BNSF network as the starting point for this analysis captures broader data set for this risk assessment."

The current study team disagrees with this assertion to a large extent. While the statement is generally true for mechanical failures in that these are likely to occur with equal probability anywhere along a rail corridor, other important causal factors for derailments are not evenly distributed along mainline tracks.

Factors that Affect Derailments

High curvature and/or grades create a higher risk of a train handling or track related derailments. For track and human error, routes such as Tehachapi or Cajon have a greater chance of a derailment occurring than Spokane to Pasco or along the Columbia. Similarly, routes through highly urbanized areas where there are numerous turnouts (such as in the Houston area where there are a lot of diverging routes, industry tracks, etc., and a lot of hazardous cars) would have a much greater likelihood of track related derailment than pure main lines between sidings or crossovers. As counterbalance to that argument, a slow speed urban or grade/curvature route is less likely to cause a hazmat release derailment than a high speed route.

The type of train also has a bearing on derailment probability. Handling a homogenous train such as a loaded unit train is easier than handling a manifest train with loads and empties mixed, particularly if the empties are ahead of the loads.

The inclusion of distributed power units (DPUs)[65] in the last five years has also reduced the likelihood of derailments. Many of the operational and equipment changes that have been implemented over the last decades that contributed to the overall reductions in derailments (as previously shown in Figure 9 and Figure 10) are not necessarily evenly distributed across all rail corridors.

Derailment Cause Studies[66]

Derailments result from many causes; primarily track condition, equipment failures, or human error. Human error has often been cited as a primary cause for concern as a contributory component of derailments. For derailments other than on the mainline and sidings, human error has been to shown to be a frequent primary cause. A study performed for the Rail Transportation and Engineering Center at the University of Illinois at Urbana-Champaign analyzed derailments throughout the United States between 2001 and 2010.[67]

The analysis revealed different results for mainline track than siding track. For mainline derailments, broken rails accounted for the largest percentage of derailment cause (15.3%). Train handling (excluding brakes), a human error factor, resulted in 4.6% of the derailments analyzed, the only human error factor specifically identified. The analysis of derailments on sidings indicated that broken rails or welds were the largest

[64] Louis Berger 2014.

[65] Locomotives distributed at different points throughout the train.

[66] See also Etkin et al. 2015.

[67] Liu et al. 2014.

contributors to derailments at 16.5%. Two human factors were on the list of the 10 most prevalent causes of derailments on sidings – switching at 7.7% and train handling (excluding brakes) at 3.5%.

To assess BNSF's derailment record on its mainlines in Washington (including meet/pass sidings), a review of its derailment record was performed for years 2003 through 2013. Data available through March 2014 were included as well.[68, 69] The data analyzed for the assessment focused on BNSF main line corridors on which crude by rail oil trains operate, e.g. Sand Point-Spokane, Spokane-Vancouver via Pasco, Vancouver-Seattle, and Seattle-Cherry Point. The Stampede Pass route between Auburn and Pasco, and the Stevens Pass route[70] between Everett and Spokane were also included due to the movement of empty crude by rail trains via those corridors.

The review of the information generated from the FRA database indicates that during the years 2003 through 2013, BNSF experienced 89 mainline and meet/pass siding derailments that were reportable under FRA criteria. BNSF experienced only three derailments per year statewide in the years 2011, 2012, and 2013, when crude by rail trains were operating; of those only one was attributable to human error. Of the 89 derailments during the review period, 18 were credited to human error, or about 20%. Most of the derailment causes were assigned to track or equipment.

In Washington State, during 2006–2013, there have been, on average 240 rail accidents annually, including 45 derailments (Table 23). Of the derailment incidents, 36.5% occurred on mainlines, 62.4% in yards, and 1.1% under other circumstances. The number of derailments has decreased in recent years even with the addition of crude by rail trains to the system.

Derailment causes are summarized in Figure 17. Nearly half of the derailments in the state occurred as a result of a signal defect. Equipment defects were cited as the cause of 27% of incidents. Track condition was the next highest cited cause with 13% of incidents. Human factors were cited in 10% of cases.

Table 23: Washington State Rail Accidents/Incidents 2006–2014[71]

Incident Type	Number of Incidents by Year									Total 2006-2013
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Incidents	**271**	**280**	**261**	**254**	**269**	**207**	**195**	**183**	**48**	**1,928**
Derailments	59	55	51	39	51	40	32	32	4	**359**

[68] FRA Office of Safety and Analysis, *Section 2.03 Train Accidents by Railroad Groups.*
[69] The FRA database can be sorted by railroad and geographically. The source of the derailment data was the Federal Railroad Administration Office of Safety and Analysis database, which maintains a record of all derailments meeting the damage criteria for reporting an accident (currently $10,500 in track, equipment and other property damages).Yard derailments and at-grade crossing accidents were not downloaded and analyzed at this time, although that information is also retrievable from the FRA database. As indicated elsewhere in this report, however, there are concerns about the adequacy and accuracy of the FRA reported information. It was noted in the review that 3 BNSF derailments incidents, one each in 2011, 2012 and 2013, did not yet have an assigned incident number or cause yet assigned. That issue can result from a railroad investigation as to a cause not yet determined or the FRA updating process not yet complete.
[70] It is expected that the main route for return trains will be Stampede Pass, but there is a possibility that Steven Pass might be utilized under some circumstances.
[71] 2014 data through March 31, 2014. Data from Federal Railroad Administration (FRA). FRA has a $10,500 damage threshold for the reporting of derailments, except for the release of hazardous materials.

Table 23: Washington State Rail Accidents/Incidents 2006–2014[71]

Incident Type	Number of Incidents by Year									Total 2006-2013
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Derailment Location	**Number of Incidents by Year and Derailment Location**									**Total**
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Yard	37	31	29	26	32	29	17	23	1	**224**
Main Line	18	24	22	13	19	11	15	9	3	**131**
	% Incidents by Derailment Location in Each Year									**Total**
Yard	67%	56%	57%	67%	63%	73%	53%	72%	-	**63%**
Main Line	33%	44%	43%	33%	37%	28%	47%	28%	-	**37%**
Derailment Cause	**Number of Incidents by Year and Derailment Cause**									**Total**
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Human Factor	8	5	5	4	6	4	0	2	2	**34**
Equip. Defect	17	13	16	8	14	9	10	9	1	**96**
Track Condition	10	11	9	3	6	3	0	5	0	**47**
Miscellaneous	1	0	1	1	1	0	0	0	0	**4**
Signal Defect	23	26	20	23	24	24	17	16	1	**173**
	% Incidents by Derailment Cause in Each Year									
Human Factor	13.6%	9.1%	9.8%	10.3%	11.8%	10.0%	0.0%	6.3%	-	**9.6%**
Equip. Defect	28.8%	23.6%	31.4%	20.5%	27.5%	22.5%	37.0%	28.1%	-	**27.1%**
Track Condition	16.9%	20.0%	17.6%	7.7%	11.8%	7.5%	0.0%	15.6%	-	**13.3%**
Miscellaneous	1.7%	0.0%	2.0%	2.6%	2.0%	0.0%	0.0%	0.0%	-	**1.1%**
Signal Defect	39.0%	47.3%	39.2%	59.0%	47.1%	60.0%	63.0%	50.0%	-	**48.9%**
Hazardous Material Release	**Number by Year**									
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Car Number	0	0	0	0	2	4	1	0	0	**7**
Incident Number	0	0	0	0	2	3	1	0	0	**6**
Other Incidents	**Number of Incidents by Year**									**Total**
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Crossing	18	16	14	16	12	20	13	14	1	**123**
Fatalities	21	16	14	17	13	22	13	15	1	**131**
Other	173	193	182	182	191	122	136	122	42	**1,309**

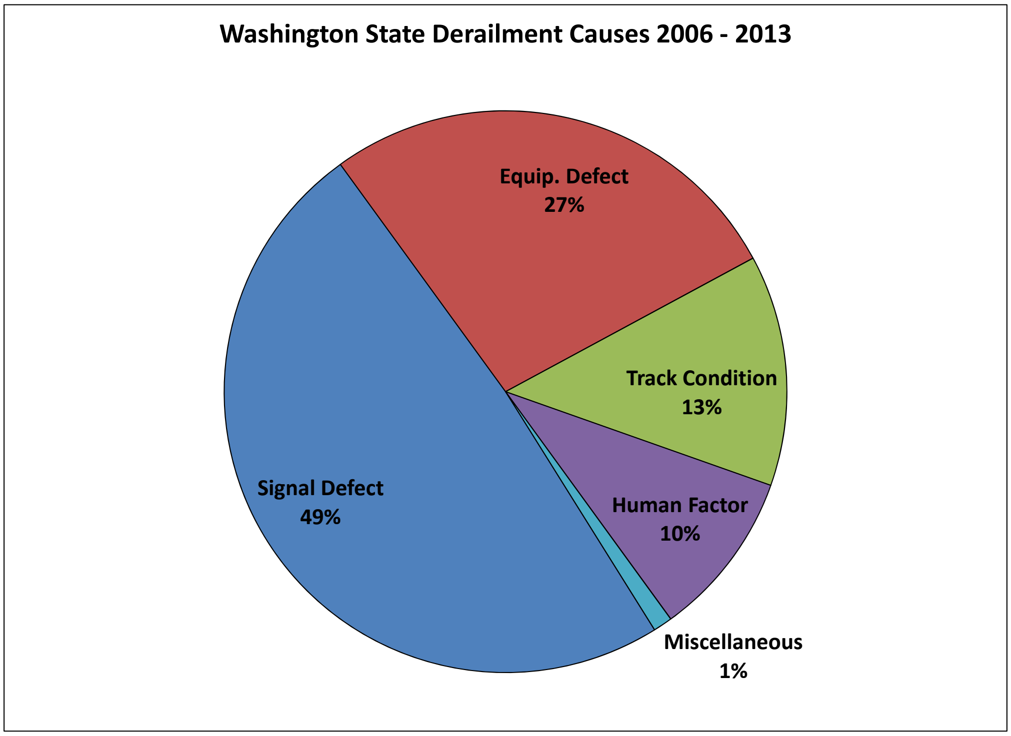

Figure 17: Washington State Derailment Causes 2006–2013

Derailment and other accidents by location are in Figure 18, and further detailed in Table 24.

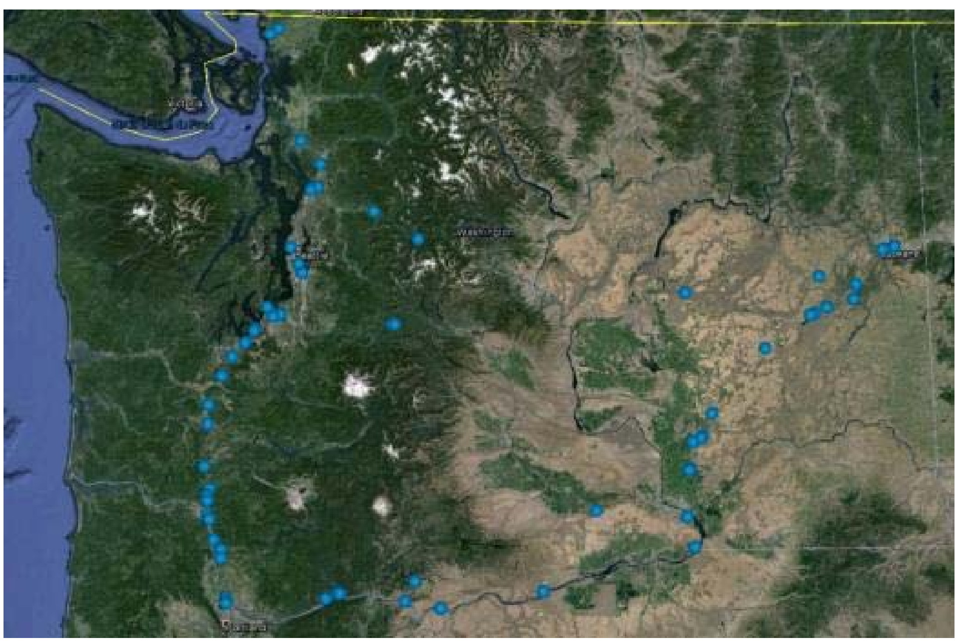

Figure 18: Derailment and Other Major Accident Locations in Washington 2003–2013[72]

[72] Based on FRA Data.

Table 24: Derailment and Other Major Accident Incidents in Washington 2003–2013			
Station	**Number Incidents**	**Hazardous Cars Involved**	**Hazardous Cars Damaged**
Avery	1	4	0
Berrian	1	0	0
Cactus	1	0	0
Castle Rock	2	12	0
Centennial	1	3	0
Centralia	1	0	0
Cheney	1	28	1
Cunningham	1	0	0
Custer	2	10	7
Edwall	1	12	0
Eltopia	2	20	0
Everett	6	22	0
Gold Bar	1	4	1
Home Valley	1	15	1
Hover	1	7	0
Kalama	1	0	0
Kelso	2	10	0
Lester	2	78	8
Longview	1	1	0
Lyle	1	0	0
Mesa	2	26	0
Napavine	1	0	0
Nisqually	2	6	2
Ostrander	2	15	0
Prosser	1	6	0
Ritzville	1	0	0
Roosevelt	1	22	3
Scribner	1	0	0
Seattle	2	11	0
Skykomish	1	2	0
Spokane	4	5	0
Sprague	4	33	0
Stanwood	1	6	0
Steilacoom	2	14	2
Stevenson	2	37	1
Tacoma	5	6	1
Tenino	2	3	0
Titlow	1	11	0
Tukwila	1	14	0
Vader	1	0	0

Table 24: Derailment and Other Major Accident Incidents in Washington 2003–2013			
Station	**Number Incidents**	**Hazardous Cars Involved**	**Hazardous Cars Damaged**
Vancouver	3	32	1
Wilson Creek	1	0	0
Wishram	2	8	0
Woodland	2	0	0
Total	**75**	**483**	**28**

The Port of Vancouver requested that TÜV Rheinland Mobility Rail Sciences Division (TÜV Rail Sciences) evaluate the derailment risk of a proposed route exiting BNSF Fallbridge Subdivision at MP 10.69 into the Port of Vancouver (Figure 19).[73] As part of this, TÜV Rail Sciences analyzed the derailment probability for a 120-car crude by rail unit train with three locomotives at the head end and two at the rear end.

Figure 19: BNSF Fallbridge Subdivision Tracks into Port of Vancouver[74]

The in-train force analysis indicated that the maximum in-train longitudinal forces observed in all nominal and braking simulation scenarios are well within industry and AAR- recommended limits. The lateral-to-vertical ratio (L/V) is the lateral (side-to-side) force pushing outward against the rail compared to the vertical force pushing downward on the top of the rail (Figure 20). The tendency for the rail to tip and/or move laterally, or for the wheel to climb the rail increases as the L/V ratio increases:

- L/V = 1.29, wheel may climb new rail.
- L/V = 0.82, wheel lift impending.

[73] TÜV Rheinland Mobility Rail Sciences Division 2014.

[74] TÜV Rheinland Mobility Rail Sciences Division 2014.

- L/V = 0.75, wheel may climb worn rail.
- L/V = 0.64, rail overturn force starts (unrestrained rail may overturn).

The results of the analyses of the crude by rail unit train, as shown in Table 25, show that all individual wheel L/V ratios are well under the maximum allowable values for the industry. TÜV Rail Sciences concluded that the proposed operation and track configuration is well within industry safety standards, and thus represents a low risk of derailment.

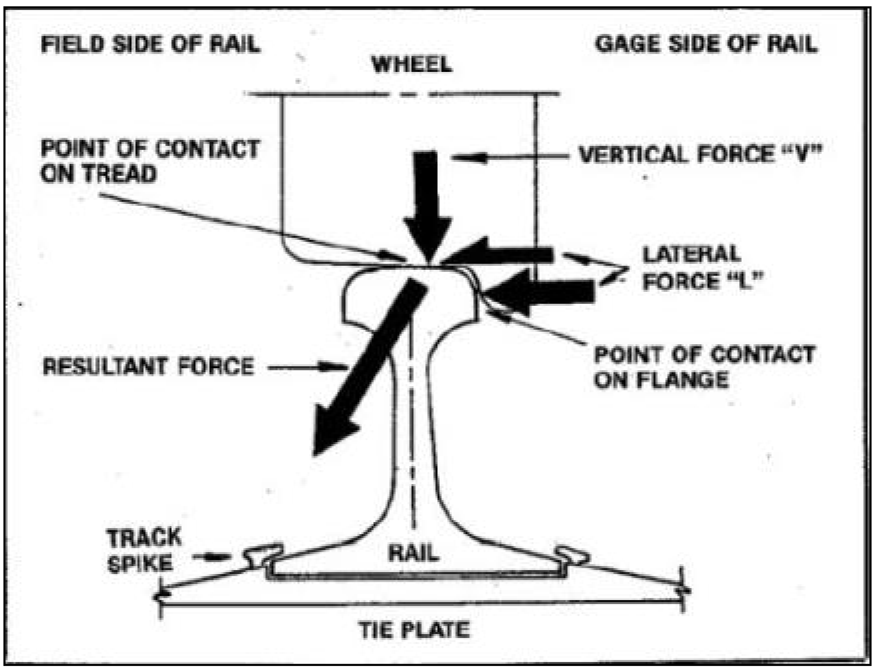

Figure 20: Lateral to Vertical Force Relationship between Rail and Wheel[75]

Table 25: Vehicle Dynamic Results – Loaded Tanker Cars[76]					
Parameter	**Industry Standard**	**In-Train Force**	**As Designed Tack**	**Class I Cross Level Dip**	**FRA Class 2 Cross Level Dip**
Maximum Individual Wheel L/V Ratio	Maximum 0.82[77] 1.00[78]	300 Kips Buff	0.43	0.59	0.57
		300 Kips Draft	0.34	0.52	0.50
		None	0.39	0.56	0.54
Minimum % Wheel Unloading	Minimum 10.0%	300 Kips Buff	83.86	56.96	59.42
		300 Kips Draft	90.60	68.37	70.75
		None	90.87	62.09	64.75

[75] From: TÜV Rheinland Mobility Rail Sciences Division 2014.
[76] TÜV Rheinland Mobility Rail Sciences Division 2014.
[77] Industry recommended maximum allowable L/V ratio = 0.82
[78] AAR Chapter XI Standard maximum allowable L/V ratio = 1.00.

Table 25: Vehicle Dynamic Results – Loaded Tanker Cars[76]					
Parameter	**Industry Standard**	**In-Train Force**	**As Designed Tack**	**Class I Cross Level Dip**	**FRA Class 2 Cross Level Dip**
Maximum Axle Sum L/V Ratio	Maximum 1.50	300 Kips Buff	0.76	0.91	0.89
		300 Kips Draft	0.67	0.84	0.83
		None	0.73	0.88	0/86
Maximum Truck Side L/V Ratio	Maximum 0.60	300 Kips Buff	0.32	0.39	0.38
		300 Kips Draft	0.33	0.32	0.31
		None	0.30	0.36	0.35

Geographic Analysis of Probability of Derailments and Spills

The track conditions throughout the rail corridors that would be utilized for the CBR traffic to and from the Vancouver Energy facility would determine the relative likelihood of a derailment and potential subsequent spill in different geographic zones. Five BNSF Subdivisions that were reviewed for this study[79] and the corresponding environmental sensitivity zones are shown in Table 26.

Table 26: BNSF Rail Subdivisions and Corresponding Environmental Sensitivity Zones				
BNSF Subdivision	**Endpoints**	**Status**	**Sensitivity Zones**	**% Distance in Subdivision**
Kootenai/Spokane	Sand Point, ID/Spokane	Loaded/Empty	Middle Spokane (57)	100%
Lakeside	Spokane/ Pasco	Loaded/Empty	Palouse (34)	30%
			Lower Snake (33)	55%
			Hangman (56)	10%
			Walla Walla (32)	5%
Fallbridge	Pasco/Vancouver	Loaded[80]	Rock Glade (31)	20%
			Klickitat (30)	10%
			Wind-White Salmon (29)	10%
			Salmon-Washougal (28)	10%
			Western Columbia River	50%
Stampede	Vancouver to Auburn/Ellensburg	Empty	Duwamish-Green (9)	15%
			Lewis (27)	15%

[79] Two BNSF sources were utilized in this analysis. The first is BNSF's Northwest Division Timetable No. 4, effective June 17, 2009. That Timetable was utilized extensively in the routing analysis for the recently completed Washington Department of Ecology's Marine & Rail Oil Transportation Study. In that study, the subject subdivisions identified above were thoroughly vetted for geographic characteristics, traffic volumes and types, speeds for freight operations, and areas of concern. The second document utilized in this analysis is BNSF's System Special Instructions, No. 3, dated July 18, 2012. The portion of the System Special Instructions reviewed for this analysis is item number 33, which addresses the requirements for operations when certain natural events occur, such as excessive wind, tornados, flash floods, cold weather and earthquakes. Each of the subject Subdivisions also have specifications for operations during hot weather periods, generally for temperatures exceeding 85 degrees to 95 degrees (requiring reduction in maximum speeds of 10 mph below posted maximum speeds, but under no conditions less than 10 mph maximum speed).

