Petroleum Crude Oil Unit Train Transportation Risk Analysis: Vancouver Energy Project

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EXECUTIVE SUMMARY

This report describes an analysis of the estimated petroleum crude oil train derailment rate, the estimated conditional probability of release given a derailment event and the estimated conditional probability of quantity released given a release event. The route studied was the BNSF rail line from the Idaho/Washington state line at Newman Lake, WA, to the Vancouver Energy Project site in Vancouver, WA. Several major risk factors were taken into account, including Federal Railroad Administration track class, railroad method of operation, tank car safety design, traffic volume, and train configuration. The train operation is summarized below and the risk estimates are summarized in the table on the following page.

It should be noted that the estimates presented in this report may be conservative in terms of future projections of risk, i.e. they may tend to overestimate the risk for several reasons. These include BNSF's lower than average derailment rate compared to national statistics, the general decline in train accident rate that is expected to continue due to improvements in infrastructure, rolling stock and implementation of new and improved defect detection technologies that detect problems before they cause an accident, additional safety practices implemented by BNSF for rail transport of petroleum crude oil and the installation of PTC on this and other routes. The derailment rate and consequent risk analysis did not account for the safety benefits of any of these factors.

Summary of Operation Analyzed

Four trains per day over the route, configured as follows:
- 3 locomotives (2 head-end, 1 rear-end)
- 2 buffer cars (1 head-end, 1 rear-end)
- 118 loaded tank cars

Summary of Probability Estimates

	FRA Reportable Mainline Derailment Rates				
Derailment Rate for All Trains on the Route (per million train miles)	0.75				
Estimated Derailment Frequency (per year)	0.424				
Derailment Return† (years)	2.4				
Tank Car Types	**Legacy DOT 111**		**CPC-1232**		**DOT-117**
	Non-Jacketed (7/16") 111A100W1	**Jacketed (7/16") 111A100W1**	**Non-Jacketed CPC 1232 (1/2")**	**Jacketed CPC 1232 (7/16")**	**Jacketed (9/16")**
Route Estimates					
Car-Conditional Probability of Release (Car - CPR)	30.3%	14.5%	16.2%	7.9%	5.1%
Train-Conditional Probability of Release (Train - CPR)	78.6%	62.2%	62.3%	45.4%	36.7%
Any Spill Return (years)	3.0	3.8	3.8	5.2	6.4
Median spill: 700 bbl / 30,000 gal Spill Return (years)	5	9	8	15	23
Large Spill: 2,200 bbl / 92,000 gal Spill Return (years)	13	33	25	57	110
EWCD**: 20,000 bbl / 840,000 gal Spill Return (years)	1,297	5,182	2,072	5,847	20,176
Average Route Location Estimates					
Median spill: 700 bbl / 30,000 gal Spill Return (years)	2,000	3,400	3,200	5,800	9,000
Large Spill: 2,200 bbl / 92,000 gal Spill Return (years)	4,900	12,600	9,500	21,900	42,500
EWCD**: 20,000 bbl / 840,000 gal Spill Return (years)	500,000	1,996,000	798,000	2,253,000	7,773,000

† In this table and throughout this report, "Return" refers to the expected interval between events in years. It is the inverse of the annual probability of an event.

**EWCD: Effective Worst Case Discharge: as defined by DEIS Appendix E

1. INTRODUCTION

The purpose of this analysis was to estimate the train derailment rate, conditional probability of release of a tank car given a derailment, and the conditional probability of quantity released given a release event of trains transporting petroleum crude oil on the BNSF rail line from the Idaho/Washington state line at Newman Lake, WA to the Vancouver Energy Project site in Vancouver, WA. The analysis was conducted based on segment-specific rail infrastructure information, tank car safety design, train configuration, and transportation volume. This study is intended to assist the understanding of the risk associated with rail transportation of petroleum crude oil in the state of Washington

2. METHODOLOGY

The risk analysis methodology described in this report consists of four major parts:

1) Description of the analytical method
2) Estimation of the train derailment rate
3) Estimation of the probability distribution of a release event in terms of the total number of tank cars in the train given a derailment event
4) Estimation of the probability distribution of the quantity released given a multiple tank car release event

2.1. Analytical Method

The occurrence of a crude oil train release incident is the result of a sequence of events that are affected by a number of factors. Using the algorithm depicted in Figure 1 the probability of each stage in the event tree leading to a release incident was calculated, culminating in the results of particular interest, namely the probability distribution of the frequency and size of releases. In particular, this is the conditional probability distribution for the number of tank cars that will release some or all of their contents in an FRA-reportable derailment.