[80] Direct routing of empty trains over the Fallbridge Subdivision between Vancouver and Pasco may be possible if capacity slots are available

Table 26: BNSF Rail Subdivisions and Corresponding Environmental Sensitivity Zones				
BNSF Subdivision	**Endpoints**	**Status**	**Sensitivity Zones**	**% Distance in Subdivision**
(via Vancouver-Auburn)			Cowlitz (26)	20%
			Upper Chehalis (23)	20%
			Deschutes (13)	5%
			Chambers-Clover (12)	5%
			Nisqually (11)	5%
			Central Puget	5%
			Southern Puget	10%
Yakima Valley	Ellensburg/ SP&S Jct.-Pasco	Empty	Upper Yakima (39)	55%
			Lower Yakima (37)	40%
			Esquatzel Coulee (36)	5%

For this analysis, focus was placed on track curvature and flash flood warning areas. Following is a recap by Subdivision of the geometric profiles that might affect safe train operations. The sequence of Subdivision review is westbound for loaded CBR trains from Sand Point to Vancouver and eastbound empty trains over Stampede Pass to Pasco.

For BNSF's engineering standard for track curvature in new construction main line track (and realignments) is a maximum of 7 degrees 30 minutes of curvature. Industry/lead track curvature is a maximum of 9 degrees 30 minutes but they will grant waivers for up to 12 degrees 30 minutes if it does not affect other rail operations.

The characteristics of the rail subdivisions are summarized in Table 27 and Table 28.

Table 27: Characteristics of BNSF Rail Subdivisions for Vancouver Energy CBR Traffic					
Feature	**Subdivision**[81]				
	Kootenai/ Spokane	**Lakeside**[82]	**Fallbridge**	**Stampede**	**Yakima Valley**
Length	71 mi.	146.4 mi.	229.7 mi.	102.9 mi.	124.35 mi.
Profile	Generally undulating with maximum ascending grade westbound of 0.98% between MP18 and MP20	Generally undulating with maximum ascending grades of 1.15% westbound (MP4.0-10.0)	River grade ascending Pasco to Vancouver	Mountain grade territory with grades >2% east- and westbound approaches to Stampede Pass Tunnel;	Generally gently ascending grade eastbound

[81] MP = milepost.

[82] The Lakeside Subdivision features the most conspicuous area of curvature over the entire route between Sand Point and Vancouver, the area known as Hatton Canyon between MP90 and MP110. The area features multiple reverse curves but track speed is generally limited to 35 mph to 50 mph. In addition, the track in the area crosses a dry wash in a number of locations. The wash is normally without water but every so often enough rain falls above the run off to cause flooding and wash out concerns. Maximum curvature through the canyon is 6 degrees 50 minutes at MP101.4 with 6 degree 30 minutes curves at MP104.6, MP103.7 and MP88.9.7.

Table 27: Characteristics of BNSF Rail Subdivisions for Vancouver Energy CBR Traffic					
Feature	**Subdivision[81]**				
	Kootenai/ Spokane	**Lakeside[82]**	**Fallbridge**	**Stampede**	**Yakima Valley**
	and eastbound of 0.64% between MP66 and MP64.	and westbound in Providence/ Connell area 1.0 eastbound (3 locations)		numerous curves, slower track speeds, mountain grade between Lester and Stampede.	
Curvature	10 curves ≥4° 0 curves ≥6° Maximum curve 5°, 15' at MP71.7 (Spokane)	55 curves ≥4° 19 curves ≥6° 0 curves ≥7°30'	No curves exceed 4°	114 curves ≥4° 77 curves ≥6° 38 curves ≥7°30' 34 curves ≥8° 13 curves ≥10° (max 10° 30')	47 curves ≥4° 16 curves ≥6° 9 curves ≥7°30' 5 curves ≥8° 2 curves ≥10° (max 10° 31')
Flash Flood Warning Areas	MP7.8: Algoma MP51.3: Hauser Jct. MP58: Otis Orchards	MP2.5: Empire MP3.3: Empire MP19.9-20.5: Babb MP60: Essig MP82.3: Lind and Sand MP97-98: Cunningham MP107-108.7 0 Connell	MP204.85-204.75: Berrian MP190.65-190.55: Plymouth MP174.95-174.85 - Patterson and Whitcomb MP167.95-167.85 - by Whitcomb MP161.85-161.75: by McCredie MP1475-146.95: Roosevelt MP141.15-1415: Roosevelt and Bates MP133.75-133.65: by Bates MP42.75-42.70: Skamania	As normal in mountain operations, there are 14 warning areas, with 8 between MP32.6 and MP81.5, essentially over mountain and through Stampede Pass Tunnel. Predominant maximum track speed through area of excessive curvature and flash flood warnings is 20 mph	MP3: Kennewick MP59-60: Satus MP76: Toppenish and Wapato MP84: by Parker MP85: by Parker MP86-86.19: Parker and Yakima MP90-91.1: Yakima MP96-98: Pomona MP99-120: Pomona and Thrall MP121: Thrall MP123: Thrall and Ellensburg MP125.1: Ellensburg
Wayside Detectors	17, avg. 4.18 mi. apart, longest gap 7.7 mi.	29, avg. 5.05 avg. mi. apart, longest gap 8.2 mi.	28, 8.2 avg. mi. apart, longest gap 25 mi. (MP177.2 – MP152.2)	21, avg. 4.9 mi. apart, longest gap 16.4 mi. (MP20.5 – MP36.9)	13, 9.57 avg. mi. apart, longest gap 30.2 mi. (MP496 – MP79.8)
Maximum Freight Train Speed	60 mph	60 mph	60 mph	49 mph	49 mph

Table 28: Derailment Factors of BNSF Rail Subdivisions					
Feature	**Subdivision**				
	Kootenai/ Spokane	**Lakeside**	**Fallbridge**	**Stampede**	**Yakima Valley**
Curves	None	None	None	85	16

Table 28: Derailment Factors of BNSF Rail Subdivisions					
Feature	**Subdivision**				
	Kootenai/ Spokane	**Lakeside**	**Fallbridge**	**Stampede**	**Yakima Valley**
≥7°30'					
Flash Flood Warning Areas	3	7	9	14	12
Average Wayside Detector Spacing	4.18 miles	5.05 miles	8.2 miles	4.9 miles	9.57 miles
Wayside Detectors Longest Gap	7.7 miles	8.2 miles	25 miles	16.4 miles	30.2 miles
Maximum Freight Train Speed	60 mph	60 mph	60 mph	49 mph	49 mph

The derailment factors were given relative scores in Table 29. The relative scores were derived by assigning a five-point scale (lowest, low, medium, high, highest) to the values for the factors shown in Table 9. Five point scoring scale used lowest to highest with 1 point for lowest and 5 points for highest. Curvature was given the highest weight (0.40), followed by the two wayside detector factors (0.15 and 0.15 each), and then flash flood areas (0.25), and maximum train speed (0.05). These weighting factors were based on expert judgement of the degree to which these factors would contribute to derailment probability. The total scores were derived by adding the weighted point scores for each subdivision. These scores were then normalized to derive a relative probability by adding the total number of points for all the subdivisions (15.85) and dividing each subdivision by the grand total. The final result is a relative probability, so that, for example, it could be expected that 21% of derailments would occur in the Lakeside Subdivision and 10% would occur in the Koontenai/Spokane Subdivision.

Table 29: Scores for Derailment Probability by BNSF Rail Subdivision[83]					
Feature	**Subdivision**				
	Kootenai/ Spokane	**Lakeside**	**Fallbridge**	**Stampede**	**Yakima Valley**
Curves ≥7°30'	Lowest (1 pt.)	High (4 pts.)[84]	Lowest (1 pt.)	Highest (5 pts.)	Medium (3 pts.)
Flash Flood Warning Areas	Low (2 pts.)	Medium (3 pts.)	Medium (3 pts.)	Highest (5 pts.)	Highest (5 pts.)
Average Wayside Detector Spacing	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	Medium (3 pts.)	High (4 pts.)
Wayside Detectors Longest Gap	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	High (4 pts.)	Highest (5 pts.)
Maximum Freight Train Speed	Medium (3 pts.)	Medium (3 pts.)	Medium (3 pts.)	Low (2 pts.)	Low (2 pts.)

[83] Five point scoring scale used lowest to highest with 1 point for lowest and 5 points for highest. Curvature was given the highest weight (0.40), followed by the two wayside detector factors (0.15 and 0.15 each), and then flash flood areas (0.25), and maximum train speed (0.05).

[84] Risk score increased due to most conspicuous area of curvature over the entire route. The area features multiple reverse curves but track speed is generally limited to 35 mph to 50 mph. In addition, the track in the area crosses a dry wash in a number of locations.

Table 29: Scores for Derailment Probability by BNSF Rail Subdivision[83]					
Feature	**Subdivision**				
	Kootenai/ Spokane	**Lakeside**	**Fallbridge**	**Stampede**	**Yakima Valley**
Total Score	**1.65**	**3.4**	**2.5**	**4.4**	**3.9**
Relative Probability	**0.10**	**0.21**	**0.16**	**0.28**	**0.25**

Geographic Analysis of Vancouver Energy CBR Spill Probability Summary

The relative probabilities of derailment accidents for Vancouver Energy CBR traffic by location are summarized in Table 30. The probabilities were derived by taking the relative ranking in Table 29 spread across the different zones transited in each subdivision based on the percentages in Table 26. The probabilities of derailments by zone are from Table 13.

Table 30: Effected Annual Derailment Frequencies by Geographic Zone		
WRIA/Zone	**Loaded Trains**	**Empty Trains**
	Bakken Crude or Diluted Bitumen	**Diesel Fuel**
Middle Spokane (57)	0.105	0.069
Palouse (34)	0.066	0.044
Lower Snake (33)	0.122	0.080
Hangman (56)	0.022	0.015
Walla Walla (32)	0.011	0.007
Rock Glade (31)	0.034	0.000
Klickitat (30)	0.017	0.000
Wind-White Salmon (29)	0.017	0.000
Salmon-Washougal (28)	0.017	0.000
Western Columbia River	0.084	0.000
Duwamish-Green (9)	0.000	0.029
Lewis (27)	0.000	0.029
Cowlitz (26)	0.000	0.039
Upper Chehalis (23)	0.000	0.039
Deschutes (13)	0.000	0.010
Chambers-Clover (12)	0.000	0.010
Nisqually (11)	0.000	0.010
Central Puget	0.000	0.010
Southern Puget	0.000	0.019
Upper Yakima (39)	0.000	0.095
Lower Yakima (37)	0.000	0.069
Esquatzel Coulee (36)	0.000	0.009
Total	**0.495**	**0.581**

Geographic Analysis for CBR Spills: Incident Impacts

The environmental impact of a specific spill is determined by the sensitivity by geographic location (*G*), seasonal timing (*T*), and oil type (*J*). For a particular location, season, and oil type combination (G_E, T_E, J_E), the magnitude of impact is determined by the volume of spillage (V_S).

$$I_{S_E} = V_S \cdot (G_E T_E J_E)$$

Where:

E	= environment
I_{SE}	= impact of spill in specific environment
V_S	= volume of spillage
G_E, T_E, J_E	= combination of geographic location, seasonal timing, and oil type

Relative Environmental Sensitivity Scoring

The methodological approach to determining the relative degree of input by geographic location and oil type are described in detail in the Appendix. The relative per-volume scores for the marine and estuarine zones that could potentially by affected by an oil spill related to the Vancouver Energy facility CBR transit (loaded and empty trains) are shown in Table 31, based on the zones shown in the map in Figure 21.

Table 31: Estuarine/Marine Zone Impact Risk Scores for Vancouver Energy Analysis

Zone	Season	Relevance for Vancouver Energy Analysis (Oil Type) Railroad[85]		Heavy Oil (H)	Light Oil (L)
		Loaded Trains	Empty Trains	Diluted Bitumen	Bakken Oil Diesel
Western Columbia River	Spring	H + L	L	26.81	16.35
	Summer	H + L	L	26.81	16.35
	Fall	H + L	L	24.59	14.99
	Winter	H + L	L	24.37	14.86
	Average	H + L	L	25.65	15.64
Central Puget Sound	Spring	-	L	21.02	12.58
	Summer	-	L	19.84	11.82
	Fall	-	L	18.67	10.94
	Winter	-	L	18.65	10.87
	Average	-	L	19.55	11.55
Southern Puget Sound	Spring	-	L	27.7	16.52
	Summer	-	L	23.78	14.34
	Fall	-	L	22.15	13.35
	Winter	-	L	24.01	14.4

[85] Only includes railroad spills that enter marine or estuarine waterways.

Table 31: Estuarine/Marine Zone Impact Risk Scores for Vancouver Energy Analysis					
Zone	Season	Relevance for Vancouver Energy Analysis (Oil Type)		Heavy Oil (H)	Light Oil (L)
		Railroad[85]			
		Loaded Trains	Empty Trains	Diluted Bitumen	Bakken Oil Diesel
	Average	-	L	24.41	14.65

The relative per-unit volume scores for the inland zones that could potentially by affected by an oil spill related to the Vancouver Energy facility CBR transit (loaded and empty trains) are shown in Table 32, based on the zones shown in the map in Figure 22.

The per-unit volume impact scores are shown in rank order in Table 33 with the most environmentally-sensitive zone (by oil type) first. In this table, the impact scores were also normalized so that the lowest number (other than zero) was given a rank of 1.0 and the other scores were divided by that raw impact score. The environmental impacts of a heavy oil spill in Klickitat (WRIA 30) are roughly 3.6 times as high as a light oil (Bakken crude or diesel) spill of the same volume in the Lower Snake zone (WRIA 33).

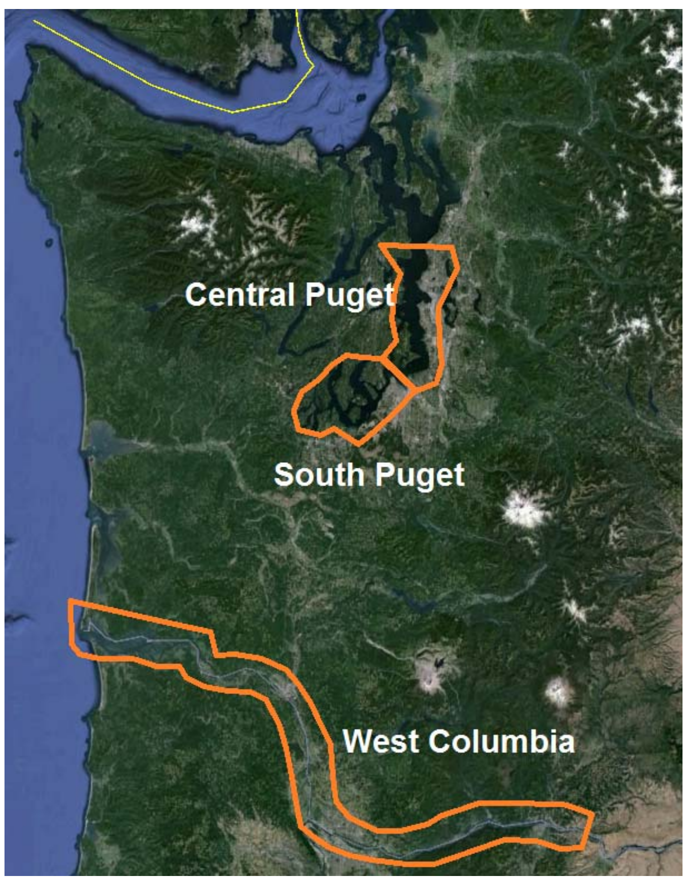

Figure 21: JLARC Study Marine/Estuarine Zones Impacted by Vancouver Energy CBR

Table 32: Per-Gallon Impact Scores for WRIAs/Oil Types in Vancouver Energy Analysis					
#	WRIA	Relevance for Vancouver Energy Analysis (Oil Type)		Heavy Oil (H)	Light Oil (L)
		Railroad			
		Loaded Trains	Empty Trains	Diluted Bitumen	Bakken Oil Diesel
9	Duwamish-Green	-	L	25.61	15.61
11	Nisqually	-	L	27.15	16.55
13	Deschutes	-	L	24.67	15.05
23	Upper Chehalis	-	L	30.02	18.30
26	Cowlitz	-	L	26.17	15.96
27	Lewis	-	L	26.27	16.02
28	Salmon-Washougal	H + L	L	25.28	15.42
29	Wind-White Salmon	H + L	-	22.69	13.84
30	Klickitat	H + L	-	27.98	17.06
31	Rock-Glade	H + L	-	12.95	7.90
32	Walla Walla	H + L	-	18.14	11.06
33	Lower Snake	H + L	-	12.77	7.79
34	Palouse	H + L	-	26.20	15.97
36	Esquatzel Coulee	H + L	-	23.05	14.06
37	Lower Yakima	-	L	26.96	16.44
39	Upper Yakima	-	L	22.15	13.51
56	Hangman	H + L	-	20.16	12.29
57	Middle Spokane	H + L	-	15.82	9.65

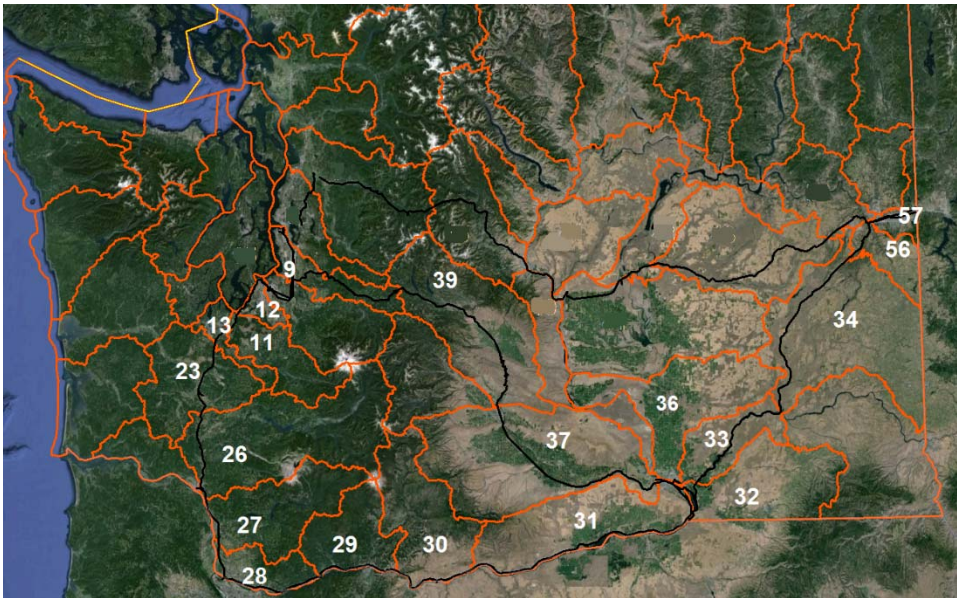

Figure 22: Inland Zones Potentially Impacted by CBR Spills[86]

Table 33: Per-Unit Impact Scores for Zones Potentially Impacted by CBR Spills				
WRIA #	**Zone**	**Oil Type**	**Per-Unit Score**	**Normalized Score**
30	**Klickitat**	**Heavy (Diluted Bitumen)**	27.98	3.59
34	**Palouse**	**Heavy (Diluted Bitumen)**	26.20	3.36
-	**Western Columbia River**	**Heavy (Diluted Bitumen)**	25.65	3.29
28	**Salmon-Washougal**	**Heavy (Diluted Bitumen)**	25.28	3.25
36	**Esquatzel Coulee**	**Heavy (Diluted Bitumen)**	23.05	2.96
29	**Wind-White Salmon**	**Heavy (Diluted Bitumen)**	22.69	2.91
56	**Hangman**	**Heavy (Diluted Bitumen)**	20.16	2.59
-	**Central Puget Sound**	**Heavy (Diluted Bitumen)**	19.55	2.51
23	**Upper Chehalis**	**Light (Bakken or Diesel)**	18.30	2.35
32	**Walla Walla**	**Heavy (Diluted Bitumen)**	18.14	2.33
30	**Klickitat**	**Light (Bakken or Diesel)**	17.06	2.19
11	**Nisqually**	**Light (Bakken or Diesel)**	16.55	2.12
37	**Lower Yakima**	**Light (Bakken or Diesel)**	16.44	2.11
27	**Lewis**	**Light (Bakken or Diesel)**	16.02	2.06
34	**Palouse**	**Light (Bakken or Diesel)**	15.97	2.05
26	**Cowlitz**	**Light (Bakken or Diesel)**	15.96	2.05
57	**Middle Spokane**	**Heavy (Diluted Bitumen)**	15.82	2.03
-	**Western Columbia River**	**Light (Bakken or Diesel)**	15.64	2.01
9	**Duwamish-Green**	**Light (Bakken or Diesel)**	15.61	2.00
28	**Salmon-Washougal**	**Light (Bakken or Diesel)**	15.42	1.98
13	**Deschutes**	**Light (Bakken or Diesel)**	15.05	1.93
-	**Southern Puget Sound**	**Light (Bakken or Diesel)**	14.65	1.88
36	**Esquatzel Coulee**	**Light (Bakken or Diesel)**	14.06	1.80
29	**Wind-White Salmon**	**Light (Bakken or Diesel)**	13.84	1.78
39	**Upper Yakima**	**Light (Bakken or Diesel)**	13.51	1.73
31	**Rock-Glade**	**Heavy (Diluted Bitumen)**	12.95	1.66
33	**Lower Snake**	**Heavy (Diluted Bitumen)**	12.77	1.64
56	**Hangman**	**Light (Bakken or Diesel)**	12.29	1.58
-	**Central Puget Sound**	**Light (Bakken or Diesel)**	11.55	1.48
32	**Walla Walla**	**Light (Bakken or Diesel)**	11.06	1.42
57	**Middle Spokane**	**Light (Bakken or Diesel)**	9.65	1.24
31	**Rock-Glade**	**Light (Bakken or Diesel)**	7.90	1.01
33	**Lower Snake**	**Light (Bakken or Diesel)**	7.79	1.00

[86] The inland zones are based on Water Resource Inventory Areas (WRIAs). Mainline rails are shown in black.

Incident Impacts Based on JLARC Analysis

Total impact scores by most-credible WCD volume, location, and oil type were calculated as shown in Table 34. These scores do not take into account the relative probabilities that there would be rail incidents in these locations. These values only reflect the relative impacts that would occur in these locations based on spill volume and oil type.

The relative ranking of spill scenarios based on impact are shown in Table 35. In this table, the impact scores were normalized so that the lowest number (other than zero) was given a rank of 1.0 and the other scores were divided by that raw impact score. This means that the highest-ranked scenario – a WCD spill from a train loaded with diluted bitumen spill in the Klickitat WRIA (30) would have an impact that is 274 times as high as a diesel spill from locomotives in the Chambers-Clover WRIA (12).

Table 34: Total Impact Scores for WCDs by Location and Oil Type							
Zone		Loaded Trains			Empty Trains	
		Most Credible WCD (bbl)	Bakken Crude Score	Diluted Bitumen Score	Most Credible WCD (bbl)	Diesel Fuel Score
-	Western Columbia River	20,000	312,800	513,000	0	0
-	Southern Puget Sound	0	0	0	262	3,838
9	Duwamish-Green	0	0	0	262	4,090
11	Nisqually	0	0	0	262	4,336
12	Chambers-Clover	0	0	0	262	2,547
13	Deschutes	0	0	0	262	3,943
23	Upper Chehalis	0	0	0	262	4,795
26	Cowlitz	0	0	0	262	4,182
27	Lewis	0	0	0	262	4,197
28	Salmon-Washougal	20,000	308,400	505,600	0	0
29	Wind-White Salmon	20,000	276,800	453,800	0	0
30	Klickitat	20,000	341,200	559,600	0	0
31	Rock-Glade	20,000	158,000	259,000	0	0
32	Walla Walla	20,000	221,200	362,800	262	2,898
33	Lower Snake	20,000	155,800	255,400	262	2,041
34	Palouse	20,000	319,400	524,000	262	4,184
36	Esquatzel Coulee	0	0	0	262	3,684
37	Lower Yakima	0	0	0	262	4,307
39	Upper Yakima	0	0	0	262	3,540
56	Hangman	20,000	245,800	403,200	262	3,220
57	Middle Spokane	20,000	193,000	316,400	262	2,528

Table 35: Ranked and Normalized Impact Scores for Rail WCDs by Oil Type and Zone				
WRIA #	Zone	Oil Type	Impact Score	Normalized Score
30	Klickitat	Diluted Bitumen	559,600	274.18
34	Palouse	Diluted Bitumen	524,000	256.74
-	Western Columbia River	Diluted Bitumen	513,000	251.35
28	Salmon-Washougal	Diluted Bitumen	505,600	247.72
36	Esquatzel Coulee	Diluted Bitumen	461,000	225.87
29	Wind-White Salmon	Diluted Bitumen	453,800	222.34
56	Hangman	Diluted Bitumen	403,200	197.55
32	Walla Walla	Diluted Bitumen	362,800	177.76
30	Klickitat	Bakken	341,200	167.17
34	Palouse	Bakken	319,400	156.49
57	Middle Spokane	Diluted Bitumen	316,400	155.02
-	Western Columbia River	Bakken	312,800	153.26
28	Salmon-Washougal	Bakken	308,400	151.10

Table 35: Ranked and Normalized Impact Scores for Rail WCDs by Oil Type and Zone				
WRIA #	**Zone**	**Oil Type**	**Impact Score**	**Normalized Score**
36	**Esquatzel Coulee**	Bakken	281,200	137.78
29	**Wind-White Salmon**	Bakken	276,800	135.62
31	**Rock-Glade**	Diluted Bitumen	259,000	126.90
33	**Lower Snake**	Diluted Bitumen	255,400	125.13
56	**Hangman**	Bakken	245,800	120.43
32	**Walla Walla**	Bakken	221,200	108.38
57	**Middle Spokane**	Bakken	193,000	94.56
31	**Rock-Glade**	Bakken	158,000	77.41
33	**Lower Snake**	Bakken	155,800	76.34
23	**Upper Chehalis**	Diesel	4,795	2.35
11	**Nisqually**	Diesel	4,336	2.12
37	**Lower Yakima**	Diesel	4,307	2.11
27	**Lewis**	Diesel	4,197	2.06
34	**Palouse**	Diesel	4,184	2.05
26	**Cowlitz**	Diesel	4,182	2.05
9	**Duwamish-Green**	Diesel	4,090	2.00
13	**Deschutes**	Diesel	3,943	1.93
-	**Southern Puget Sound**	Diesel	3,838	1.88
36	**Esquatzel Coulee**	Diesel	3,684	1.80
39	**Upper Yakima**	Diesel	3,540	1.73
56	**Hangman**	Diesel	3,220	1.58
-	**Central Puget Sound**	Diesel	3,026	1.48
32	**Walla Walla**	Diesel	2,898	1.42
12	**Chambers-Clover**	Diesel	2,547	1.25
57	**Middle Spokane**	Diesel	2,528	1.24
33	**Lower Snake**	Diesel	2,041	1.00

Relative Risk Scoring (Probability and Impacts)

The relative (normalized) risk scores for CBR WCD spills in each of the geographic zones are presented in Table 36. These scores combine the relative probability that a derailment incident (and spill) will occur in that location with the impact score based on location, oil type, and potential WCD volume.

The probability of a Bakken crude spill versus a diluted bitumen spill will depend on the relative volumes of the two crude oil types that are handled by the Vancouver Energy facility and are thus transported by rail. In this analysis, it is assumed that it is equally likely that there will be a Bakken crude spill as a diluted bitumen spill.

Table 36: Ranked and Normalized Risk Scores for Rail WCDs by Oil Type and Zone

WRIA #	Zone	Oil Type	Normalized Impact Score	Normalized Relative Frequency	Normalized Risk Score
	Western Columbia River	Diluted Bitumen	251.35	0.69	173.43
34	Palouse	Diluted Bitumen	256.74	0.54	138.64
57	Middle Spokane	Diluted Bitumen	155.02	0.86	133.32
33	Lower Snake	Diluted Bitumen	125.13	1	125.13
	Western Columbia River	Bakken	153.26	0.69	105.75
34	Palouse	Bakken	156.49	0.54	84.50
57	Middle Spokane	Bakken	94.56	0.86	81.32
33	Lower Snake	Bakken	76.34	1	76.34
30	Klickitat	Diluted Bitumen	274.18	0.14	38.39
31	Rock Glade	Diluted Bitumen	126.9	0.28	35.53
28	Salmon-Washougal	Diluted Bitumen	247.72	0.14	34.68
29	Wind-White Salmon	Diluted Bitumen	222.34	0.14	31.13
56	Hangman	Diluted Bitumen	197.55	0.14	27.66
30	Klickitat	Bakken	167.17	0.14	23.40
56	Hangman	Bakken	120.43	0.18	21.68
31	Rock Glade	Bakken	77.41	0.28	21.67
28	Salmon-Washougal	Bakken	151.1	0.14	21.15
29	Wind-White Salmon	Bakken	135.62	0.14	18.99
32	Walla Walla	Diluted Bitumen	177.76	0.09	16.00
32	Walla Walla	Bakken	108.38	0.09	9.75
39	Upper Yakima	Diesel	1.73	0.78	1.35
37	Lower Yakima	Diesel	2.11	0.57	1.20
23	Upper Chehalis	Diesel	2.35	0.32	0.75
34	Palouse	Diesel	2.05	0.36	0.74
57	Middle Spokane	Diesel	1.24	0.57	0.71
33	Lower Snake	Diesel	1	0.66	0.66
26	Cowlitz	Diesel	2.05	0.32	0.66
27	Lewis	Diesel	2.06	0.24	0.49
9	Duwamish-Green	Diesel	2	0.24	0.48
	Southern Puget	Diesel	1.88	0.16	0.30
56	Hangman	Diesel	1.58	0.12	0.19
11	Nisqually	Diesel	2.12	0.08	0.17
13	Deschutes	Diesel	1.93	0.08	0.15
36	Esquatzel Coulee	Diesel	1.8	0.07	0.13
	Central Puget	Diesel	1.48	0.08	0.12
12	Chambers-Clover	Diesel	1.25	0.08	0.10
32	Walla Walla	Diesel	1.42	0.06	0.09

Based on this analysis, the highest risk based on probability and environmental impacts is to the Columbia River with a worst-case discharge diluted bitumen spill.

Railroad Spill Volume Planning Standards

Based on a Research and Special Programs Administration (RSPA) final rule published on 17 June 1996 (49 CFR 130)[87] a basic oil spill response plan (OSRP) is required for all oil shipments in "packages" containing 3,500 gallons (83 bbl) or more and a comprehensive OSRP is required for oil shipments in packages containing more than 42,000 gallons (1,000 bbl). However, there are no specific definitions of minor discharges up to WCDs. Since a single tank car holds about 33,000 gallons (786 bbl), with some variability due to oil density, this means that oil trains, even unit oil trains with 100 or more cars each, are not subject to the comprehensive OSRP requirement, but only the basic OSRP requirement. This particular issue is addressed in the recommendations that Washington State (Ecology, DNR, DFW) made to the PHMSE in its comments on the Advanced Notice of Proposed Rulemaking (Docket No. PHMSA–2014–0105 (HM–251B), Hazardous Materials: Oil Spill Response Plans for High-Hazard Flammable Trains - Advanced Notice of Proposed Rulemaking).

With respect to classifications of "average most-probable discharge" (AMPD), "maximum most-probable discharge" (MMPD), or "worst-case discharge" (WCD) for railroad tank car or unit train spills, analogous with those for facilities and vessels, there is no current regulatory guidance.

Railroad Cars at Facilities

According to the 1971 Memorandum of Understanding between Department of Transportation (DOT) and the Environmental Protection Agency (EPA), railroad cars and trains fall under the definition of DOT for railroad transport, and rail-to-facility transfer operations at the facility fall under EPA jurisdiction (Table 37).

Table 37: Transportation- and Non-Transportation-Related Facilities (DOT EPA MOU) [88]

Transportation-Related Facilities (DOT Jurisdiction)[89]	Non-Transportation-Related Facilities (EPA SPCC Jurisdiction)
Onshore and offshore terminal facilities, including transfer hoses, loading arms, and other equipment used to transfer oil in bulk to or from a vessel, including storage tanks and appurtenances for the reception of oily ballast water or tank washings from vessels Transfer hoses, loading arms, and other equipment appurtenant to a non-transportation-related facility used to transfer oil in bulk to or from a vessel Interstate and intrastate onshore and offshore pipeline systems. **Highway vehicles and railroad cars that are used for the transport of oil.** Equipment used for the fueling of locomotive units, as well as the rights-of-way on which they operate.	Fixed or mobile onshore and offshore oil drilling and oil production facilities Oil refining and storage facilities Industrial, commercial, agricultural, and public facilities that use and store oil Waste oil treatment facilities **Loading racks, transfer hoses, loading arms, and other equipment used to transfer oil in bulk *to or from highway vehicles or railroad cars*** Highway vehicles, railroad cars, and pipelines used to transport oil exclusively within the confines of non-transportation-related facility

[87] Federal Register Vol. 16 (117): 30,533.

[88] Based on: EPA 2013.

[89] Note that DOT turned over responsibility for marine transportation related facilities, including vessel transfer operations to the USCG.

Railroad Cars

DOT regulates railroad cars used for the transport of oil in interstate or intrastate commerce and the related equipment and appurtenances. DOT jurisdiction includes railroad cars that are passing through a facility or are temporarily stopped on a normal route. EPA regulates railroad cars under the SPCC rule if they are operating exclusively within the confines of a non-transportation-related facility. EPA regulates both transfers to or from railroad cars and when the railroad cars serve as non-transportation-related storage at an SPCC-regulated facility.

When the railcar is serving as non-transportation-related storage, if the railroad car has a storage capacity above the regulatory threshold amount of oil, and there is a reasonable expectation of discharge to navigable waters or adjoining shorelines, the railroad car itself may become a non-transportation-related facility, even if no other containers at the property would qualify it as an SPCC-regulated facility. If a rail car containing oil passes through a facility and the oil is not unloaded, it is considered to be "in storage" incidental to transportation in commerce and falls under DOT requirements.

Loading/Unloading Activities

DOT regulates equipment used for the fueling of locomotive units, as well as the rights-of-way on which they operate. EPA regulates the activity of loading or unloading oil in bulk into storage containers (such as those on tank trucks or railroad cars), as well as all equipment involved in this activity (e.g., a hose or loading arm attached to a storage tank system). Different requirements apply to oil transfer areas and to loading/unloading racks at a regulated facility. A transfer area is any area of a facility where oil is transferred between bulk storage containers and tank trucks or railroad cars. These areas are subject to the general secondary containment requirements in §112.7(c). If a "loading/unloading rack" (as defined in §112.2) is present, the requirements of §112.7(h) apply to the loading/unloading rack area. For more information, refer to Chapter 4: Secondary Containment and Impracticability which discusses secondary containment requirements for loading/unloading areas and racks.

Marine Terminals

A marine terminal is an example of a "complex" subject to both U.S. Coast Guard (USCG) and EPA jurisdiction. The jurisdictional boundary of a complex facility for both USCG and EPA is defined in 33 CFR part 154, Facilities Transferring Oil or Hazardous Material in Bulk under the definition of a marine transportation-related facility (MTR facility) in §154.1020.The USCG regulates the pier structures, transfer hoses, hose-piping connection, containment, controls, and transfer piping associated with the transfer of oil between a vessel and an onshore facility. EPA regulates the tanks, internal piping, loading racks, and vehicle/rail operations that are completely within the non-transportation portion of the facility. EPA jurisdiction begins at the first valve inside secondary containment. If there is no secondary containment, EPA jurisdiction begins at the valve or manifold adjacent to the storage tank.

Marine transportation-related transfer facilities that contain fixed aboveground onshore structures used for bulk oil storage are jointly regulated by EPA and the U.S. Coast Guard (USCG), and are termed "complexes." Because the USCG also requires response plans from transportation-related facilities to address a worst case discharge of oil, a separate calculation for the worst case discharge planning volume for USCG-related facilities is included in the USCG IFR. All complexes that are jointly regulated by EPA and the USCG must compare both calculations for worst case discharge planning volume derived by using the EPA and USCG methodologies and *plan for whichever volume is greater*.[90]

For multiple-tank facilities *without secondary containment*, the WCD planning volume is the total capacity of all storage tanks. Since the Vancouver Energy facility would have secondary containment, this does not apply. If there is adequate secondary containment, the WCD planning volume is the capacity of the largest single aboveground oil storage tank within an adequate secondary containment area or the combined capacity of aboveground oil storage tanks permanently manifolded together, whichever is greater.

Railroad Planning Volumes

The only planning volume mentioned by DOT for railroads is the requirement to plan for a basic OSRP since the "package," i.e., the tank car is less than 42,000 gallons (1,000 bbl). This planning involves a 3,500-gallon (83-bbl) scenario. This is applicable along the rail lines, not within the facility.

Within the facility, the train – the locomotive(s) and the tank cars – are covered under EPA SPCC regulations, which means that planning volumes apply to the facility, which only mention the capacity of the largest storage tank. Technically, a rail tank car at a facility is considered a temporary storage tank. Since its volume is 786 bbl at most, the larger volume for the largest storage tank (in the case of Vancouver Energy, 360,000 bbl) would cover the smaller volume of a rail tank car.

Potential Risk Mitigation for CBR Spills

Risk mitigation for CBR spills can take two major forms – prevention, which reduces the probability of incidents occurring, and response, which reduces the impacts of a spill (Figure 23).

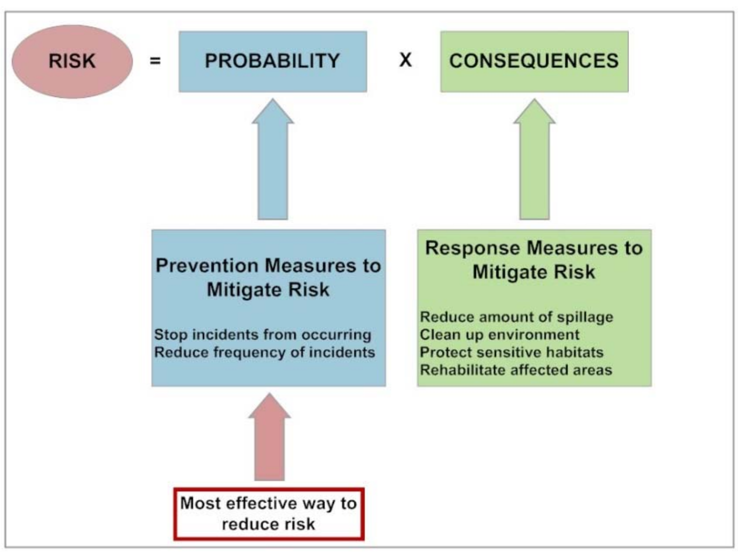

Figure 23: Risk Mitigation Strategies

[90] 40 CFR 112 Appendix D: Determination of Worst Case Discharge Planning Volume

Risk Mitigation through Prevention

While there has been a large public outcry about CBR trains and grass-roots movements to ban these trains and cargoes from certain states in the US, these efforts have been ineffective because the regulation of railroads is largely under exclusive federal jurisdiction (reviewed in Etkin et al., 2015). This limits a state government's authority even with regard to safety measures under the Federal Railroad Safety Act (FRSA), and controlling, restricting, or banning outright the transport of commodities, including hazardous materials. Railroads have a common carrier obligation to transport all goods offered for transportation, including hazardous materials. This obligation is a common law doctrine, codified in the Interstate Commerce Act and recognized by the US Supreme Court in the early 1900s.

The Interstate Commerce Commission Termination Act of 1995 (ICCTA) maintains the common carrier obligations of railroads and requires railroads to "provide the transportation or service on reasonable request." The Surface Transportation Board (STB), which succeeded the Interstate Commerce Commission, has exclusive jurisdiction over the transportation of commodities by rail within the US, as well as intrastate operations along an interstate rail network, preempting state and local authority.

Since 1970, there have been a number of changes in federal law that limits the ability of states to regulate railroad companies. For example, states no longer have a role in determining the rates and routes of railroad companies or in protecting consumers. These responsibilities rest with the STB. The federal laws that limit the states' ability to regulate railroads for public safety issues are the 1970 FRSA and the ICCTA. In particular, the FRSA preempts states from passing laws or adopting rules on safety where the federal government has adopted its own laws or rules.

Given that under current laws, it is not possible to stop or ban CBR traffic per se, the major types of incident prevention efforts that officials need to focus on:

- Preventing derailments and other accidents from occurring (e.g., training, positive train control or PTC, improvements in braking systems, track inspections and maintenance);
- Preventing leakage or spillage of oil from tank cars in the event of an accident (i.e., newer tank car designs); and
- Reducing the volatility of the oil to reduce the incidence of fires and explosions (i.e., conditioning of Bakken crude).

US Federal Actions to Reduce CBR Accidents

The US Department of Transportation (DOT) and the Pipeline and Hazardous Material Safety Administration (PHMSA) have taken a number of actions over the last two years to prevent CBR incidents, as summarized in Table 38.

Table 38: US Federal Action on CBR Incident Prevention Measures[91]

Date	Action
September 2012	PHMSA Administrator Quarterman visits North Dakota Bakken Region to observe operations at rail loading facilities and the application of USDOT regulations.
October 2012	PHMSA Bakken Field Working Group established to increase inspection focus on hazmat shipments by truck and rail from the Bakken region and increase awareness within the emergency response community.
December 2012	FRA begins Bakken Rail Accident Mitigation Project (RAMP).
July 29, 2013	In a letter to the American Petroleum Institute, FRA informed industry that it will use PHMSA's test sampling program to ensure that crude oil is being properly tested and classified.
August 2, 2013	FRA Safety Advisory 2013-06 "Preventing Unintended Movement of Freight Trains and Vehicles on MainlineTrack or Mainline Siding Outside of a Yard or Terminal"
August 7, 2013	FRA Emergency Order 28, "Establishing Additional Requirements for Attendance and Securement of Certain Freight Trains and Vehicles on Mainline Track or Mainline Siding Outside of a Yard or Terminal"
August 27, 2013	FRA and PHMSA public meeting with industry stakeholders.
August 29, 2013	FRA convenes emergency session of Railroad Safety Advisory Committee (RSAC). RSAC established three working groups on new rulemaking: 1) hazardous materials by rail, 2) train crew size and 3) train securement procedures. Launch of Bakken Blitz.
September 6, 2013	PHMSA issues 78 FR 54849 – ANPRM (2012-0082 HM-251), in response to railroad industry petitions and recommendations to improve the safety of railroad tank car transportation.
October 1, 2013	FRA Administrator Szabo sends a letter to railroad industry organization asking they detail actions they have taken in response to the Safety Advisory issued on August 2, 2013.
November 5, 2013	PHMSA extension of comment period of HM-251.
November 20, 2013	PHMSA and FRA issue Safety Advisory 2013-07 "Safety and Security Plans for Class 3 Hazardous Materials Transported by Rail".
December 11, 2013	FRA Safety Advisory, "Notice of safety advisory; Operational tests and inspections for compliance with maximum authorized train speeds and other speed restrictions".
January 2, 2014	PHMSA safety advisory issued stating that crude oil from the Bakken region may be more flammable than traditional crude.
January 16, 2014	Secretary Foxx meets with rail company CEOs and rail and energy association leadership as part of the USDOT's Call to Action to discuss how to maintain a safety record even as domestic crude oil production and movement has increased.
January 21, 2014	Secretary Foxx issues follow-up letter to Call to Action participants summarizing industry commitments.
February 4, 2014	PHMSA issues $93,000 in proposed civil penalties after investigation into the transportation of Bakken crude oil finds companies improperly classified shipments.
February 10, 2014	PHMSA meets with emergency response stakeholders and industry groups to discuss training and awareness related to the transport of Bakken crude. Follow-up meeting to be scheduled in late February 2014.
February 21, 2014	Secretary of Transportation sends letter to President/CEO of AAR to request members voluntarily: impose speed restrictions, braking signal propagation system, routing analysis, additional track and rail inspections, more frequent mechanical inspections, emergency response inventory, funding for emergency responder training, and more communication with communities.
February 25, 2014	USDOT Emergency Order requiring the testing and proper classification of oil being transported and does not allow crude oil to be transported at the lowest packing group.