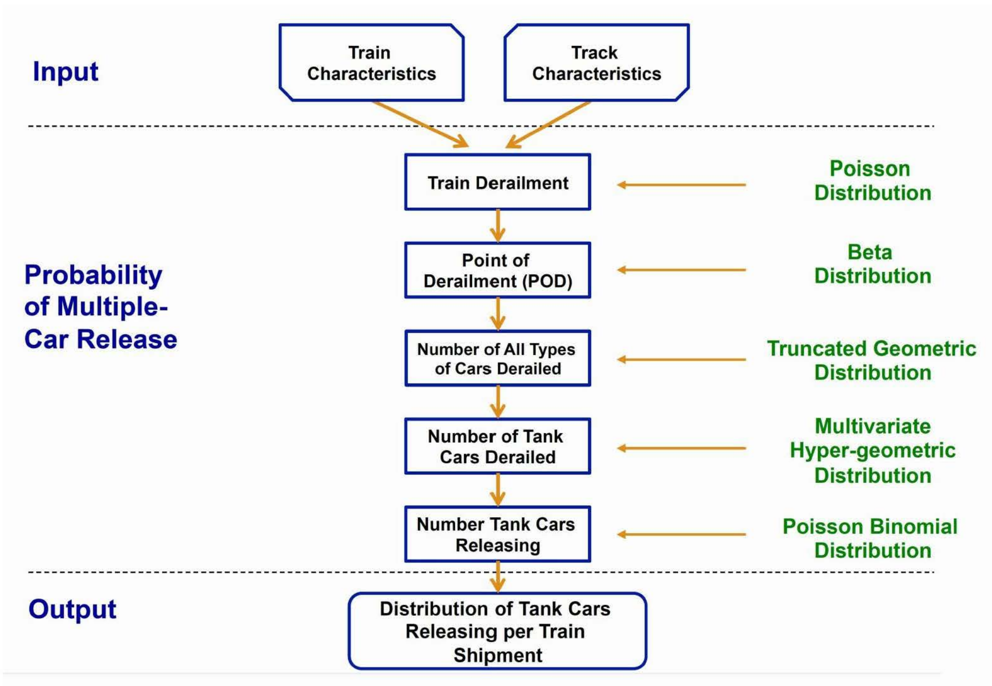

Figure 1. Analytical Procedure for Estimating the Conditional Probability Distribution of the Number of Hazardous Materials Cars Releasing (Liu et al., 2014)

(This flowchart is from a general characterization of the train derailment and release probability analysis model developed by Liu et al. (2014) in which all types of trains and cars can potentially be evaluated. The analysis described in this report is for unit trains in which all cars except for the buffer cars are the same type, and is therefore a simpler, special case of the more general model.)

In order to estimate the probability distribution of the total number of tank cars releasing given a derailment, each of the following distributions need to be estimated (Liu et al., 2014):

1. Point of derailment (POD), the position of the first car derailed in the train
2. Total number of railcars derailed, including both tank cars and other types of railcars, given the POD
3. Number of tank cars derailed given the total number of cars derailed
4. Number of tank cars releasing given the total number of tank cars derailed

The mathematical expression used to estimate the distribution of the number of tank cars releasing is:

$$P(X_R) \approx \sum_{i=1}^{N} \left\{ Z_i \times L_i \times \sum_{X_D=0} \left\{ P_i(X_R|X_D) \left\{ \sum_{X=0} P_i(X_D|X) \left[\sum_{K=1} P_i(X|K) POD_i(K) \right] \right\} \right\} \right\}$$

Where:

$P(X_R)$ = probability of number of tank cars releasing per train shipment on a route

N = number of track segments on the route

Z_i = train derailment rate per train-mile on the i^{th} segment

L_i = segment length (miles)

K = Point of derailment (POD) (Position of first car derailed)

X = number of cars (tank cars and non-tank cars) derailed

X_D = number of tank cars derailed

X_R = number of tank cars releasing

$POD_i(K)$ = probability distribution of point of derailment

$P_i(X|K)$ = probability distribution of number of cars derailed given point of derailment

$P_i(X_D|X)$ = probability distribution of tank cars derailed given total number of cars derailed

$P_i(X_R|X_D)$ = probability distribution of tank cars releasing given number of tank cars derailed

Since the trains evaluated in this study are made-up almost entirely of tank cars, X_D is approximately equal to X.

2.2. Estimation of train derailment rate

Train derailment rate is the likelihood that a train derails, normalized by some unit of traffic exposure such as ton-miles, car-miles or train miles. U.S. Department of Transportation (DOT), Federal Railroad Administration (FRA) commonly expresses such rates in derailments per million train miles and that is what is used in this analysis. Average train derailment rate over the 5-year period 2005 – 2009 has previously been estimated using FRA data from their Rail Equipment Accident (REA) database, combined with traffic data provided by the railroad industry (Liu et al., 2016).