[91] Etkin et al. 2015.

Table 38: US Federal Action on CBR Incident Prevention Measures[91]	
Date	**Action**
March 6, 2014	To provide further clarity for shippers and to prevent attempts to circumvent the requirements in its recent Emergency Order concerning the safe transport of crude oil by rail, the USDOT issued an amended version that specifies which tests are required, while also prohibiting shippers from switching to an alternate classification that involves less stringent packaging.
April 9, 2014	FRA announced intention to issue proposed rule requiring two-person train crews on crude oil trains.
May 7, 2014	Joint safety advisory issued by FRA and PHMSA strongly urging those shipping Bakken crude oil to use tank car designs with the highest level of integrity. Also recommended avoiding use of older legacy DOT 111 or CTC 111 tank cars for shipment of Bakken crude.
May 7, 2014	DOT Emergency Order requiring reporting to State Emergency Response Committees (SERCs) of information on trains with more than one million gallons within 30 days of order.
July 23, 2014	USDOT releases regulations pertaining to the transportation of oil by rail and tank car standards.
September 10, 2014	FRA proposes amendments to the brake system safety standards for freight and other non-passenger trains and equipment to strengthen the requirements relating to the securement of unattended equipment. Specifically, FRA would codify many of the requirements already included in its Emergency Order 28, Establishing Additional Requirements for Attendance and Securement of Certain Freight Trains and Vehicles on Mainline Track or Mainline Siding Outside of a Yard or Terminal.
May 1, 2015	DOT (PHMSA and FRA) issued its Final Rule "Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains."

Tank Car Standards

One of the standards that is being addressed in the rulemaking process, and clearly the one that has captured public attention is the tank car standard. A "safer" tank car design (CPC-1232) is thought to be analogous to the double-hulled tanker with similar reductions in spillage probability from the older "DOT-111" tank cars (Figure 24). The CPC-1232 standard originated with Transport Canada in October 2011.

A 1991 National Transportation Safety Board (NTSB) study[92] found that the DOT-111 tank car is significantly more likely to release its product, suffer a failure or experience a head or shell puncture than other tank car models (DOT-105, -112 and -114 pressurized tank cars), which have a tank shell thickness of 14.3 mm and thermal protection.

Anecdotal evidence from recent CBR incidents indicates that the newer tank car standards do not necessarily prevent spillage. Notably, in the Lynchburg, Virginia, incident, the only tank cars that spilled were of the newer design (Figure 25). In addition, two recent derailments in Canada and in Galena, Illinois. involved CPS-1232 cars that spilled oil and burned. In the Canadian incidents, bitumen products were involved, showing that crudes other than Bakken can also ignite in a derailment accident.

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[92] Kolstad 1991.

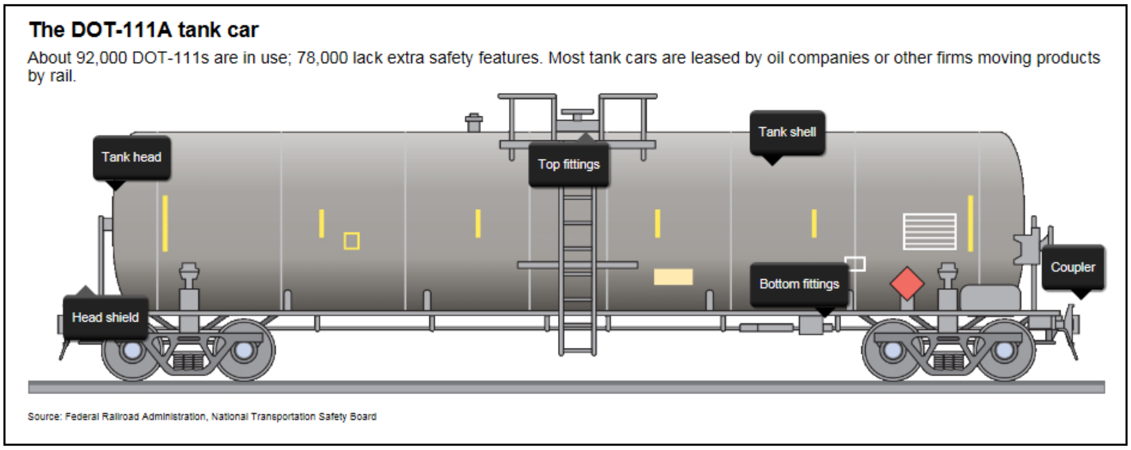


Figure 24: DOT-111 Tank Car Design (Federal Railroad Administration)

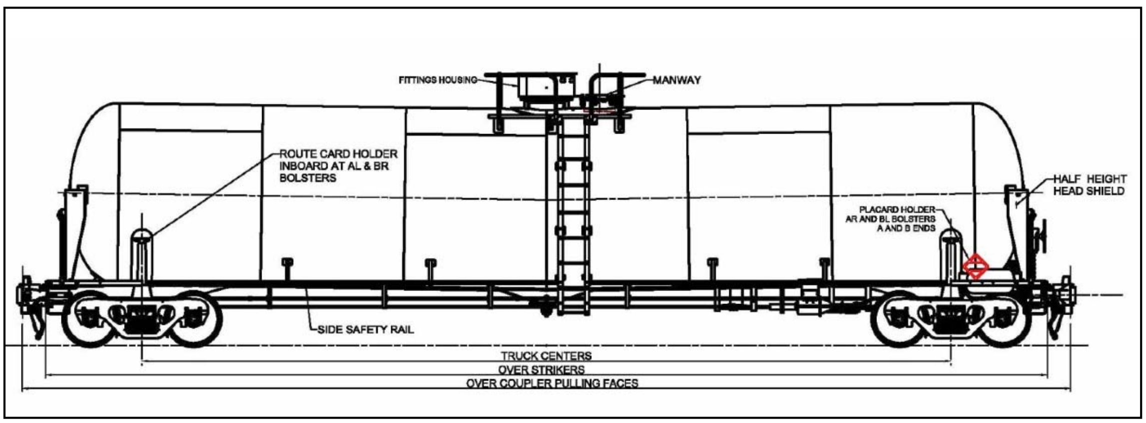


Figure 25: CPC-1232 Compliant Tank Car Design[93]

US DOT Final Rule (May 1, 2015)

On May 1, 2015, the Department of Transportation (PHMSA and FRA) issued a final rulemaking, "Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains," [94] that included a number of provisions aimed at reducing risk from "high-hazard flammable trains" (HHFTs). HFFTs are trains that have a continuous block of 20 or more tank cars loaded with a flammable liquid or 35 or more cares loaded with a flammable dispersed through a train (i.e., with other cargo-type cars interspersed). This rulemaking is directly relevant to CBR train transport for the Vancouver Energy project.

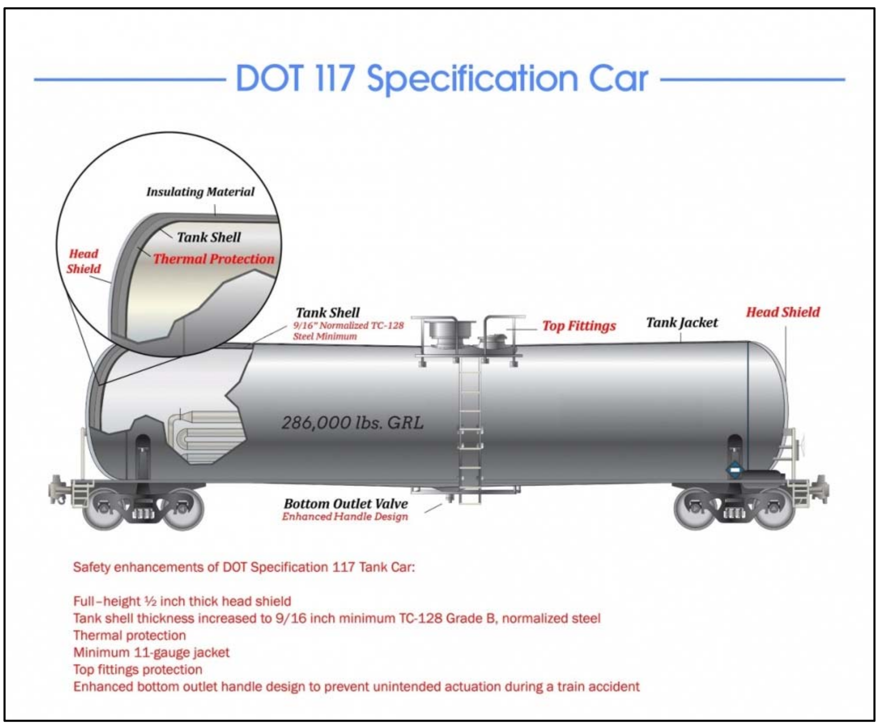
The rule contained a new standard for tank cars – the DOT-117 specification (Figure 26). The timeline for retrofitting of affected tank cars for use in North America for high-hazard flammable freight trains (HHFTs), including CBR trains, is summarized in Table 39.

[93] Barkan et al. 2014.

[94] 49 CFR Parts 171, 172, 173, 174, and 179] DOT Pipeline and Hazardous Materials Safety Administration Docket No. PHMSA-2012-0082 (HM-251) ROM 2137-AE91

Table 39: Timeline for Retrofit of Affected Tank Cars for Use in North American HHFTs[95]

Tank Car Type/Service	US Retrofit Deadline	Tank Car Type/Service	Transport Canada Retrofit Deadline
Non Jacketed DOT-111 tank cars in PG I service	(January 1, 2017)[96] January 1, 2018	**Non Jacketed DOT-111 tank cars in Crude Oil service**	May 1, 2017
Jacketed DOT-111 tank cars in PG I	March 1, 2018	**Jacketed DOT-111 tank cars in Crude Oil service**	March 1, 2018
Non Jacketed CPC-1232 tank cars in PG I service	April 1, 2020	**Non Jacketed CPC-1232 tank cars in Crude Oil service**	April 1, 2020
Non Jacketed DOT-111 tank cars in PG II service	May 1, 2023	**Non Jacketed DOT-111 tank cars in Ethanol service**	May 1, 2023
Jacketed DOT-111 tank cars in PG II service	May 1, 2023	**Jacketed DOT-111 tank cars in Ethanol service**	May 1, 2023
Non Jacketed CPC-1232 tank cars in PG II service	July 1, 2023	**Non Jacketed CPC-1232 tank cars in Ethanol service**	July 1, 2023
Jacketed CPC-1232 tank cars in PG I and PG II service and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).	May 1, 2025	**Jacketed CPC-1232 tank cars in in Crude and Ethanol service and all remaining tank cars carrying PG III materials in an HHFT (pressure relief valve and valve handles).**	May 1, 2025



95 http://www.dot.gov/mission/safety/rail-rule-summary

96 The January 1, 2017 date would trigger a reporting requirement, and shippers would have to report to DOT the number of tank cars that they own or lease that have been retrofitted, and the number that have not yet been retrofitted.

Figure 26: DOT-117 Specification Car[97]

According to the rule, new tank cars constructed after October 1, 2015 are required to meet enhanced DOT Specification 117 design or performance criteria for use in an HHFT. Existing tank cars must be retrofitted in accordance with the DOT-prescribed retrofit design or performance standard for use in an HHFT. Retrofits must be completed based on a prescriptive retrofit schedule. The retrofit timeline focuses on two risk factors, the packing group and differing types of DOT-111 and CPC-1232 tank car. A retrofit reporting requirement is triggered if consignees owning or leasing tank cars covered under this rulemaking do not meet the initial retrofit milestone.

In addition to provisions for tank car standards, this rulemaking also contains regulations regarding enhanced braking, operating speeds, classification of unrefined petroleum-based products, rail routing risk assessments, and rail routing information access:

- **Enhanced Braking**
    - Requires HHFTs to have in place a functioning two-way end-of-train (EOT) device or a distributive power (DP) braking system.
    - Requires any high-hazard flammable unit train (HHFUT) —a train comprised of 70 or more loaded tank cars containing Class 3 flammable liquids traveling at greater than 30 mph— transporting at least one packing group I flammable liquid be operated with an electronically controlled pneumatic (ECP) braking system by January 1, 2021.
    - Requires all other HHFUTs be operated with an ECP braking system by May 1, 2023.
- **Reduced Operating Speeds**
    - Restricts all HHFTs to 50-mph in all areas.
    - Requires HHFTs that contain any tank cars not meeting the enhanced tank car standards required by this rule operate at a 40-mph speed restriction in high-threat urban areas defined the Transportation Security Administration's regulations at 49 CFR § 1580.3.
- **More Accurate Classification of Unrefined Petroleum-Based Products**
    - Requires documentation of sampling and testing program for all unrefined petroleum-based products, such as crude oil.
    - Requires certification that programs are in place, document the testing and sampling program outcomes, and make information available to DOT personnel upon request.
- **Rail Routing - Risk Assessment**

[97] http://www.dot.gov/mission/safety/rail-rule-summary

- Requires railroads operating HHFTs to perform a routing analysis that considers, at a minimum, 27 safety and security factors and select a route based on its findings. These planning requirements are prescribed in 49 CFR § 172.820.

- **Rail Routing – Information Access**
    - Ensures that railroads notify State and/or regional fusion centers, and that State, local and tribal officials who contact a railroad to discuss routing decisions are provided appropriate contact information for the railroad in order to request information related to the routing of hazardous materials through their jurisdictions.

Thermal Protection

In early April 2015, the National Transportation Safety Board (NTSB)[98] issued a Safety Recommendation for thermal protection systems for tank cars, which neither the DOT-111 nor the CPC-1232 designs have. This thermal protection is intended to limit the heat flux to the tank car containers when exposed to fire. According to NTSB:

> *Appropriately designed thermal protection systems will prevent a rapid increase in the temperature of the lading and commensurate increase in vapor pressure in the tank, and are intended to limit the volume of materials required to be evacuated through the pressure relief device, thereby limiting dangerous over-pressurization of the tank.*
>
> *Exposing a bare steel, flammable-liquid filled tank car to a large pool fire from product released in an accident can result in tank failure from a thermal tear in the tank that was not otherwise breached in a derailment. When the tank is exposed to heat from a pool fire, the internal pressure increases while the strength of the tank decreases. The tank will rupture if the pressure relief device cannot sufficiently relieve internal pressure. The resulting thermal tear in the shell material suddenly releases built-up pressure, ejecting vapor and liquid to ignite in a violent fireball eruption. Research studying accidents involving tank cars has shown that use of tank cars with thermal protection and a jacket will significantly reduce the amount of product released in accidents.[99] PHMSA estimates that jacketed CPC-1232 tank cars with thermal protection systems could provide an 18 percent reduction in lading loss in accidents relative to comparable accidents involving non-jacketed CPC-1232 tank cars.[100]*

NTSB made the following safety recommendations to PHMSA:

- **R-15-14**: Require that all new and existing tank cars used to transport all Class 3 flammable liquids be equipped with thermal protection systems that meet or exceed the thermal performance standards outlined in Title 49 *Code of Federal Regulations*179.18(a) and are appropriately qualified for the tank car configuration and the commodity transported

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[98] NTSB 2015.

[99] Safety Performance of Tank Cars in Accidents: Probabilities of Lading Loss, Report RA-05-02, Railway Supply Institute and Association of American Railroads Safety Research and Test Project (January, 2006).

[100] *Calculating Effectiveness Rates of Tank Car Options*, PHMSA Docket PHMSA-2012-0082.

- **R-15-15**: In conjunction with thermal protection systems called for in safety recommendation R-15-14, require that all new and existing tank cars used to transport all Class 3 flammable liquids be equipped with appropriately sized pressure relief devices that allow the release of pressure under fire conditions to ensure thermal performance that meets or exceeds the requirements of Title 49 *Code of Federal Regulations* 179.18(a), and that minimizes the likelihood of energetic thermal ruptures.
- **R-15-16**: Require an aggressive, intermediate progress milestone schedule, such as a 20 percent yearly completion metric over a 5-year implementation period, for the replacement or retrofitting of legacy DOT-111 and CPC-1232 tank cars to appropriate tank car performance standards, that includes equipping these tank cars with jackets, thermal protection, and appropriately sized pressure relief devices.
- **R-15-17:** Establish a publicly available reporting mechanism that reports at least annually, progress on retrofitting and replacing tank cars subject to thermal protection system performance standards as recommended in safety recommendation R-15-16.

Positive Train Control

Another aspect of regulatory action is positive train control (PTC), an advanced automatic train protection system that enforces movement authorities, speed restrictions[101] (signal and civil), and protection of roadway workers. The US federal government is mandating PTC for all railroads by the end of 2015. There are divergent views on the capacity impact PTC will make. As a result of a catastrophic accident in Southern California involving a commuter train and a UP freight train, any line segment that handles passenger operations is required to install PTC. PTC is designed to remotely monitor train movements and cause a train to be stopped if it appears it is dangerously close to overtaking or colliding with another train. There have been projections that PTC will allow trains, in conjunction with existing signal systems, to be able to operate at faster speeds at closer distances apart than existing signal systems alone will allow.[102]

Prevention of Derailments

A key prevention component in minimizing derailments is the extent to which the subject railroad employs monitoring equipment to detect anomalies with a train's operation, its equipment, or other factors which could affect the safe passage of a train. In Washington, BNSF's extensive distribution of such equipment (i.e., Wayside Detectors) is important in preventing derailments.

Other components in minimizing derailments include track condition, track inspection, operating protocols and maintenance policies. BNSF's mainline corridors in the state of Washington over which loaded crude by rail trains operate are FRA Class 4 tracks, maintained to allow Amtrak passenger trains to operate at a maximum speed of 79 mph, and freight trains to operate at a maximum speed of 60 mph. BNSF restricts loaded unit bulk trains that exceed 100 tons per operative brakes to 45 mph, which applies to crude by rail trains system-wide.

[101] Kawprasert 2009.

[102] Sweeney 2014.

Wayside Detectors[103]

The nationwide wayside detector system is a technology that allows railroads to prevent damage and accidents before they could happen. Positioned along 140,000 miles of railroad in the nation, seven kinds of wayside detectors monitor the wheels of passing trains and alert rail car operators to potential defects enabling them to schedule appropriate maintenance in a safe, timely, and cost-effective manner. According to the Association of American Railroads, since the system was developed in 2004, the broken wheel and accident rate has dropped over 20%.[104]

There are seven types of wayside detectors in operation:

- Acoustic bearing detectors (TADS-ABD) use acoustic signatures to evaluate the sound of internal bearings and identify those likely to fail in the near term.
- Railway bearing detectors (RailBAM™) detect faulty wheel bearings as trains pass by.[105]
- Truck bogie optical geometry inspection (TBOGI) is a laser-based monitoring system that measures performance of a rail car's axle and wheel suspension (commonly known as the "truck").[106]
- Truck performance detectors (TPD) assess the performance of rail car suspension systems or trucks on curved track by measuring the wheel's lateral forces at major segments of track containing four to six degrees of curvature. [107]
- Wheel impact load detectors (WILD) identify rail wheels worn or damaged into an out-of-round shape before they can damage track.
- Wheel profile measurement systems (WPMS) evaluate the complete rail profile by capturing laser images and detecting worn wheel treads or flanges. [108]
- Hot box and dragging equipment detectors are the most commonly used types of wayside detectors. A hot box detector is a heat-sensitive device used to measure the temperature of journal bearings on passing rail cars.[109] Dragging equipment detectors detect loose components and dragging under freight cars.[110]

The Association of American Railroads (AAR)[111] defines in Circular OT-55-N a "Key Route" (or HHFT) route as "Any track with a combination of 10,000 car loads or intermodal portable tank loads of hazardous material, or a combination of 4,000 car loadings of PIH or TIH (Hazard zone A, B, C or D), anhydrous

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[103] See also Etkin et al. 2015.
[104] http://freightrailworks.org/wp-content/uploads/safety2.pdf
[105] Not currently present in Washington State.
[106] Not currently present in Washington State.
[107] Not currently present in Washington State.
[108] Not currently present in Washington State.
[109] There are more than 6,000 hot box detectors on 140,000 miles of track in North America.
[110] More than 1,000 dragging equipment detectors are installed on the North American freight rail network.
[111] AAR is an industry trade group representing primarily the major freight railroads of North America (Canada, Mexico and the United States); Amtrak and some regional commuter railroads are also members.

ammonia, flammable gas, Class 1.1 or 1.2 explosives, environmentally sensitive chemicals, Spent Nuclear Fuel (SNF),[112] and High Level Radioactive Waste (HLRW)[113] over a period of one year".[114]

Contained within *Circular OT-55-N* are the Wayside Detector requirements for Key Routes. Those requirements are:

- Wayside defective bearing detectors shall be placed at a maximum of 40 miles apart on "Key Routes", or equivalent level of protection may be installed based on improved technology.
- Main Track on "Key Routes" is inspected by rail defect detection and track geometry inspection cars or any equivalent level of inspection no less than two times each year. Sidings are similarly inspected no less than one time each year. Main tracks and sidings will have periodic track inspections that will identify cracks or breaks in joint bars.
- Any track used for meeting and passing "Key Trains" must be FRA Class 2[115] or higher. If a meet or pass must occur on less than FRA Class 2 track, due to an emergency, one of the trains must be stopped before the other train passes.