The FRA database records all accidents that exceed a specified monetary damage cost to on-track equipment, signals, track, track structures, and roadbed (FRA, 2014). Mainline train derailment rate has been shown to vary with infrastructure and operating conditions, in particular: FRA track class, method of operation and traffic density (Liu et al., 2016). Higher FRA track classes (corresponding to higher operational speeds and more stringent track safety standards), signaled trackage, and higher traffic density, all demonstrate lower derailment rates compared to: lower FRA track classes, non-signaled trackage and lower traffic density (Figure 2).

The Class 1 railroad mainline, train accident rate has continued to decline since the time frame when Liu et al.'s study was conducted. Liu (2015) developed an approach to account for this in estimating derailment rates in the near future, which has been used in this analysis to estimate the risk in 2017.

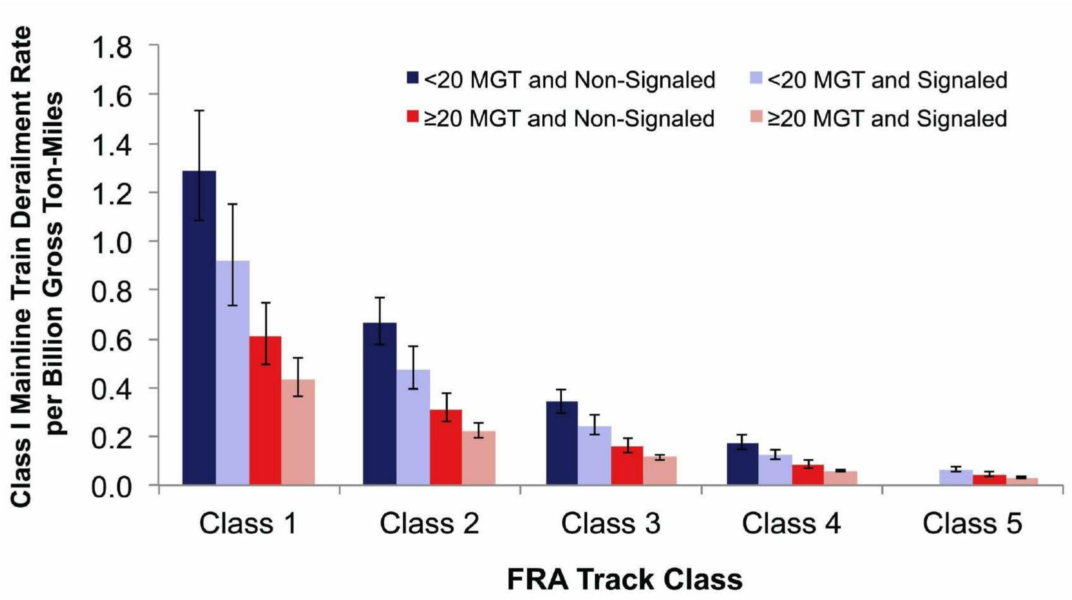

Figure 2. Estimated Class I mainline freight-train derailment rates by FRA track class, method of operation and annual traffic density (Liu et al., 2016)
(Error bars represent 95% confidence intervals)

The train derailment rates presented in Figure 2 can be used to estimate the probability of a derailment on any given segment of a rail line, given the three key characteristics mentioned above. They also permit estimates over an entire route by accounting for the percentage of each combination of characteristics found along its length. Using the route-specific characteristics combined with expected train configuration, enables calculation of overall estimated derailment rate for the route studied.

2.3. Estimation of the conditional probability distribution of a multiple tank car release event

The probability that a tank car experiences a release in a derailment has been extensively studied by the RSI-AAR Railroad Tank Car Safety Research and Test Project. The RSI-AAR Tank Car Project has gathered data on the design, damage and accident conditions for over 47,000 tank cars involved in more than 30,000 accidents that have occurred on North American railroads. These data enable robust, statistical estimation of the safety performance of tank cars under actual accident conditions. The safety performance of the principal tank cars in use or planned for transportation of petroleum crude oil have been analyzed and presented to the National Transportation Safety Board (Treichel, 2014).

Information on individual tank car safety design performance in accidents is an essential aspect of estimating the rail transportation risk of hazardous materials. It can be used to quantify the probability that an individual tank car will release some or all of its contents given its safety design features. In evaluations of unit-train transportation risk it is also important to understand the probability distribution of multiple-car derailments and releases. This was among the topics addressed by Liu in his Ph.D. dissertation research and other publications cited in this report (Liu et al., 2013, 2014).

2.4. Estimation of the conditional probability distribution of the quantity released

The RSI-AAR Tank Car Project has also developed statistical estimates of the distribution of the percentage of a tank car's contents lost in accidents. These enable finer-grained statistical estimation of the distribution of quantities lost from tank cars in accidents and were used to develop the overall probability distribution of release quantity given a multiple-car release accident.

3. VANCOUVER ENERGY PROJECT INFORMATION

3.1. Route information

This analysis considered the route from the state line near Newman Lake, WA to Vancouver, WA (Figure 3). A summary of the characteristics of the route is shown in Table 1. The entire route is signaled trackage with an annual traffic density greater than 20 million gross tons (MGT).

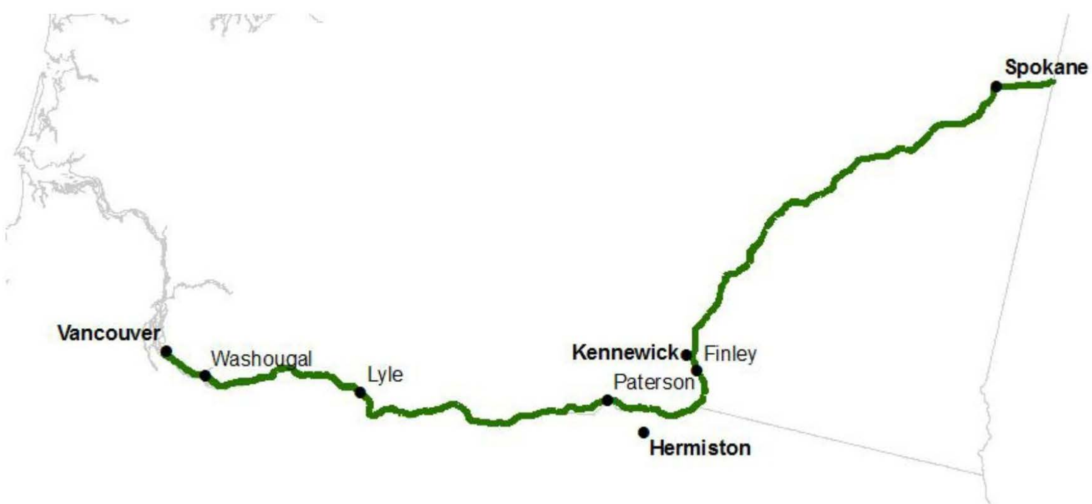

Figure 3. Map showing the route analyzed

Table 1. Summary of route characteristics affecting derailment rate

	Newman Lake, WA to Vancouver, WA	
	Length (Miles)	Percentage of total length
Distribution of FRA Track Class		
Track Class 1	0	0.0%
Track Class 2	7	1.7%
Track Class 3	34	8.9%
Track Class 4	344	89.3%
Track Class 5	0	0.0%
Total	385	100%
Method of Operation		
Signaled	385	100.0%
Non-Signaled		0.0%
Annual Traffic Density		
≥ 20 MGT	385	100.0%
< 20 MGT		0.0%

3.2. Train configuration

The train composition considered in this analysis was as follows:

- Two locomotives and one buffer car in the front, followed by 118 loaded tank cars, followed by one buffer car and one locomotive

It was assumed that four loaded trains per day would operate over the route.

3.3 Tank car safety design

This analysis considered five tank car safety designs presently in use, or defined in the US DOT rulemaking HM-151, the new regulations for rail transportation of flammable liquids (PHMSA, 2015). The cars evaluated include the non-jacketed and jacketed versions of the legacy DOT 111 tank cars, the non-jacketed and the jacketed versions of the CPC-1232 cars, which are the current standard designs, and the new DOT 117.

A widely used metric to measure safety performance of a tank car is its conditional probability of release (CPR). CPR is defined as the probability that a single tank car derailed in an FRA-reportable accident releases some or all of its contents due to the impacts it receives during the derailment. The design features affecting the safety performance of each of these cars in accidents, and their respective CPRs are summarized in Table 2. DOT 120 tank cars are also expected to be used in the service analyzed in this report. They will have a slightly thicker tank head and more damage resistant manway protection than the DOT 117. Although an exact estimate of the CPR for the DOT 120 is not available at this time, it will be a bit lower than that of the DOT 117 thereby reducing the risk relative to what is presented here for the 117 (Table 2).