BNSF Railway's Northwest Division Timetable No. 4 identifies Wayside Detectors at multiple locations on its primary mainline corridors in the state of Washington. The detectors include dragging equipment detection, rail car journal integrity exception reporting, wheel impact detectors and slide fence detectors.

By subdivision/corridor segment the Timetable provides the following information for Wayside Detectors on BNSF's mainline rail corridors in the state, as shown in Table 40.

Table 40: Summary of Wayside Detectors on BNSF Main Line Rail Corridors in Related to Vancouver Energy CBR Traffic[116]

Subdivision/Corridor	Mileposts	Route Miles	Number Wayside Detectors	Average Miles Between Detectors	Longest Mileage Gap
Sand Point–Spokane, Kootenai/Spokane	MP3.0–MP71.5	68.5	14	4.89	10.4 miles between MP60.1–MP70.5 (Spokane Terminal)
Spokane (Sunset Jct.)–Pasco (SP&S Jct.), Lakeside	MP1.1–MP147.5	146.4	28	5.23	8.2 miles between MP6.1–MP14.3
SP&S Jct.–Vancouver, Fallbridge	MP229.7–MP9.9	219.8	28	7.85	17.0 miles between MP207.8–MP190.8

[112] Irradiated fuel or targets containing uranium, plutonium, or thorium that is permanently withdrawn from a nuclear reactor or other neutron irradiation facility following irradiation, the constituent elements of which have not been separated by reprocessing.
[113] Waste generated in core fuel of a nuclear reactor, found at nuclear reactors or by nuclear fuel reprocessing.
[114] Association of *American Railroads Circular OT-55-N*, Effective August 5, 2013, II. *Designation of "Key Routes"*, paragraph A.
[115] Track classified by FRA with respect to maximum speed for track condition as 25 mph for freight, 30 mph for passenger; Branch lines, secondary main lines, many regional railroads, and some tourist operations frequently fall into this class.
[116] *BNSF Railway Northwest Division Timetable No. 4*, 2009.

Table 40: Summary of Wayside Detectors on BNSF Main Line Rail Corridors in Related to Vancouver Energy CBR Traffic[116]					
Subdivision/Corridor	**Mileposts**	**Route Miles**	**Number Wayside Detectors**	**Average Miles Between Detectors**	**Longest Mileage Gap**
Vancouver–King Street Station, Seattle	MP136.5–MP0.3	136.2	12	11.35	29.5 miles between MP87.4–MP57.9
King Street Station–Everett (Everett Jct.), Scenic	MP0.0–MP32.2	32.2	4	8.05	10.1 miles between MP17.1–MP27.2
Everett (Everett Jct.)–Wenatchee, Scenic	MP1784.7–MP1650.2	134.5	22	6.11	23.9 miles between MP1721.2–MP1697.3
Wenatchee–Spokane (Latah Jct.), Columbia River	MP1650.2–MP1481.6	168.6	11	15.33	27.7 miles between MP1607.9–MP1580.2
SP&S Jct. (Pasco)–Ellensburg, Yakima Valley	MP1.9–MP127.0	125.1	12	10.43	30.2 miles between MP49.6–MP79.8
Ellensburg–Stampede Wye (Auburn), Stampede	MP0.0–MP102.6	102.6	18	5.7	16.4 miles between MP20.5–MP36.9

AAR Circular OT-55-N provides restrictions for the operation of HHFT/Key trains that are impacted by Wayside Detectors. Item B, paragraphs 2, 3 and 4, under Road Operating Practices, I. “Key Trains”, provides the following restrictions:

- Unless siding or auxiliary track meets FRA Class 2 standards, a Key Train will hold main track at meeting or passing points, when practicable.
- Only cars equipped with roller bearings will be allowed in a Key Train.
- If a defect in a Key Train bearing is reported by a wayside detector, but a visual inspection fails to confirm evidence of a defect, the train will not exceed 30 mph until it has passed over the next wayside detector or delivered to a terminal for a mechanical inspection. If the same car again sets of the next detector or is found to be defective, it must be set out from the train.

Trackside Warning Devices (TWD) inspect passing trains for defects or monitor for unusual trackside conditions that could adversely affect the safe and efficient movements of trains. Examples of such devices in operation in Washington include the following:

- Overheated journal bearings (HBD)
- Hot wheels
- Dragging equipment detector (DED)[117]
- High/Wide/Shifted load (SLD)
- High water detector

[117] A device that detects dragging equipment on a railroad, which can damage the track and grade crossings.

- Earth/Rock slide fence.

Individual subdivision special instructions identify detector location and type.

A more detailed description of wayside detectors in Washington is shown in Table 41. Unless otherwise stated, protection will be hot journal and dragging equipment with bidirectional operation. Exceptions are shown as follows:

- Northward direction only (NWD)
- Southward direction only (SWD)
- Eastward direction only (EWD)
- Westward direction only (WWD)
- Dragging equipment only (DED)
- Shifted loads only (SLD)
- Detectors that project bridges, tunnels or other structures
- Exception Report detector.

A message stating, "You have a defect," will be transmitted during the train passage if a defect is detected. When this message is received from a TWD, the train crew must immediately reduce train speed to less than 30 mph, utilizing train handling methods that minimize in-train forces. After train passes the detector, a radio message will be transmitted (unless defined as "Exception Reporting" or "Failure Reporting"). This message will indicate "no defects" or will state any "alarms" or "integrity failures" that were detected during train passage. The detector message is not complete until "Out" is received. Radios at Exception Reporting detectors will only transmit a message when an alarm is present.

Table 41: Details on BNSF Wayside Detectors in Washington State

Subdivision	Start	End	MP Location	Type[118]
Kootenai/Spokane Subdivision 68.5 Miles in Length 14 TWDs Average distance apart: 4.89 miles Longest gap: 10.4 miles	Sand Point MP 3.0	Spokane MP 71.5	MP 2.9	Exception Reporting, recall code 497
			MP 8.5	DED/WWD only, recall code 498
			MP 11.7	Recall code 487
			MP 16.5	DED - Exception Reporting
	MP 60.1-70.5		MP 24.2	Recall code 488
			MP 27.1	DED - Exception Reporting
			MP 35.5	DED - Exception Reporting
			MP 36.8	DED - Exception Reporting
			MP 41.2	Recall code 497
			MP 47.0	DED - Exception Reporting
			MP 51.9	DED - Exception Reporting

[118] Trackside warning device (TSD) inspect

Table 41: Details on BNSF Wayside Detectors in Washington State				
Subdivision	**Start**	**End**	**MP Location**	**Type**[118]
			MP 56.1	DED - Exception Reporting
			MP 60.1	EWD only - recall code 498
	Protecting bridges, tunnels & other structures:		MP 8.5	DED/WED only, recall code 498
			MP 60.1	WWD only, recall code 498
			MP 70.5	DED/WWD only, recall code 438
Lakeside Subdivision 146.4 Miles in Length 28 TWDs Average distance apart: 5.23 miles Longest gap: 8.2 miles	Spokane MP 1.1	Pasco MP 147.5	MP 6.1	DED/Exception Reporting
	Sunset Jct.	SP&S Jct.	MP 14.3	DED/Exception Reporting
			MP 19.2	DED/Exception Reporting
			MP 25.7	Recall code 617
	MP 6.1-14.3		MP 31.4	DED/Exception Reporting
			MP 36.5	DED/Exception Reporting
			MP 41.3	DED/Exception Reporting
			MP 47.8	Exception code 618
			MP 52.8	DED/Exception Reporting
			MP 57.4	DED/Exception Reporting
			MP 62.5	DED/Exception Reporting
			MP 66.9	Recall code 627
			MP 72.5	DED/Exception Reporting
			MP 78.4	DED/Exception Reporting
			MP 82.3	DED/Exception Reporting
			MP 88.8	DED/Exception Reporting
			MP 94.2	Both tracks. Recall code 628
			MP 99.5	DED/Exception Reporting
			MP 104.6	DED/Exception Reporting
			MP 108.2	DED/Exception Reporting
			MP 112.4	DED/Exception Reporting
			MP 118.8	DED/Exception Reporting
			MP 122.3	Recall code 638
			MP 122.5	Wheel impact detector, no readout
			MP 126.3	DED/Exception Reporting
			MP 130.5	DED/Exception Reporting
			MP 134.6	Recall code 648, transmitted on radio
			MP 138.7	DED/Exception Reporting
				Pasco Terminal - MP 145.6
Fallbridge Subdivision 219.8 Miles in Length 28 TWDs	SP&S Jct. MP 229.7	Vancouver MP 9.9	MP 207.8	Recall code 718
			MP 190.2	Recall code737
			MP 177.2	Recall code 738
			MP 152.2	Recall code 598

Table 41: Details on BNSF Wayside Detectors in Washington State				
Subdivision	**Start**	**End**	**MP Location**	**Type**[118]
Average distance apart: 7.85 miles Longest gap: 17.0 miles	(MP 207.8 - MP 190.8)		MP 147.1	DED/Exception Reporting
			MP 142.2	DED/Exception Reporting
			MP 136.7	DED/Exception Reporting
			MP 131.86	DED/Exception Reporting
			MP 128.0	Recall code 758
			MP 118.6	DED/Exception Reporting
			MP 110.1	DED/Exception Reporting
			MP 105.1	DED/Exception Reporting
			MP 100.0	Recall code768
			MP 96.1	DED/Exception Reporting
			MP 89.6	DED/Exception Reporting
			MP 81.7	Recall code 788
			MP 73.9	DED/Exception Reporting
			MP 70.7	Recall code 798
			MP 66.0	DED/Exception Reporting
			MP 61.0	Recall code 818
			MP 58.6	DED/Exception Reporting
			MP 52.5	DED/Exception Reporting
			MP 48.4	Recall code 808
			MP 43.5	DED/Exception Reporting
			MP 37.6	Recall code 238
			MP 32.2	DED/Exception Reporting
			MP 25.1	DED/Exception Reporting
			MP 19.8	Recall code 508
				Vancouver Terminal MP 9.9
Seattle Subdivision 136.47 Miles in Length 12 TWDs Average distance apart: 11.37 miles Longest gap: 29.5 miles	Vancouver MP 136.5	Seattle MP 0.3 (KSS)	MP 113.5	Recall code 298
			MP 87.4	Recall code 258
			MP 57.9	Recall code 468
			MP 30.0	Recall code 268
	MP 87.4-57.9		MP 18.5	Recall code 518, DED
			MP 35.2X	DED/Exception Reporting
			MP 31.4X	DED/Exception Reporting
			MP 26.4X	Recall code 428
			MP 20.8X	DED/Exception Reporting
			MP 15.1X	DED/Exception Reporting
			MP 5.2X	Recall code 407
	Protecting bridges, tunnels & other structures:		MP 18.5	Recall code 518, DED
			MP 10.1	Recall code 528

Table 41: Details on BNSF Wayside Detectors in Washington State				
Subdivision	**Start**	**End**	**MP Location**	**Type**[118]
Scenic Subdivision 32.2 Miles in Length 4 TWDs Average distance apart: 8.05 miles Longest gap: 10.1 miles	King Street Station MP 0.0	Everett Jct. MP 32.2	MP 10.4	DED/EWD Recall code 548
			MP 17.1	Recall code 368
			MP 27.2	Recall code 358
	MP 17.1-27.2)			
	Protecting bridges, tunnels & other structures:		MP 6.0	DED/EWD - Main 2
			MP 10.4	DED/EWD Recall code 548
			MP 1776.2	Recall code 348
			MP 1771.1	DED/EWD - Recall code 329
			MP 1765.8	DED/Exception Reporting
	MP 1721.2-1697.3		MP 1762.0	Recall code 308
			MP 1756.8	DED/Exception Reporting
			MP 1745.7	DED/Exception Reporting
			MP 1735.0	Recall code 318
			MP 1730.7	DED/WWD - Recall code 738
			MP 1725.5	DED/EWD - Recall code 728
			MP 1721.1	DED/WWD - Recall code 317
			MP 1690.0	Recall code 308
			MP 1683.7	DED/Exception Reporting
			MP 1677.2	DED/Exception Reporting
			MP 1673.0	DED/Exception Reporting
			MP 1668.2	Recall code 298
			MP 1661.6	DED/EWD - Recall code 297
			MP 1654.7	Recall Code 278
	Protecting bridges, tunnels & other structures:		MP 1778.6	DED/EWD - Recall code 338
			MP 1771.1	DED/WWD - Recall code 329
			MP 1751.9	DED - Recall code 337
			MP 1740.5	DED - Recall code 319
			MP 1730.7	DED/EWD - Recall code 738
			MP 1725.5	DED/WWD - Recall code 728
			MP 1721.2	DED/EWD - Recall code 317
			MP 1697.3	DED - Recall code 309
			MP 1695.1	DED - Recall code 307
			MP 1661.6	DED/WED - Recall code 297
Columbia River Subdivision 168.6 Miles in Length 11 TWDs	Wenatchee MP 1650.2	Latah Jct. MP 1481.6	MP 1644.6	DED/Exception Reporting
		(Spokane)	MP 1638.1	DED/EWD Only - Recall code 277
			MP 1633.6	Recall code 518
			MP 1622.2	DED/EWD Only - Recall code 277

Table 41: Details on BNSF Wayside Detectors in Washington State				
Subdivision	**Start**	**End**	**MP Location**	**Type[118]**
Average distance apart: 15.33 miles Longest Gap: 27.7 miles	MP 1607.9-1580.2		MP 1607.9	Recall code 268
			MP 1580.2	Recall code 258
			MP 1555.8	Recall code 248
			MP 1543.2	Recall code 218
			MP 1519.3	Recall code 208
			MP 1495.9	Recall code 198
	Protecting bridges, tunnels & other structures:		MP 1638.1	DED/WWD Only
			MP 1624.2	DED
			MP 1622.2	DED/WWD Only
Yakima Valley Subdivision 125.10 Miles in Length 12 TWDs Average distance apart: 10.43 miles Longest Gap: 30.2 miles	SP&S Jct. MP 1.9	Ellensburg MP 127.0	MP 19.5	Recall code 588
	(Pasco)		MP 30.9	Slidefence detector MP 30.9 - MP 31.0
			MP 35.8	Slidefence detector MP 35.9 - MP 36.0
			MP 49.6	Recall code 238
	MP 49.6- 79.8		MP 79.8	Recall code 498
			MP 94.8	Recall code 478
			MP 101.2	DED/Exception Reporting
			MP 106.5	DED/Exception Reporting
			MP 106.5	Slidefence detector MP 106.5 - MP 107.3
			MP 110.2	DED/Exception Reporting
			MP 116.4	DED/Exception Reporting
			MP 124.2	EWD Only, Recall code 598
	Protecting bridges, tunnels & other structures:		MP 124.2	WWD Only, Recall code 598
Stampede Subdivision 102.6 Miles in Length 18 TWDs Average distance apart: 5.7 miles Longest Gap: 16.4 miles	Ellensburg MP 0.0	Stampede Wye MP 102.6	MP 9.2	DED/Exception Reporting
		(Auburn)	MP 13.9	DED/Exception Reporting
			MP 20.5	Recall code 518
			MP 36.9	Recall code 617
	MP 20.5-36.9		MP 43.5	DED (EWD Only) - Recall code 618
			MP 46.0	DED/Exception Reporting
			MP 49.0	DED/Exception Reporting
			MP 52.0	DED (WWD Only) - Recall code 537
			MP 56.4	DED/Exception Reporting
			MP 59.0	DED/Exception Reporting
			MP 62.9	Recall code 538

Table 41: Details on BNSF Wayside Detectors in Washington State				
Subdivision	**Start**	**End**	**MP Location**	**Type[118]**
			MP 66.8	DED/Exception Reporting
			MP 71.6	DED/Exception Reporting
			MP 77.9	DED/Exception Reporting
			MP 81.4	DED/Exception Reporting
			MP 86.0	DED/Exception Reporting
			MP 91.5	Recall code 528
			MP 100.6	WWD Only - Recall code 628
	Protecting bridges, tunnels & other structures:		MP 43.5	DED (WWD Only) - Recall code 618
			MP 52.0	DED (EWD Only) - Recall code 537
			MP 100.6	EWD Only - Recall code 628

Risk Mitigation Measures to Prevent Accidents in Extreme Conditions

As with all operating and safety rules that been put into effect by BNSF and other railroads, over 100 years of learning of what can go wrong and did go wrong has played a large role in the development and promulgation of railroad rules. Weather, extraordinary events such as earthquakes and track geometry have played a major role in the development of safe operating rules, as has employee performance requirements. Following is an overview in part of the specific requirements contained in the BNSF System Special Instructions No. 3:

Excessive Wind Instruction: When wind warnings are received meeting the wind speed criteria, the train dispatcher will notify all affected trains and employees with movement authority in the area providing the time and limits of the expected high winds. The following table will govern train movement:

Wind Speed 51 – 60 mph, Passenger Trains – 40 mph: Light engines, loaded bulk commodity unit trains handling coal, grain, ore, taconite, ballast, molten sulfur and potash (and presumably unit CBR trains) – not affected; All other trains – staging requirements.

Staging Requirements: Affected trains and equipment may proceed not exceeding 20 mph to a staging location (e.g. station, siding or location with double crossovers) as directed by the dispatcher to allow trains not affected by the wind warning to pass.1

Tornado Watch Instructions: When tornado watch or warnings are received, the train dispatcher will notify all affected trains and employees with authority in the area of the tornado watch or warning information. During a tornado watch, all train movements and yard activities will continue, keeping alert for any signs of weather change. When a crew knows they are in a watch area, the radio on a locomotive or a packset should be used to monitor instructions and information to and from the train dispatcher. In the event a crew spots a funnel cloud, the train dispatcher should be immediately notified, consistent with the crew's safety.

Tornado Warning Instructions: A “tornado warning” means a tornado has been sighted or verified by the National Weather Service or by persons associated with official weather spotters. The train dispatcher will keep trains and crews appraised of limits of tornado warnings. Trains crews are to follow instructions as follows:

- During a tornado warning all train movements and yard activities must stop. Any train en route will stop and employees should seek appropriate shelter consistent with the safety of all involved, avoiding the stopping of a train on a high bridge, across railroad and highway crossing at grade, or anywhere the presence of the train could be a hindrance.
- After a tornado warning has expired:
  - If determination is made that the path of the tornado crossed the tracks at the location or in the immediate vicinity of the train, crew members must inspect their train before moving to determine if any damage or derailment has occurred to the train or if the track structure has been damaged.
  - All trains within or entering the tornado warning limits may proceed, prepared to stop when approaching bridges, culverts, or other points likely to be affected until relieved by the dispatcher. The train dispatcher must be advised immediately of damage or unexpected conditions.
  - The train dispatcher must restrict trains as prescribed in the second bullet, until an inspection has been completed by division employees or all of the limits of the tornado,
  - Warnings have been traversed by a train and it is confirmed by the train crew(s) that no damage or unexpected conditions were observed.

Flash Flood Warnings: Weather information received by BNSF from AccuWeather Enterprise Solutions, Inc. is categorized as a ”Warning” when it describes conditions that require immediate action by the train dispatcher to notify the train crews of imminent danger. These warnings are immediately distributed to the relevant train dispatchers.

- When AccuWeather issues a “Flash Flood Warning”, the dispatching center will immediately advise all involved trains of the specific conditions. When crews of these trains are so advised and are not operating through areas which have been designated by the Division Engineer as being “critical”, passenger carrying trains will operate at a maximum speed of 50 mph through the limits identified in the warning, and freight trains will be operated at a maximum speed of 40 mph through those limits. These restrictions will remain in effect until the track has been inspected.
- If the “Flash Flood Warning” limits include locations identified as being “critical” all trains will be further limited to restricted speed within the critical locations until the track structure has been inspected on a priority basis at the request of the dispatching center. These temporary speed restrictions must remain in place until the track has been inspected and local personnel have assessed the need for modifications to the speed restrictions as conditions warrant.
- When local maintenance personnel become aware of current conditions that might produce flash flooding that could result in damage to BNSF track or structures, they will:
  - Immediately place the speed restriction described above on the affected route.