Table 2. Summary of the tank car design features affecting safety performance in accidents

	Legacy DOT 111		CPC-1232		DOT-117 (DOT-120)
	Non-Jacketed 111A100W1	**Jacketed 111A100W1**	**Non-Jacketed CPC 1232**	**Jacketed CPC 1232**	**Jacketed**
Head Thickness (inches)	0.4375	0.4375	0.5	0.4375	0.5625 (0.59375)
Shell Thickness (inches)	0.4375	0.4375	0.5	0.4375	0.5625
Jacket	No	Yes	No	Yes	Yes
Head Shields	None	None	Half Height	Full Height	Full Height
Top Fittings Protection	No	No	Yes	Yes	Yes (manway protection also)
Bottom Fittings	Yes	Yes	Yes	Yes	Yes
Average Conditional Probability of Release	0.266	0.128	0.132	0.064	0.042 (<0.042)

* The CPR estimates presented in Table 2 were developed using statistical results and methods from the RSI-AAR Project TWP-17 report and assumed the following "average" conditions for FRA-reportable, mainline derailments: 26 mph derailment speed, with the tank car being the 6th car in a derailment in which 11 cars are derailed (Treichel, 2014). In the risk analysis presented in this report, the estimated CPRs are statistically adjusted upward or downward depending on the average speed of derailment on different FRA track classes.

All tank car release incidents are not equivalent. The amount lost in a particular accident can vary from a relatively small quantity to the entire carload. The RSI-AAR Tank Car Project has developed probability distributions for the amount lost (Treichel et al 2005). The results for non-pressure tank cars are presented in Figure 4. The distribution of expected quantity lost can be incorporated into the analysis to develop finer-grained estimates of the distribution of spill sizes, using the multiple-car release model.

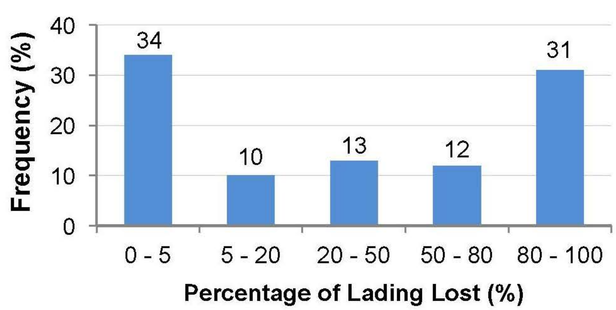

Figure 4. Distribution of quantity lost from non-pressure tank cars derailed in accidents (Treichel et al 2005)

4. RESULTS

The input data, statistics and methodology presented in the preceding sections were used to evaluate the specific conditions along the Newman Lake to Vancouver, WA route that is the subject of this report. The following sections describe the results of this analysis.

4.1. Train derailment rate

The train derailment rate for locations along the route was calculated based on the traffic volume and the infrastructure conditions along route. The derailment rates can also be expressed in terms of the expected interval between occurrences, which is simply the inverse of the annual rate. Both the rates and the expected intervals are summarized in Table 3.

Table 3. Summary of estimated derailment rates on the route

	Annual Derailment Rate per Mile	Expected Interval Between Derailments
Minimum	0.00097	1,029
Average	0.00110	908
Maximum	0.00368	272

The overall annual average derailment rate for trains on the route was estimated to be 0.424 per year with an expected interval between derailments of 2.4 years.

4.2. Route Release Probability Distributions

The analytical method enabled development of "risk profiles". These allow one to assess the probability of events of various magnitudes (Figure 5). The horizontal axis indicates the size of the incident, in this case the number of cars releasing at least some of their contents, and the vertical axis indicates the annual probability that an event equal to or greater than the value on the horizontal axis will occur. For all car types, larger incidents are less likely than smaller incidents, so there is a general decline in the relationship between number of cars releasing and annual probability, as seen in Figure 5. As an example of how to interpret these graphs, Figure 5 indicates that the estimated annual probability that five or more conventional, non-jacketed DOT 111 tank cars releasing is approximately 0.125, compared to approximately 0.018 for DOT 117 tank cars. The curve for the DOT 120 would be slightly lower than that of the DOT 117 in Figure 5.

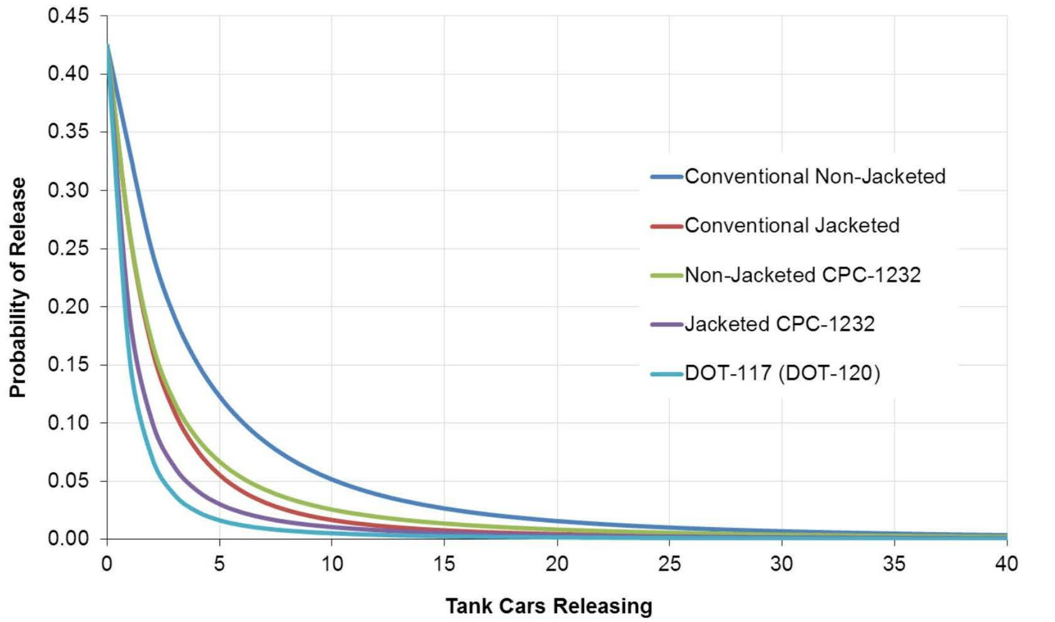

Figure 5. Estimated annual probability of the number of cars releasing in accidents for different tank car types

Very low annual probabilities such as those shown in Figure 5 may be difficult to evaluate so it is useful to present the inverse relationship as well, which is the expected interval between events. The same data for Figure 5 are used to present the information in this manner in Figure 6. In this case, the curve for the DOT 120 would be slightly higher than that of the DOT 117 indicating longer expected intervals between events of various magnitudes.

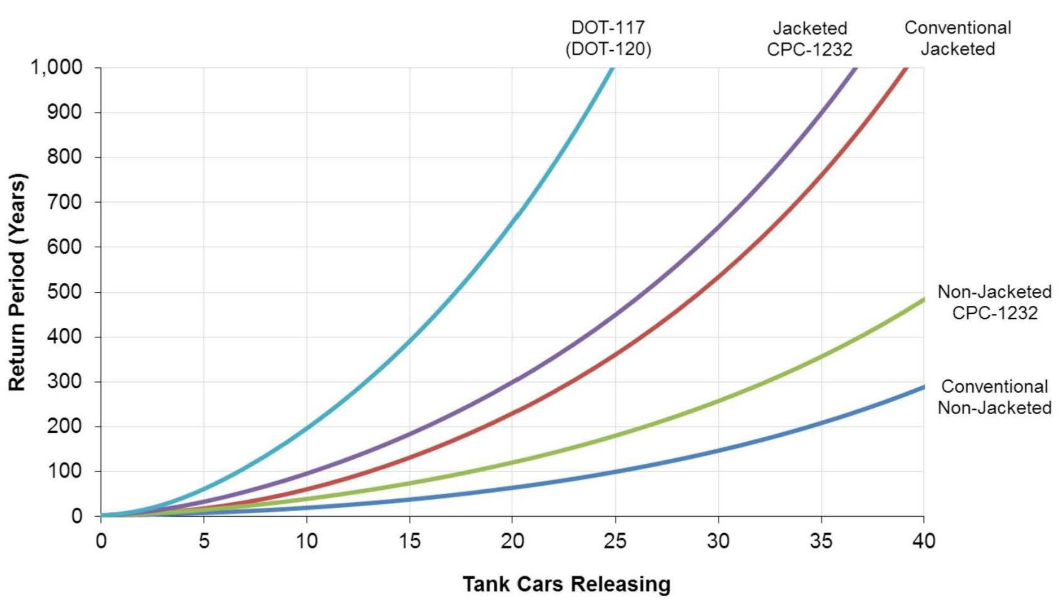

Figure 6. Estimated interval between release events on the route in accidents for different tank car types

4.2. Route risk compared to location-specific risk estimates

The results presented in Figures 5 and 6 represent the annual probabilities, and the corresponding expected intervals between events occurring, anywhere along the route analyzed. They do not represent the risk of an event at any particular location. The same methodology described above was used to estimate the risk profiles at an average location along the route.

4.3. Probability of a release at an average location along a route

The annual probability distribution of an accident-caused release event of various sizes was calculated for each tank car type at an average location along the route and the corresponding expected intervals between events (Figures 7 and 8). Again, using a five-or-more car release as an example, the estimated annual probability at an average location on the route for a non-jacketed DOT 111 is 0.00032 with a corresponding estimated return period of 3,132 years. For the DOT 117 the estimated annual probability is 0.000042, with an estimated return interval of 23,664 years (beyond the upper bound of the graph in Figure 8).