    - Inspect the track for washouts, side-scour wash, surface irregularities, and/or water over the rail.
    - Carefully inspect bridge foundations and drainage structure, with careful attention to bridges with mud sills, for erosion behind dump planks, head walls, erosion around piers and footings, and obstructions from drift and debris.
- If water level, turbulence, or other conditions make a thorough inspection impossible at the site of such a bridge, operations of all trains will be reduced to no more than restricted speed until it is possible to make a proper inspection.
- If, during the initial track inspection, there is any doubt about the safety of train operations over bridges, a qualified Structures employee must be called at once, and any speed restrictions that have been placed on the bridge will not be lifted until authorized by the Structures employee.
- Track and bridge foremen must continue to patrol past their respective territories if an adjoining territory is likely to have been damaged, and such damage might not have been discovered.

Cold Weather Restrictions: The correlations that exist between rail service failures, temperature,, train axle load, track and equipment conditions, and train speed are complex and involve many factors including equipment and track component design and material properties, their relative wear conditions, and the rail/wheel interaction for various traffic mixes and operating conditions. (Note: BNSF has divided its system into 2 regions taking into account cold weather factors. Washington is in Region 2, which basically encompasses the Northern Tier of its System).

Cold Weather Train Speeds: The Engineering Department has identified two factors which require Cold Weather Train Speeds, as follows:

- Low Temperature Threshold, Region 2 – minus 20 degrees Fahrenheit
- Temperature Differential Threshold, Region 2 – unless further restricted by individual Subdivision Special Instructions, be governed by the following:

When ambient (air) temperature drops below the Low Temperature Threshold, trains must not exceed the following speeds:

- In non-signaled territory: 40 mph for all trains;
- In block signal system limits: 40 mph for trains 100 tons per operative brakes and greater;
- key trains (carrying hazardous materials): 50 mph for trains less than 100 tons per operative brakes; and
- Passenger trains, Z-symbol Intermodal trains, or single level Intermodal trains: 65 mph.

If in doubt as to the temperature, contact the train dispatcher. Notify the train dispatcher when your train is restricted due to this requirement. These restrictions remain in effect until the ambient (air) temperatures rise above the Low Temperature Threshold.

Temperature Differential Threshold: The train dispatcher will make notification to trains that the temperature has exceeded the Temperature Differential Threshold. When so notified, trains must observe Cold Weather Train Speeds, by Region. Be aware that Cold Weather Train Speeds may still be required due to Low Temperature Threshold. In other words, once track inspection is completed following a Temperature Differential Threshold, the ambient (air) temperature may still be below the Low Temperature Threshold, requiring that Cold Weather Train Speeds still be observed.

Earthquake Instructions: BNSF has divided its system into 4 groups of State/Provinces, with Washington being in Group 4 with Oregon and British Columbia. Following are the instructions for an earthquake incident in Group 4.

When an earthquake is reported, the dispatcher will do the following by region:

- If the magnitude and epicenter is unknown, instruct all train within 150 miles of the reporting location to "proceed at restricted speed due to earthquake conditions." An acknowledgment must be obtained from each train or engine receiving these instructions.
- Once magnitude and epicenter are known, the following inspection criteria will apply:
    - If magnitude is less than 5.0, no inspection is required.
    - If magnitude is 5.0 or greater, response will depend on the group of states and provinces within which the epicenter is located and the following criteria will apply within the designated radius from the epicenter:
    - 5.0 – 5.49, Trains proceed at restricted speed until signals have been inspected – 70 miles.
    - 5.5 – 5.99, Trains proceed at restricted speed until signals and bridges have been inspected – 70 miles.
    - 6.0 - 6.49, Trains proceed at restricted speed until signals, track and bridges have been inspected – 150 miles. Trains stop until signals, track and bridges have been inspected – 80 miles.
    - 6.5 – 6.99, Trains proceed at restricted speed until signals, track and bridges have been inspected – 220 miles. Trains stop until signals, track and bridges have been inspected – 140 miles.
    - 7.0 – 7.49, Trains proceed at restricted speed until signals, track and bridges have been inspected – 400 miles. Trans stop until signal, track and bridges have been inspected – 300 miles.
    - 7.5 and above, as directed by the Command Center.5

Bakken Oil Conditioning

To reduce the volatility of Bakken crude oil it can be catalytically "conditioned" to remove volatile fractions. One industry study (Catalytic Resources LLC) on catalytic conditioning of Bakken crude oil showed the results in Table 42. The density (°API) is higher and the flash point is higher for the conditioned Bakken oil, which reduces the likelihood of fire or explosion as the result of a spill.

Table 42: Laboratory Test Data for Baseline Bakken Crude and Conditioned Product		
Test	**Bakken Crude Feedstock**	**Conditioned Bakken Product**
°API (D1298)	43	37. 2
Flash point (D93)	20°C	30°C
Vapor Pressure (D6377)	8. 48 psi (58. 5 kPa)	1. 2 psi (8. 27 kPa)
D86 Initial Boiling Point	38°C	92°C

On 9 December 9 2014, the Industrial Commission of North Dakota issued new conditioning standards, requiring all crude oil produced in the Bakken Petroleum System to be conditioned to remove lighter, volatile hydrocarbons, and thereby make the oil safer to transport by railroad. The new standards seek to address safety concerns stemming from several high-profile train derailments in Quebec, North Dakota, Alabama, and Virginia in the past year, and complement continuing efforts by the US Department of Transportation (DOT) to improve transportation of crude and ethanol by rail.

According to the North Dakota Industrial Commission Oil and Gas Division, the goal is to produce crude oil that does not exceed a vapor pressure of 13.7 psi. National standards recognize oil with a vapor pressure of 14.7 psi or less to be stable. An estimated 80% of Bakken wells will be able to produce a product below 13.7 psi vapor pressure by complying with the following temperature and pressure parameters:

- Operate all well site crude oil conditioning equipment within flow rate, pressure, and temperature ranges specified by the manufacturer;
- Operate at a pressure of no more than 50 psi must heat fluid to at least 43°C; and
- Operating at a pressure greater than 50 psi must heat fluid to at least 43°C and install equipment to recover vapors from the crude oil storage tanks.

Other Rail Risk Mitigation Measures

In response to the TÜV Rail Sciences study, to further improve safety, Port of Vancouver proposed all of the following enhancements:

- Maintain track to a minimum of FRA Class 2 standard to reduce levels of allowable track deviation and the associated risks of local track perturbations over time.
- Install a high guard rail frog on #15 turnout and double guard rail on the connection track between #15 turnout and the BNSF overhead bridge and through the "Trench" to further lessen the potential for damage.
- Construct the track structure with new concrete or wooden ties, premium fasteners, and continuously welded 141-pound rail to maintain a robust and less dynamically-varying track structure.
- Perform rail neutral temperature measurements during track construction to properly set track neutral temperature.

- Periodically measure track geometry to ensure safety against derailment as the track changes over time.

Risk Mitigation through Response Preparedness

The various prevention measures may reduce the probability of incidents in which there is spillage or the potential for spillage, but it is still necessary to have sufficient response preparedness to mitigate the impacts of a spill. There are some specific issues of concern for response preparedness for CBR spills:

- Current regulatory thresholds on railroads in the US by FRA/PHMSA are such that there are no comprehensive oil spill response plans and no regulatory review, planning standards, exercises, training, or response organization management structure for these types of incidents.
- Contingency planning needs to take into account the remoteness and inaccessibility of some of the locations in which CBR spills might occur, though this challenge is similar to that for pipeline spills; areas with railroad lines in which there currently are inadequate response sources and planning may need to evaluate preparedness;
- Preparedness for the potential fires and explosions that might occur in populated areas is of particular concern due to the possibilities of human casualties;
- In instances in which a burning tank car(s) does not present an immediate danger to populated areas, fire officials may choose to allow the fire to burn rather than put first responders at undue risk; this may significantly reduce the amount of oil that is left in the environment, but may present a risk for ignition of wildfires;
- Responses to spills of Bakken crude and other more volatile shale oils, or to heavier bitumen blends should focus on the characteristics of these oils and their potential behavior when spilled in inland areas as well as into waterways or aquifers; spill responders are increasingly better trained to deal with incidents of this type; and
- Bakken oil is not the only crude oil type that could burn in the event of a CBR derailment accident. Three recent incidents involving bitumen blends – dilbit and synbit – caused fires. The properties of the bitumen blends depend on the diluents used, which vary seasonally and regionally. More information about the potential flammability of these cargoes needs to be provided to spill responders.

The challenges for response to CBR spills are not unlike those for pipelines with respect to remote and inaccessible locations, as well as populated, high-consequence areas. There are great differences, though, with respect to the oil types.

Bakken Crude Spill Emergency and Cleanup Response Challenges

Because of the volatility of Bakken crude oil, the primary concern in the event of an actual or even a potential spill (e.g., a derailment) is the possibility of a fire and/or explosion in a highly-populated area. For locations in which wildfires are a seasonal concern (e.g., eastern Washington and parts of California), there are additional fears about starting massive wildfires. Much of the attention for preparedness for Bakken crude spills has been focused on emergency response with respect to evacuations and fire-fighting.

Regions, such as the US states of Washington and New York, that have rather suddenly become CBR transport corridors, have determined that their first-responder emergency preparedness is severely insufficient in many cases.[119] Local fire departments, which would generally be the first responders in a CBR derailment incident, are developing plans for massive evacuations and emergency responses to incidents that may occur in highly-populated areas. For example, in Seattle, Washington. the fire chief expressed concerns about a CBR incident that might occur adjacent to a popular sports stadium in the city that lies adjacent to a railroad line.[120] This same line had a CBR derailment incident in July 2014 just a short distance from the stadium. While there was no spillage and no fire, the possibility of a massive fire in that location was of great concern. State officials are currently evaluating emergency response capabilities for these types of events. Similar studies are going on in New York State[121] and in Canada.[122]

There is fairly limited experience with Bakken crude spills from which to draw general recommendations for response, but two responses have been documented to some extent – the Lynchburg, Virginia, and Aliceville, Alabama, CBR derailment incidents. In both cases, some of the oil burned, but some ended up in water, and in the Alabama case in wetland areas. Another case involved a tank barge spill of Bakken crude.[123] The oil floated on the water surface and was carried downstream by currents. The light nature of the oil led to high evaporation rates, reducing the amount of oil in the water and on substrates. Sorbent- and containment booming, along with water spraying methods, were used to corral oil for skimming and vacuum pumping. Sorbent pompoms and pads were used in some areas.

Diluted Bitumen Spill Response Challenges

Since CBR spills may occur near streams and other waterways, responses to CBR spills of diluted bitumen will require capabilities for submerged oils, in case that becomes a factor.[124] But, for the most part, response to these spills will require the general preparedness for inland locations, many of which will not be in waterways. Some of these responses may be in populated areas that are transected by rail lines. Again, flammability may be an issue, depending on diluent content.

[119] Etkin et al. 2015.
[120] Graff and Vickery 2014.
[121] NY DEC 2014.
[122] Canadian Association of Fire Chiefs 2014.
[123] Doelling et al. 2014.
[124] Brown and Nicholson 1991; Brown et al. 1992; Center for Spills in the Environment at University of New Hampshire 2013.

Appendix: JLARC Impact Methodology

The environmental impact of a specific spill is determined by the sensitivity by geographic location (*G*), seasonal timing (*T*), and oil type (*J*). For a particular location, season, and oil type combination (G_E, T_E, J_E), the magnitude of impact is determined by the volume of spillage (V_S).

[1] $$I_{S_E} = V_S \cdot (G_E T_E J_E)$$

Where:

E = environment

I_{SE} = impact of spill in specific environment

V_S = volume of spillage

G_E, T_E, J_E = combination of geographic location, seasonal timing, and oil type

JLARC Study Approach

The values for G_E, T_E, J_E were determined by work previously conducted for Washington Department of Ecology and Washington State Joint Legislative Audit and Review Committee (JLARC).[125] The approach is based primarily on the Washington Compensation Schedule as described below.[126] Basically, the State was mapped out with respect to the sensitivity of different geographic areas to different types of oil (Table 43) in different seasons (Table 44). Based on °API gravity and other characteristics, Bakken crude oil can be considered in the "light" category and diluted bitumen in the "heavy" category.

Table 43: Oil Categories Applied in JLARC Study (Washington Compensation Schedule)

Oil Category	Oil Types Included
Crude	crude oil, crude condensate
Heavy	heavy fuel oil, intermediate fuel oil, Bunker C, No. 6 fuel oil, No. 5 fuel oil, asphalt, wax
Light	diesel, mineral oil, motor oil, low-sulfur marine gas oil, lubricating oil, hydraulic oil, No. 2 fuel, home heating oil, bilge slops, waste oil, naphtha, chlorinated oil, other oil, unknown oil
Gasoline	various grades of gasoline
Jet Fuel	kerosene
Non-Petroleum	biodiesel, animal fat, vegetable oil, volatile organic distillate

Table 44: Seasons Applied in JLARC Risk Scoring

Season	Months Included
Spring	March, April, May
Summer	June, July, August
Fall	September, October, November
Winter	December, January, February

[125] Based on: Etkin 2009; Etkin et al. 2009; French-McCay et al. 2008, 2009; State of Washington JLARC 2009.

[126] WAC 173-183-400.

The geographic zones analyzed were divided into marine/estuarine zones (Figure 27) and inland areas (Figure 28). The relevant geographic zones for the Vancouver Energy analysis are:

- Western Columbia River (downstream of Bonneville Dam) – zone 12
- South Puget Sound – zone 10 (empty trains only)
- Central Puget Sound – zone 9 (empty trains only)
- North Puget Sound – zone 8 (empty trains only)
- Eastern Columbia and Snake Rivers (upstream of Bonneville Dam) – zone 14
- East of Cascades – zone 17
- West of Cascades – zone 16 (empty trains only)

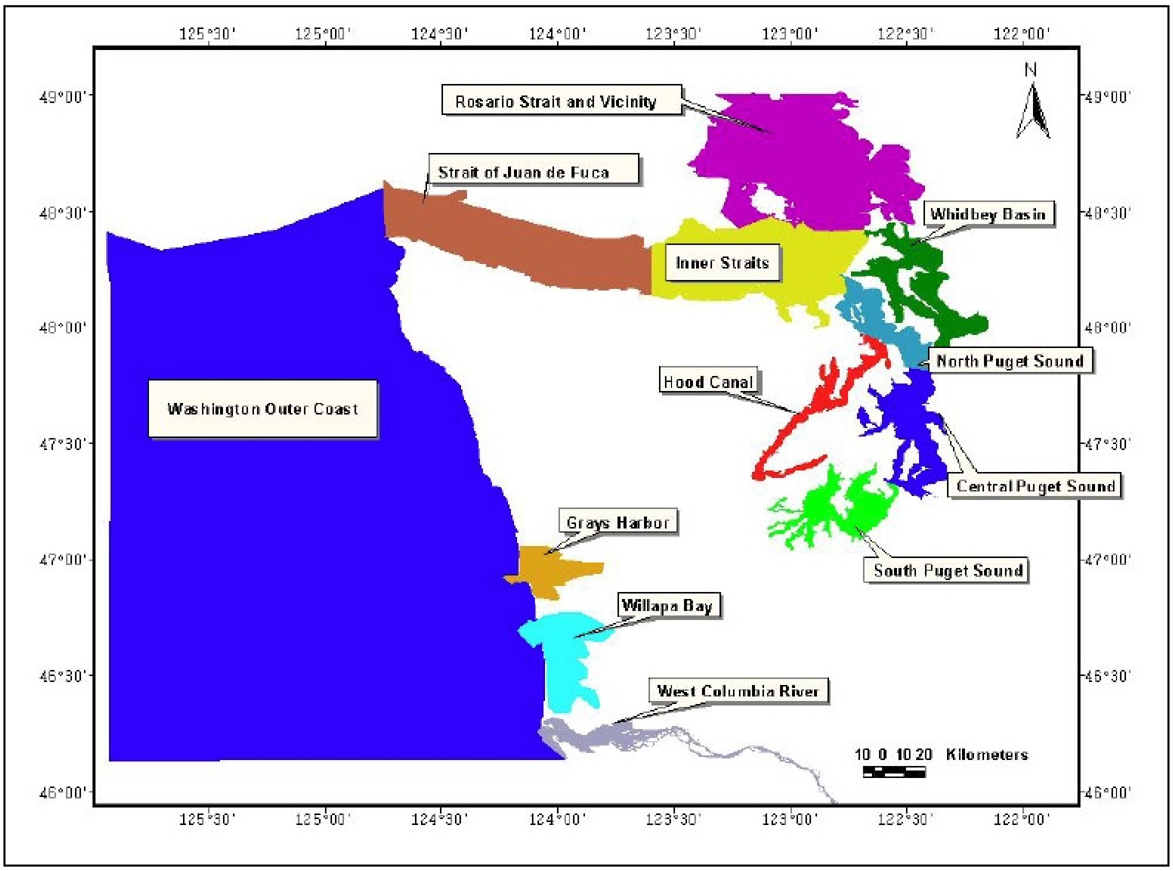

Figure 27: JLARC Study Marine and Estuarine Zones

The Spill Vulnerability Score (*SVS*) by season for each of the six oil type categories used in the study rates the vulnerability of public resources to spilled oil based on:

- The propensity of oil to cause acute toxicity;
- The propensity of oil to cause mechanical injury; and
- Its persistence.

The *SVS* is determined by summing vulnerability scores for habitats, birds, mammals, marine fish, shellfish, salmon, and recreational use for the sub-region and most sensitive season impacted by the spill.

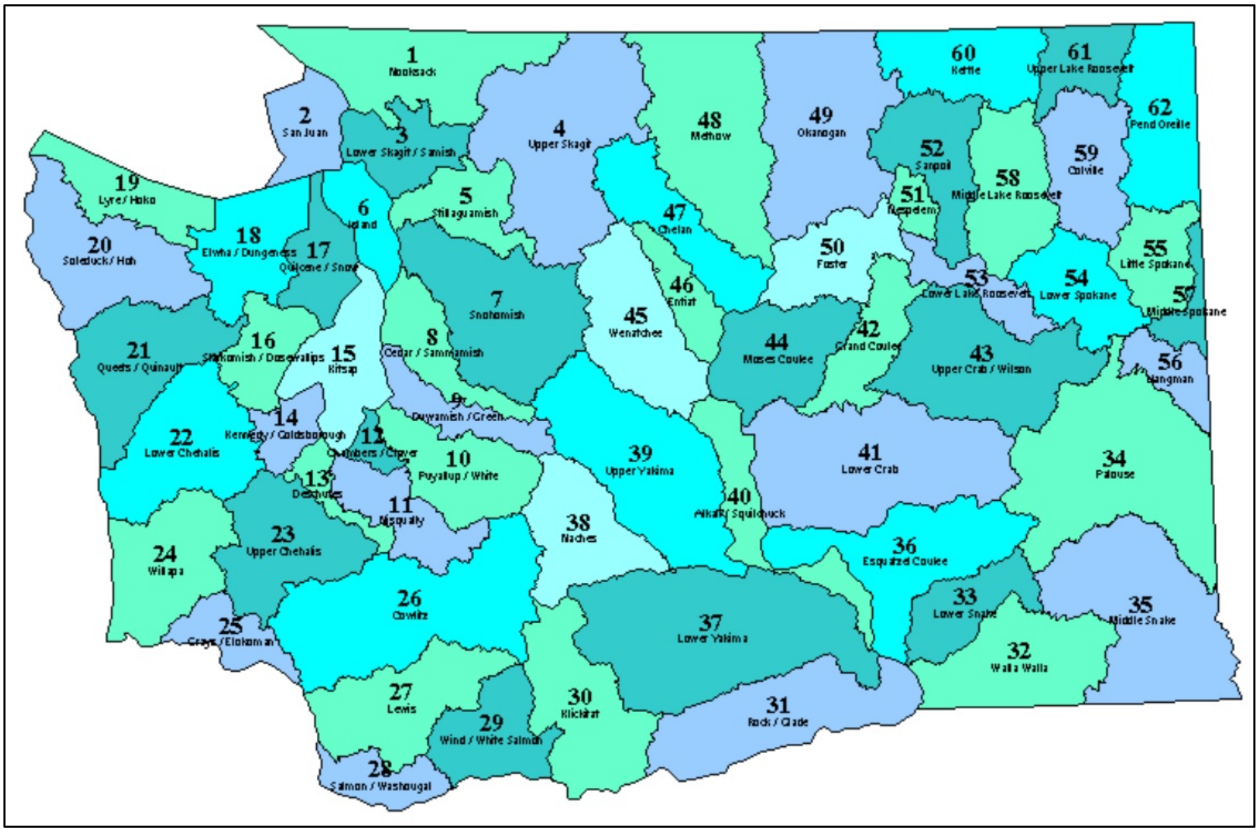

Figure 28: JLARC Study Inland Zones (with WRIA Boundaries)[127]

Marine and estuarine habitats are ranked and scored for *Habitat Vulnerability Score (HV)* for relative vulnerability to oil spills on a 1:5 scale (*HV* = 5, greatest vulnerability, *HV* = 1, least vulnerability). These scores are based on:

- Presence of living public resources at risk;
- Predicted sensitivity to acute toxicity;
- Predicted sensitivity to mechanical injury; and
- Persistence effects of oil based on energy regime of the habitat and propensity to entrain oil.

The Habitat Vulnerability Score *(HVS)* is defined as the habitat vulnerability to oil's propensity to cause impact, varies by habitat type. Habitats are divided into 37 habitat types under categories (marine intertidal,

[127] Water Resource Inventory Area

marine subtidal, estuarine intertidal, estuarine subtidal), and each type is given three habitat vulnerability scores:

- Acute toxicity,
- Mechanical injury potential, and
- Persistence.