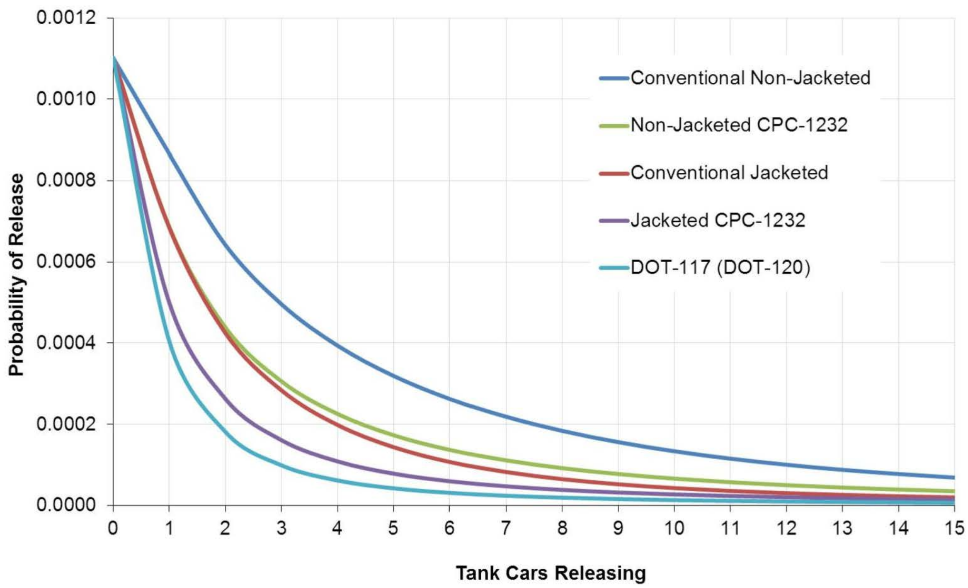

Figure 7. Estimated annual probability at an average location along the route of the number of cars releasing in accidents for different tank car types

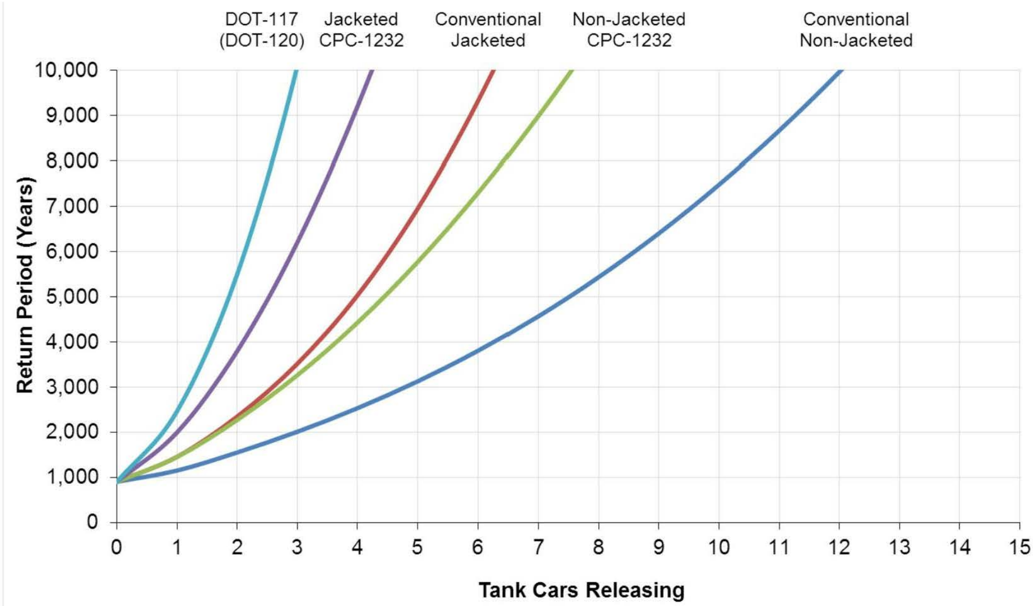

Figure 8. Estimated interval between release events at an average location along the route in accidents for different tank car types

4.4. Probability distribution of released quantity given a release event

The probability distribution of quantity released given a release event was calculated for each of the tank car designs. The overall risk results are summarized in Table 4.

4.5. Discussion and Interpretation

The risk estimates described here may be conservative in terms of future projections of risk, i.e. they may tend to overestimate the risk. The railroad derailment rates used in this analysis were calculated based on the data from 2005 – 2009 and then adjusted using Liu's (2015) method to account for the decline in accident rate (Figure 4). However, the rates used do not account for several other factors that may further reduce accident rate.