These are identified in each cell in the habitat grid for the sub-region. If seagrass or kelp beds are present, that portion of habitat is considered a separate habitat type. The habitat vulnerability score is multiplied by a factor of 1.5 if seagrass or kelp beds are present.

The *HVS* for a particular sub-region is determined by averaging all the *HVS* in the sub-region based on the Habitat Grid:

- Marine bird vulnerability score;
- Marine mammal vulnerability score;
- Marine fish vulnerability score;
- Shellfish vulnerability score;
- Salmon vulnerability score; and
- Recreation vulnerability score.

Each of these scores varies by sub-region and season.

The *SVS* for the sub-region is calculated by summing the averaged *HVS* to the sum of the vulnerability scores for marine birds, marine mammals, marine fish, shellfish, salmon and recreational use. The *SVS* for the zone is an area weighted average of the values for all the sub-regions contained within the zone.

Impact Risk Methodology for Estuarine/Marine Areas (Non-Columbia River)

The geographical zones were divided into sub-regions, as defined by the WCS, and then each sub-region was divided into a habitat grid with each cell representing a habitat type. The relative impact score (*RI*) for each cell, on a scale of 1-50 (as a relative scale), was calculated as:

[2]
$$RI_{ij} = 0.1 \cdot [(OIL_{AT} \cdot SVS_{AT_j}) + (OIL_{MI} \cdot SVS_{MI_j}) + (OIL_{PER} \cdot SVS_{PER_j})$$
$$SVS_{ij} = HVS_i + BVS_i + MVS_j + MFVS_j + SFVS_j + SAVS_j + RVS_j$$

Where:

$SVS_{i,j}$ = spill vulnerability score (from WAC 173-183-400(3), Equation 2)

OIL_{AT} = Acute Toxicity Score for oil

OIL_{MI} = Mechanical Injury Score for oil

OIL_{PER} = Persistence Score for oil

0.1 = multiplier to adjust score to the 1-50 range

i = oil property – acute toxicity (AT), mechanical injury (MI), or persistence (PER)

j = most sensitive season affected by the spill: spring, summer, fall or winter

HVS_i = habitat vulnerability to oil's propensity to cause impact, varies by habitat type and each of acute toxicity (AT), mechanical injury (MI), or persistence (PER)

BVS_j = marine bird vulnerability score, varies by sub-region and season

MVS_j = marine mammal vulnerability score, varies by sub-region and season

$MFVS_j$ = marine fish vulnerability score, varies by sub-region and season

$SFVS_j$ = shellfish vulnerability score, varies by sub-region and season

$SAVS_j$ = salmon vulnerability score, varies by species, habitat type and season

RVS_j = recreation vulnerability score, varies by sub-region and season

Acute toxicity is the degree to which oil is capable of causing adverse effects on fish, invertebrates and wildlife after short-term exposure (hours to days). The Acute Toxicity Score for the oil (from WAC 173-183-340, Equation 3) was calculated as:

[3] $$OIL_{AT} = \frac{[(SOL_1 \cdot PCTWT_1) + (SOL_2 \cdot PCTWT_2) + (SOL_3 \cdot PCTWT_3)]}{107}$$

Where:

SOL_i = solubility in seawater of i-ring aromatic hydrocarbons, where i =1, 2 or 3

$PCT\text{-}WT_i$ = percent weight of i-ring aromatic hydrocarbons in the spilled oil, i =1, 2 or 3

The Acute Toxicity Score is therefore based on the percentage of bioavailable components in the oil that could cause toxicity to fish, invertebrates and wildlife. Bioavailable components are those that are soluble or semi-soluble in water (i.e., 1- to 3-ring aromatic compounds), such that they can dissolve from the oil into water and then be taken up by the organisms directly from the water or through the gut (if oil is ingested).

The Mechanical Injury Score for the oil (from WAC 173-183-340, Equation 4) was used:

[4] $$OIL_{MI} = \frac{(SP - 0.688)}{0.062}$$

Where:

SP = *specific gravity of the spilled oil*

The Mechanical Injury Score is higher the heavier (denser) and more viscous the oil. This measures the propensity of oil to coat, fowl and/or clog organisms and their appendages and apertures, such that movements and normal behaviors are mechanically inhibited.

Persistence relative ranking scores (from WAC 173-183-340, Equation 5) were determined by empirical data describing the length of time the spilled oil is known to (or likely to) persist in a variety of habitat types (Table 45). The Oil Acute Toxicity, Oil Mechanical Injury, and Oil Persistence scores by oil type are in Table 46. Non-petroleum oils are assumed to have the same effects scores as for jet fuel. Based on °API gravity and other characteristics, Bakken crude oil can be considered in the "light" category and diluted bitumen in the "heavy" category.

Table 45: Oil Persistence Scores

Score	Anticipated Persistence
5	5-10 years or more
4	2-5 years
3	1-2 years
2	1 month to 1 year
1	days to weeks

Table 46: Effects Scores by Oil Type

Oil Category	Acute Toxicity	Mechanical Injury	Persistence
Crude Oils	0.9	3.6	5
Heavy Oils	2.3	5.0	5
Light Oils	2.3	3.2	2
Gasoline	5.0	1.0	1
Jet Fuel	1.4	2.4	1
Non-Petroleum Oils	1.4	2.4	1

Impact Risk Methodology for Western Columbia River

Relative impact scores for the Columbia River Estuary using the WCS were calculated follows:

The Columbia River Estuary has been divided into a 1 km^2 grid, with scores for each oil type and season:

- Bird, mammal, fish, invertebrate, habitat and human use sensitivities have been evaluated and rated within each cell.
- Marine and estuarine habitats are ranked and scored for relative vulnerability to oil spills on the same 1:5 scale as the system used for the rest of Washington State.

The *Vulnerability Score* (*VS*) is then derived by:

- The *VS* for a particular cell is determined by summing the sensitivity scores assigned to each cell for bird, fish, mammal, invertebrate, habitat and human use resources.

- These scores are averaged for each season over the entire area.

Final scores for each zone (*per gallon)* are then derived for the Columbia River Estuary based on oil type, *SVS(season),* and range of spill volume (assuming no credit for spill cleanup.)

The relative impact score (*RI*), on a scale of 1-50 (as a relative scale), employed the equations and scores included in the WCS statute (using procedures in WAC 173-183-810):

[5] $$RI_{ij} = 0.2 \cdot (OIL_{AT} + OIL_{MI} + OIL_{PER})$$

Where:

SVS_j = spill vulnerability score (from WAC 173-183-500(3), Equation 7)

0.2 = multiplier to adjust score to the 1-50 range

j = the most sensitive season affected by the spill

OIL_{AT} *,* OIL_{MI} *, and* OIL_{PER} *are as defined above* (Table 46).

The mean for all cells in the gridded area was used:

[6] $$SVS_j = \frac{\sum VS_i}{x}$$

$$VS_{ij} = BSS_{ij} + FSS_{ij} + MSS_{ij} + ISS_{ij} + HSS_{ij} + HUS_{ij}$$

Where:

VS_i = vulnerability score for cell i for a particular season

x = number of cells in the grid

BSS = bird sensitivity score (Appendix 6 of Chapter 173-183 WAC)

FSS = fish sensitivity score (Appendix 6 of Chapter 173-183 WAC)

MSS = mammal sensitivity score (Appendix 6 of Chapter 173-183 WAC)

ISS = invertebrate sensitivity score (Appendix 6 of Chapter 173-183 WAC)

HSS = habitat sensitivity score (Appendix 6 of Chapter 173-183 WAC)

HUS = human use sensitivity score (Appendix 6 of Chapter 173-183 WAC)

Impact Risk Model Methodology for Lakes, Rivers and Streams

According to Chapter 173-183 WAC, the relative impact score for spills into inland lakes, rivers and streams should be calculated as follows:

[7]

$$PG_s = 0.08 \cdot SVS \cdot (OIL_{AT} + OIL_{MI} + OIL_{PER})$$
$$SVS = FVS \cdot HI$$

Where:

PG_s	= per gallon impact risk score for streams, rivers and lakes
SVS	= Spill vulnerability score [from WAC 173-183-600(3)]
OIL_{AT}	= Acute Toxicity Score for Oil [from WAC 173-183-340]
OIL_{MI}	= Mechanical Injury Score for Oil [from WAC 173-183-340
OIL_{PER}	= Persistence Score for Oil [from WAC 173-183-340]
0.08	= multiplier to adjust to the 1-50 range
FVS	= Freshwater Vulnerability Score
HI	= Habitat Index

The values of OIL_{AT} , OIL_{MI} , and OIL_{PER} are the same as for the estuarine and marine zones (Table 46). The rating factor used for the inland model is 0.08 to adjust to a relative, but non-monetary, scale of 1-50.

To derive a FVS (Freshwater Vulnerability Score), freshwater streams, rivers, lakes, and portions thereof, are classified into 5 water types based on water quality, uses and support of fish and other aquatic life. The rating of biological and recreational resources ranges from 1 to 5, where 5 represents the most sensitive category and 1 represents the least sensitive category as follows:

Freshwater Vulnerability Score (FVS):

- 5 = "Type 1 waters"
- 4 = "Type 2 waters"
- 3 = "Type 3 waters"
- 2 = "Type 4 waters"
- 1 = "Type 5 waters”

There was no state-wide database with water types classified. Based on WAC 222-16-031 Interim Water Typing System, most waters would be Type 1. Thus, the Freshwater Vulnerability Score was set at 5, for “Type 1 waters”. As a result, the water type classification is not a discriminating factor in the risk ratings developed for inland waters.

In order to account for that degradation prior to assessing damages using the compensation schedule, a habitat index (*HI*) was calculated to represent existing stream conditions prior to the oil spill. The HI measures the amount of stream degradation from natural conditions and is calculated using the following formula:

[8] $$HI = \left[\frac{(P1 + P2 + P3 + P4 + P5 + P6)}{Np} \right] \cdot [f1 \cdot f2 \cdot f3]$$

Where:

P1	= barriers to natural fish movement
P2	= urbanization
P3	= condition of riparian vegetation
P4	= condition of floodplain
P5	= land use of watershed
P6	= impoundment[128]
Np	= number of P parameters used to calculate HI
f1	= channel modifications
f2	= water quality[129]
f3	= streambed conditions[130]

Below is an outline of the model for calculating *HI*. The research team eliminated two of the P variables and made constant one of the f values, because data required to accurately represent the intent was too fine scale for the JLARC study.

P3	= condition of riparian vegetation
P4	= condition of floodplain
f3	= streambed condition

Such fine scale data is appropriate for an individual spill, but for statistics with large numbers of spills, it was found there was not sufficient statewide data to represent the information appropriately. Due to this elimination, *Np=4* is used on the Habitat Index equation. The factor *f3* is not a discriminating factor in the risk ratings developed for inland waters.

The research team also altered one of the variables, *f1*, from channel modification to health of salmon and steelhead runs, as the channel modifications are too fine scale to find statewide data. However, the

[128] The original formula from WAC 222-16-031 uses the term "flow alteration", but this definition was changed to "impoundment" as it was considered to be more consistent with scoring definitions.

[129] The original formula from WAC 222-16-031 uses the term "impoundment", but this definition was changed to "water quality" as it was considered to be more consistent with scoring definitions.

[130] The original formula from WAC 222-16-031 uses the term "water quality", but this definition was changed to "streambed condition" as it was considered to be more consistent with scoring definitions.

calculation of the scoring uses an index of net fish reduction. They used health of the salmon and steelhead runs as a proxy for the fish reduction and channel modification.

The resulting modified Habitat Index equation is:

[9]
$$HI = \left[\frac{(P1 + P2 + P5 + P6)}{Np} \right] \cdot [\, f1 \cdot f2 \,]$$

Where:

P1 = barriers to natural fish movement

P2 = urbanization

P5 = land use of watershed

P6 = impoundment

Np = number of P parameters used to calculate HI = 4

f1 = channel modifications

f2 = water quality

f3 = streambed condition = 0.8.

Below is a description of the impact model as implemented in the JLARC study. In order to perform the calculation for Habitat Index (HI), each individual parameter was determined by geographic area using Geographical Information System (GIS) databases, and a score developed by each WRIA (2). An area-weighted average *HI* score by zone (as defined by Figure 28) was calculated from the watershed scores.

Barriers to Natural Fish Movement (*P1*)

According to the Washington Compensation Schedule, barriers, to some degree, limit the free passage of fish upstream, thus limiting the ability of streams to recover. The scoring of this parameter is based on the influence of barriers in the natural dispersal of fish populations. The rating is based on the height of barriers in the watershed (Table 47).[131] The locations of fish barriers are in Figure 29.

Table 47: Scoring of Barriers to Natural Fish Movement (P1)

Score	Rating Qualification
10	No manmade obstructions to free upstream passage of fish
8	No dams or other structures causing a vertical drop of more than 1 foot during low flow
5	No dams or other structures causing a vertical drop of more than 3 feet during low flow
3	No dams or other structures causing a vertical drop of more than 10 feet during low flow
0	One to several dams or other structures each causing a drop of more than 10 feet during low flow

[131] Fish barrier data from Washington Department of Fish and Wildlife (WAFW); these data contain the full dataset on dams from the Washington Department of Ecology (http://www.ecy.wa.gov/services/gis/data/data.htm) and the Washington Department of Transportation (WDOT fish) barrier data.

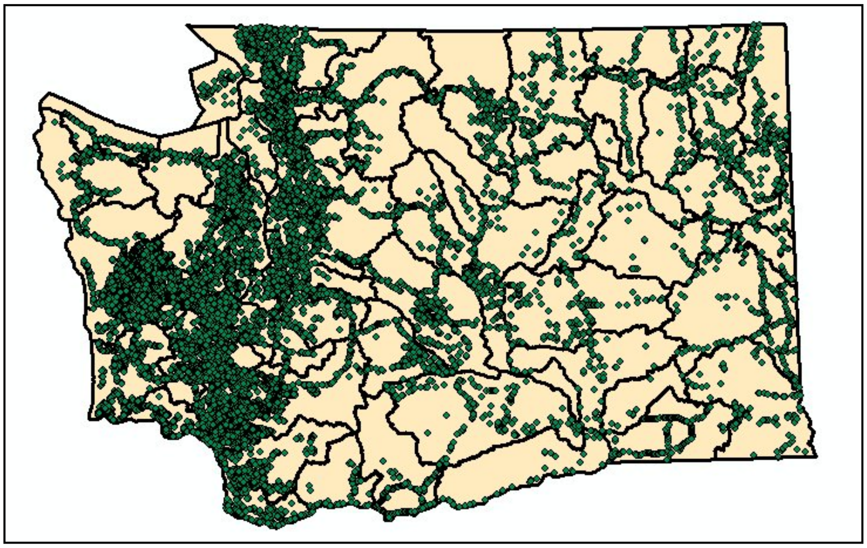

Figure 29: Coverage of Washington State Fish Barrier Data (WDFW)[132]

The number and mean height of fish barriers within each watershed (or WRIA) boundary, using the ECY GIS layer of WRIA boundaries (Figure 28), were calculated and used to assign the *P1* score for the watershed. The score (Table 48) was assigned based on the mean height of barriers in the WRIA, excluding barriers on the Columbia and Snake Rivers. The Columbia and Snake River zone and the Lake Union-Washington zone were rated on their own, with a score of 0, because there are significant barriers to fish passage in these two zones.

Urbanization (*P2*)

According to the Washington Compensation Schedule, urban development has historically had negative habitat effects on freshwater ecosystems. The percent of urban development in a watershed directly influences siltation, riparian abuse, and water quality deterioration. The scoring of this parameter is based on the percent of urbanization in the stream watershed (Table 48). The 2001 National Land Cover Database (NLCD) was used for this analysis. The NLCD categories for "Developed, Low Intensity", "Developed, Medium Intensity", and "Developed, High Intensity" were used. Totals areas of these three categories were summed and divided by the total WRIA area to estimate the percentage of urban development in the WRIA.

Table 48: Scoring of Urbanization (P2)

Score	Rating Qualification
10	Less than 5 percent of the watershed in urban development
8	Five to 10 percent of the watershed in urban development
5	Ten to 40 percent of the watershed in urban development
3	Forty to 70 percent of the watershed in urban development
0	Seventy to 100 percent of the watershed in urban development

[132] These Fish Barrier data include WDOT fish barrier data, Ecology dams information and other fish barrier data.

Condition of Riparian Vegetation (*P3*)

According to the Washington Compensation Schedule, riparian vegetation is important to seventy percent of the animal and bird species in Washington for some part of their life cycle. It also exerts thermal regulatory and thermal controls for the aquatic system. The scoring of this parameter is based on the percent of banks that are protected by effective riparian vegetation (Table 49). As noted above, a rating for Riparian Vegetation was not included.

Table 49: Scoring of Riparian Vegetation (P3)

Score	Rating Qualification
10	Ninety to 100 percent of the banks are protected by appropriate perennial vegetation
8	Sixty to 90 percent of the banks are protected by appropriate perennial vegetation
5	Forty to 60 percent of the banks are protected by appropriate perennial vegetation
3	Ten to 40 percent of the banks are protected by appropriate perennial vegetation
0	Zero to 10 percent of the banks are protected by appropriate perennial vegetation

Condition of Flood Plain (P4)

According to the Washington Compensation Schedule, the condition of the floodplain forecasts the amount of sedimentation and erosion in the watershed and as such is a primary predictor of stream degradation. The rating of the parameter is described in Table 50. As mentioned above, a rating for the condition of the flood plain was not included.

Table 50: Scoring of Flood Plain (P4)

Score	Rating Qualification
10	Little or no evidence of active or recent erosion of the floodplain during floods
5	All segments show evidence of occasional erosion of the floodplain. Stream channel essentially intact
0	Floodplain severely eroded and degraded, stream channel poorly defined with much lateral erosion and much reduced flow capacity

Land Use of Watershed (*P5*)

According to the Washington Compensation Schedule, land use practices exert a great deal of influence on the quality of the aquatic habitat. The rating of this parameter is as described in Table 51.

Table 51: Scoring of Land use of watershed (P5)

Score	Rating Qualification
10	> 80% of watershed protected by timber, improved pasture, terraces, or other conservation practices
8	60% to 80% of watershed protected by timber, improved pasture, terraces, or other conservation practices
5	40%to 60% of watershed protected by timber, improved pasture, terraces, or other conservation practices
3	20% to 40% of watershed protected by timber, improved pasture, terraces, or other conservation practices
0	0% to 20% of watershed protected by timber, improved pasture, terraces, or other conservation practices

To develop a score, land cover maps delineated by watershed (WRIA) boundary were analyzed. [133] From these maps, forested areas are easy to determine. However, areas of "improved pasture" cannot be determined from normal pasture, nor can we determine terraces or other conservation practices. Hence, the scores were based on the percentage cover of Evergreen Forest and Mixed Forest over each WRIA.

Flow alteration (*P6*) ("Impoundment" Under New Organization)

According to the Washington Compensation Schedule, alteration of the natural flow regime can frequently alter habitat conditions that are necessary for certain behavioral and ecological needs of species. The rating of this parameter is described in Table 52.

Table 52: Scoring of Flow Alteration (P6)

Score	Rating Qualification
10	<1% watershed controlled by impoundments and/or < 50% of watershed controlled by farm ponds
8	1% to 30% watershed controlled by impoundments and/or <50% of watershed controlled by farm ponds
5	31% to 59% watershed controlled by impoundments and/or <50% of watershed controlled by farm ponds
3	60% to 95% watershed controlled by impoundments and/or < 50% of watershed controlled by farm ponds
0	(% to 100% watershed controlled by impoundments and/or <50% of watershed controlled by farm ponds

To analyze this, the impoundment volumes from the Washington Dept. of Ecology Dam Safety Unit were used. The data lists all the storage volumes (as acre-feet) of all the dams in the State of Washington. Calculations for this factor were based on the ratio of mean storage volume to WRIA area, i.e. storage per unit area of the watershed. The ratios were multiplied by 100 to bring them into the range of the ratings in Table 52 and the calculated results were scored.

Habitat Alteration Functions (*F*)

According to the WCS, each habitat alteration function (*F*) has the power to reduce the habitat quality rating, dependent on the type and extent of alteration. Functions are expressed on a scale of 0 to 1.0.

Channel Modifications (*F1*)

According to the WCS, channel modification can have a dramatic effect on the ability of a stream to provide for a diversity of habitats. The channel modification rate parameter is rated as:

[10] $$F_1 = 1.0 - (SM \cdot FR)$$

Where:

F_1 = Channel modification rate

SM = Percent stream reach modified, expressed as a decimal

[133] Maps and GIS data are available at Washington Department of Ecology and US Geological Survey websites, respectively: http://www.ecy.wa.gov/services/gis/maps/wria/lc/lc.htm ;
http://landcover.usgs.gov/show_data.php?code=WA&state=Washington
http://edcftp.cr.usgs.gov/pub/data/landcover/states/

FR = Percent fish reduction, expressed as a decimal

Scoring for this parameter is in Table 53. For this analysis we used information from the WFS on the health of salmon and steelhead from the 2002 Salmonid Stock Inventory (SASI) runs to indicate the health of streams in each watershed.[134]

Table 53: Scoring for % Fish Reduction (F1) in Washington Compensation Schedule	
Channel Modification	**% Fish Reduction**
Clearing, Snagging	25
Channel Realignment	80
Channel Paving	90

With these data, the health of salmon and steelhead runs is evaluated as one of four measures. The measures and new scoring for *f1* are in Table 54. Average SASI was computed for each WRIA. For WRIAs with no data available, or if stocks are of unknown status, the average of surrounding WRIAs was used to make a continuous field over the State. A value was assigned to the Columbia and Snake Rivers.

Table 54: Scoring of the Health of Salmon and Steelhead Runs[135]	
Score	**Rating Qualification**
10	Run is considered healthy
7	Run is significantly reduced
3	Run is in critical condition
0	Run is extinct

Water Quality (*F2*)

According to the Washington Compensation Schedule, water quality exerts a variety of detrimental and/or beneficial effects on the aquatic ecosystem. The scoring for this parameter is described in Table 55. To develop a score, 2004 303(d) Impaired and Threatened Water Body Maps by WRIA boundary was used.[136] The scores assigned to each water quality class are in Table 56. The average score for each WRIA was then determined. A value was also assigned to the Columbia and Snake Rivers.

Table 55: Scoring of Water Quality (F2)	
Score	**Rating Qualification**
1.0	Stream water unpolluted. No pollutants detected by standard methods
0.8	Occasional above normal levels of one or more water pollutants usually present, but detectable only by analysis
0.5	Occasional visible signs of oversupply of nutrients or other pollutants detected by analysis
0.4	Occasional fish kills averaging about every 4 years or more
0.2	Occasional fish kills occurring more often than every 4 years
0.0	Grossly polluted waters with fish kills occurring annually or more frequently

[134] http://wdfw.wa.gov/fish/sassi/intro.htm

[135] This is the scoring basis for *F1* in the present application.

[136] http://www.ecy.wa.gov/services/gis/maps/wria/303d/303d.htm

Table 56: Scoring for Water Quality Using 303(d) Ratings	
Score	**Rating Qualification**
1.0	"AA" Outstanding water quality.
0.9	"A" Excellent water quality.
0.7	"B" Good water quality
0.5	"C" Fair water quality

Streambed Condition (F3)

According to the Washington Compensation Schedule, the condition of the substrate habitat can be altered in such a way as to reduce the effective habitat available to the aquatic community as a whole. This parameter is ranked as shown in Table 57. As discussed earlier, the data required to score this parameter are too fine scale for a statewide analysis. Instead, we have estimated a constant value of 0.8 for streambed condition and a conservative measure (neither very high nor very low). The values for Lake Union / Lake Washington were assigned those of surrounding WRIA 8, Cedar-Sammamish, except that *P1* = 0, as noted above.

Table 57: Scoring of Streambed Condition (F3)	
Score	**Rating Qualification**
1.0	No apparent unstable material in channel with substrate of bedrock, boulders, rubble, gravel or firm alluvium
0.9	Traces of unstabilized silt, sand, or gravel in quiet areas or large pools with firm substrate
0.8	Quiet areas covered with unstable materials, deep pools restricted to areas of greatest scour
0.7	Pools shallow, filled with silt, sand or gravel, riffles contain noticeable silt deposits
0.5	Streambed completely covered by varying thicknesses of transported material such as silt, sand and gravel
0.0	Stream channel nearly or completely filled with unconsolidated, transported material; no surface flow except during floods

Impact Risk Model for Wetlands

According to Chapter 173-183 WAC, the rating factor for spills into inland freshwater wetlands should be calculated as follows:

[11]
$$PG_w = 10 \cdot SVS \cdot (OIL_{AT} + OIL_{MI} + OIL_{PER})$$
$$SVS = WVS$$

Where:

PG_w = per gallon impact risk score for wetlands

SVS = Spill Vulnerability Score

OIL_{AT} = Acute Toxicity Score for Oil [from WAC 173-183-340]

OIL_{MI} = Mechanical Injury Score for Oil [from WAC 173-183-340]

OIL_{PER} = Persistence Score for Oil [from WAC 173-183-340]

10 = multiplier to adjust to the 1-50 range

WVS = wetlands vulnerability score (from WAC 173-183-710)

In WAC 173-183, wetlands vulnerability is based on wetlands classification as Category I, II, III or IV (see WAC-173-183-710). Table 58 outlines the scoring for Wetland Vulnerability Score (*WVS*). Although wetlands category data was available by county in some cases (e.g. Thurston Country provided wetland coverages), statewide wetlands data indicating the above categories were not available. Thus, we assumed a conservative Category III with a score of 3 points for *WVS*. The values of OIL_{AT} , OIL_{MI} , and OIL_{PER} are the same as for the estuarine and marine zones.

Table 58: Scoring of Wetland Categories

Score	Rating Qualification
5	Category I wetlands
4	Category II wetlands
3	Category III wetlands
1	Category IV wetlands

Impact Risk Model: Combined Score for All Freshwaters (by WRIA/Zone)

The weighted mean score for the streams-lakes impact score and the wetlands impact score was calculated, and combined with as an area-weighted average for each WRIA. Areas of water bodies were calculated from the US Geological Survey National Hydrography 100k Dataset. The area of open water in inland areas, not including marine and estuarine waters, was used as an estimate of the surface area of lakes in each WRIA. The area of streams and lakes in the WRIA was the sum of open waters (lakes) and streams, not including the eastern Columbia and Snake rivers main stems. The area of wetlands in this coverage was also calculated for each WRIA.

The surface area of streams was calculated as the length of streams in the WRIA from the US Geological Survey National Hydrography 100k Dataset[137] times an estimate of the mean width of streams in the WRIA. The mean width was calculated from wetted width data collected by the WA DEP from bio-monitoring stations located inside each WRIA. The number of bio-monitoring stations varied between WIRAs, ranging from 0-14 stations. At each bio-monitoring station, data was collected at up to five locations along the stream system. Wetted width is a standard field measurement defined as the actual width of the stream from water edge to water edge. The wetted width data was specific to stream systems consisting of riffles and pools, not from big river systems such as the Colombia or Snake Rivers (which were considered separately). Wetted width data (meters) at each location was compiled and averaged. The most current data set available, which ranged from the late nineteen nineties to 2007 was used. The majority of the data used to determine typical stream width was measured in the late nineteen nineties.[138]

[137] http://nhd.usgs.gov/data.html

[138] Data source: http://www.ecy.wa.gov/apps/watersheds/wriapages/index.html

The surface area of the Columbia and Snake Rivers was calculated using polygons for those rivers from the 2001 NLCD coverage.[139] The area within or bordering each WRIA was calculated, so that area-weighted scored of *P2*, *P5* and *P6* could be derived for the Columbia-Snake River zone. To do this, the area of the river in each WRIA was weighed by the number of banks in or bordering the WRIA and multiplied by the *P2* (or *P5* or *P6*) score, then summed and divided by the total area (with bank weighing factors) to derive a mean score for the Columbia-Snake River zone.

After the values for each WRIA were calculated, the values for the combined inland areas were calculated from the WRIA data using an area based weighting scheme. The total area of the WRIA was based on the 2001 NLCD coverage.

Impact Risk Model Results: Estuarine/Marine Zones

Impact risk scores by oil type and season, averaged over all estuarine and marine zones are presented in Table 59. The seasonal variation is relatively small; however, the scores are higher in spring and summer than in fall or 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.

Table 59: Impact Risk Scores by Oil Type/Season, Averaged over Estuarine/Marine Zones

Oil Category	Spring	Summer	Fall	Winter
Crude Oils	20.27	19.03	17.76	17.88
Heavy Oils	26.56	24.82	23.18	23.36
Light Oils	16.04	15.07	13.99	14.05
Gasoline	15.22	14.28	13.34	13.38
Jet Fuel	10.12	9.45	8.77	8.81
Non-Petroleum Oil	10.12	9.45	8.77	8.81

Table 60 shows the impact risk scores averaged over the 4 seasons. The impact risk is highest for the heavy fuels, followed by crude oil; lower for light oils and gasoline, which are similar for a given zone; and lowest for jet fuel and non-petroleum oils. This trend is related to the higher persistence and mechanical injury scores of the heavier oils, which therefore have more impact on birds, marine mammals, habitats, and recreation then the non-persistent oils. This trend is in agreement with spill impact observations and modeling, in general. The impact risk scores for the estuarine/marine zones by season that are relevant to the Vancouver Energy analysis are shown in Table 61.

Table 60: Impact Risk Scores by Estuarine/Marine Zone/Oil Type, Averaged Seasons

Zone	Crude Oils	Heavy Oils	Light Oils	Gasoline	Jet Fuel	Non-Petroleum
Washington Outer Coast	17.99	23.86	14.34	14.33	9.14	9.14
Grays Harbor	19.05	24.73	14.93	13.98	9.31	9.31
Willapa Bay	21.86	28.51	17.16	16.15	10.72	10.72
Strait of Juan de Fuca	13.28	17.38	10.24	9.24	6.16	6.16

[139] http://landcover.usgs.gov/show_data.php?code=WA&state=Washington
http://edcftp.cr.usgs.gov/pub/data/landcover/states/

Table 60: Impact Risk Scores by Estuarine/Marine Zone/Oil Type, Averaged Seasons						
Zone	**Crude Oils**	**Heavy Oils**	**Light Oils**	**Gasoline**	**Jet Fuel**	**Non-Petroleum**
Inner Straits	23.58	30.81	18.96	18.22	11.78	11.78
Rosario Strait and Vicinity	19.00	24.87	15.13	14.60	9.56	9.56
Whidbey Basin	19.95	26.09	15.84	15.03	10.01	10.01
Northern Puget Sound	21.68	28.22	17.28	16.41	10.91	10.91
Central Puget Sound	14.87	19.54	11.55	10.98	7.30	7.30
South Puget Sound	18.72	24.41	14.65	14.06	9.30	9.30
Hood Canal	15.05	19.73	11.76	11.07	7.28	7.28
Western Columbia River	19.81	25.64	15.64	14.59	10.01	10.01

Table 61: Estuarine/Marine Zone Impact Risk Scores by Oil Type/Season						
Zone	**Oil Type**	**Spring**	**Summer**	**Fall**	**Winter**	**Average**
Western Columbia River	**Heavy oils**	26.81	26.81	24.59	24.37	25.65
	Light oils	16.35	16.35	14.99	14.86	15.64
Central Puget Sound	**Heavy oils**	21.02	19.84	18.67	18.65	19.55
	Light oils	12.58	11.82	10.94	10.87	11.55
Northern Puget Sound	**Heavy oils**	30.51	29.47	26.5	26.4	28.22
	Light oils	18.68	18.04	16.16	16.25	17.28
South Puget Sound	**Heavy oils**	27.7	23.78	22.15	24.01	24.41
	Light oils	16.52	14.34	13.35	14.4	14.65

Impact Risk Model Results: Inland Zones

Table 62 shows the summary of the per gallon inland impact risk scores, PG, by zone. The risk scores are weighed by the relative areas of streams + lakes versus wetlands and the scores for each in the WRIAs. Note that the inland scores do not have a seasonal component. The results show a similar relative pattern by oil type as for the estuarine and marine scores. The impact risk is highest for the heavy fuels, followed by crude oil; lower for light oils and gasoline, which are similar for a given zone; and lowest for jet fuel and non-petroleum oils. This trend is related to higher persistence and mechanical injury scores of heavier oils, which therefore have more impact on birds, mammals, habitats, and recreation than non-persistent oils. The highest impact risk for inland zones is in the Olympic Peninsula, followed by West of Cascades and then East of Cascades. The Columbia-Snake River and Lake Union-Washington have lower scores due to urbanization, fish barriers, and impoundments in the watershed.

Table 62: Per-Gallon Impact Risk Scores by Inland Zone and Oil Type						
Zone	**Crude Oils**	**Heavy Oils**	**Light Oils**	**Gasoline**	**Jet Fuel**	**Non-Petroleum**
Lake Union/Washington	8.27	10.71	6.53	6.09	4.18	4.18
East Columbia/Snake River	10.29	13.32	8.12	7.58	5.20	5.20
Olympic Peninsula	22.11	28.63	17.46	16.29	11.17	11.17
West of Cascades	20.27	26.24	16.00	14.93	10.24	10.24

East of Cascades	15.85	20.53	12.52	11.68	8.01	8.01

WRIA zone-specific risk scores are shown by zone (Figure 30) in Table 63. Note that there are no seasonal components to the inland risk scores.

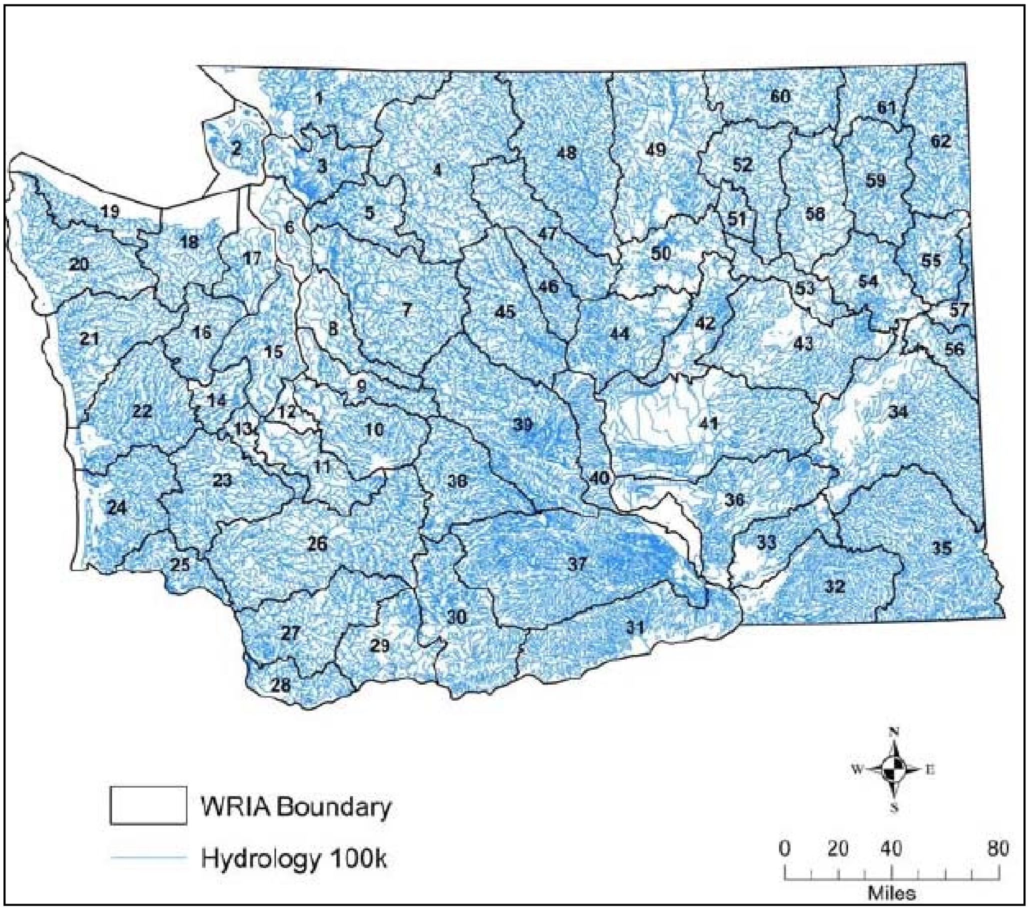

Figure 30: Streams in WRIAs from USGS National Hydrography 100K Dataset

Table 63: Per-Gallon Impact Scores for Inland Rivers, Lakes, Wetlands by WRIA/Oil Type

#	WRIA	Crude Oils	Heavy Oils	Light Oils	Gasoline	Jet Fuel	Non-Petroleum
1	**Nooksack**	19.80	25.63	15.63	14.59	10.00	10.00
2	**San Juan**	21.17	27.41	16.71	15.60	10.70	10.70
3	**Lower Skagit / Samish**	22.66	29.34	17.89	16.70	11.45	11.45
4	**Upper Skagit**	18.23	23.60	14.39	13.43	9.21	9.21
5	**Stillaguamish**	22.47	29.09	17.74	16.55	11.35	11.35
6	**Island**	16.61	21.50	13.11	12.24	8.39	8.39
7	**Snohomish**	21.45	27.77	16.93	15.80	10.84	10.84
8	**Cedar-Sammamish**	13.49	17.46	10.65	9.94	6.82	6.82
9	**Duwamish-Green**	19.78	25.61	15.61	14.57	9.99	9.99

Table 63: Per-Gallon Impact Scores for Inland Rivers, Lakes, Wetlands by WRIA/Oil Type

#	WRIA	Crude Oils	Heavy Oils	Light Oils	Gasoline	Jet Fuel	Non-Petroleum
10	**Puyallup-White**	14.16	18.33	11.18	10.43	7.15	7.15
11	**Nisqually**	20.97	27.15	16.55	15.45	10.59	10.59
12	**Chambers-Clover**	12.31	15.93	9.72	9.07	6.22	6.22
13	**Deschutes**	19.06	24.67	15.05	14.04	9.63	9.63
14	**Kennedy-Goldsborough**	22.01	28.50	17.38	16.22	11.12	11.12
15	**Kitsap**	21.90	28.35	17.29	16.13	11.06	11.06
16	**Skokomish-Dosewallips**	24.43	31.63	19.28	18.00	12.34	12.34
17	**Quilcene-Snow**	20.16	26.10	15.91	14.85	10.18	10.18
18	**Elwha-Dungeness**	14.47	18.73	11.42	10.66	7.31	7.31
19	**Lyre-Hoko**	21.46	27.78	16.94	15.81	10.84	10.84
20	**Soleduc**	24.71	31.99	19.50	18.20	12.48	12.48
21	**Queets-Quinault**	23.08	29.88	18.22	17.00	11.66	11.66
22	**Lower Chehalis**	22.64	29.32	17.88	16.68	11.44	11.44
23	**Upper Chehalis**	23.19	30.02	18.30	17.08	11.71	11.71
24	**Willapa**	22.71	29.40	17.93	16.73	11.47	11.47
25	**Grays/Elochoman**	20.21	26.17	15.96	14.89	10.21	10.21
26	**Cowlitz**	20.21	26.17	15.96	14.89	10.21	10.21
27	**Lewis**	20.29	26.27	16.02	14.95	10.25	10.25
28	**Salmon-Washougal**	19.53	25.28	15.42	14.39	9.87	9.87
29	**Wind-White Salmon**	17.53	22.69	13.84	12.91	8.86	8.86
30	**Klickitat**	21.61	27.98	17.06	15.92	10.92	10.92
31	**Rock-Glade**	10.01	12.95	7.90	7.37	5.06	5.06
32	**Walla Walla**	14.01	18.14	11.06	10.32	7.08	7.08
33	**Lower Snake**	9.86	12.77	7.79	7.27	4.98	4.98
34	**Palouse**	20.23	26.20	15.97	14.91	10.22	10.22
35	**Middle Snake**	9.92	12.84	7.83	7.31	5.01	5.01
36	**Esquatzel Coulee**	17.80	23.05	14.06	13.12	9.00	9.00
37	**Lower Yakima**	20.82	26.96	16.44	15.34	10.52	10.52
38	**Naches**	18.61	24.09	14.69	13.71	9.40	9.40
39	**Upper Yakima**	17.11	22.15	13.51	12.61	8.65	8.65
40	**Alkali-Squilchuck**	15.29	19.80	12.07	11.27	7.73	7.73
41	**Lower Crab**	19.14	24.79	15.11	14.11	9.67	9.67
42	**Grand Coulee**	7.06	9.14	5.57	5.20	3.57	3.57
43	**Upper Crab-Wilson**	20.36	26.36	16.07	15.00	10.29	10.29
44	**Moses Coulee**	9.30	12.04	7.34	6.85	4.70	4.70
45	**Wenatchee**	19.34	25.04	15.27	14.25	9.77	9.77
47	**Chelan**	11.78	15.26	9.30	8.68	5.95	5.95
48	**Methow**	17.37	22.49	13.71	12.80	8.78	8.78

Table 63: Per-Gallon Impact Scores for Inland Rivers, Lakes, Wetlands by WRIA/Oil Type							
#	**WRIA**	**Crude Oils**	**Heavy Oils**	**Light Oils**	**Gasoline**	**Jet Fuel**	**Non-Petroleum**
49	**Okanogan**	15.03	19.47	11.87	11.08	7.60	7.60
50	**Foster**	9.52	12.32	7.51	7.01	4.81	4.81
51	**Nespelem**	11.17	14.46	8.82	8.23	5.64	5.64
52	**Sanpoil**	11.91	15.42	9.40	8.78	6.02	6.02
53	**Lower Lake Roosevelt**	12.16	15.74	9.60	8.96	6.14	6.14
54	**Lower Spokane**	14.11	18.26	11.14	10.39	7.13	7.13
55	**Little Spokane**	14.98	19.39	11.82	11.04	7.57	7.57
56	**Hangman**	15.57	20.16	12.29	11.47	7.87	7.87
57	**Middle Spokane**	12.22	15.82	9.65	9.01	6.18	6.18
58	**Middle Lake Roosevelt**	14.82	19.18	11.70	10.92	7.49	7.49
59	**Colville**	18.67	24.18	14.74	13.76	9.44	9.44
60	**Kettle**	14.43	18.68	11.39	10.63	7.29	7.29
61	**Upper Lake Roosevelt**	11.84	15.33	9.35	8.73	5.98	5.98
62	**Pend Oreille**	17.88	23.15	14.11	13.17	9.03	9.03

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