The BNSF's overall accident rate has been lower than the national average so estimates based on national averages may tend to overestimate the probability on this route and the BNSF system in general. Empirical analysis of the Newman Lake to Vancouver route found that it had a lower-than-average accident rate over the past ten years, compared to national averages.

More broadly, the Class 1 railroads' accident rate has been declining for more than a decade (Barkan et al., 2013) and this trend can be expected to continue (Liu, 2015). This is due to ongoing investment in infrastructure, rolling stock and new technologies that can detect incipient flaws allowing them to be repaired before they cause an accident. The risk analysis assumed accident rates would remain static at 2017 levels. This is unlikely given the continued investments and downward trends in accidents for BNSF and the Class 1 railroads in general.

Table 4. Summary of Results for the Route

	FRA Reportable Mainline Derailment Rates				
Derailment Rate for All Trains on the Route (per million train miles)	0.75				
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Route Estimates					
Car-Conditional Probability of Release (Car - CPR)	30.3%	14.5%	16.2%	7.9%	5.1%
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† In this table and throughout this report, "Return" refers to the expected interval between events in years. It is the inverse of the annual probability of an event.

* The different spill volumes considered (median spill, large spill and EWCD) are based on the EFSEC analysis of recent accidents involving crude by rail.

**EWCD = Effective Worst Case Discharge as defined by DEIS Appendix E: 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.as defined by DEIS Appendix E

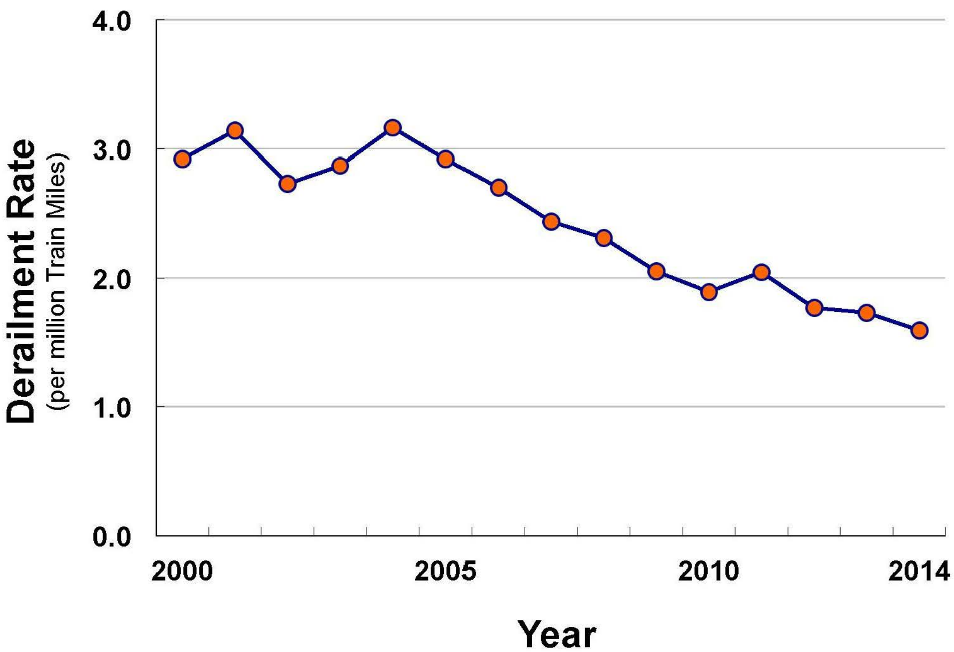

Figure 4. Average US railroad derailment rate 2000 – 2014
Data from US DOT Federal Railroad Administration and Association of American Railroads

Furthermore, the accident rates used in this analysis do not take into account the effect of various additional safety practices specific to rail transportation of petroleum crude oil that the railroads, including BNSF, have implemented (AAR, 2014). The analysis also does not account for improvements in train operating safety due to the implementation of Positive Train Control in the coming years.

4.6. Caveats

The nature of risk analysis is that even if an event has a low likelihood of occurring, there is no guarantee that it will not. For example, if the estimated probability of an event is 0.01, i.e. one in one hundred, corresponding to an expected interval between occurrences of 100 years, such an event could still happen in the near future, and in fact multiple events are possible within that time period. Conversely, in the example above, the actual interval between events could also be much longer than 100 years. The occurrence or non-occurrence of events within a particular time period would not mean that the risk analysis was incorrect, instead it may be due to two factors, the laws of chance, and uncertainty in the statistics. This is the nature of risk analysis and it is important that readers understand this, and that statements to this effect be included in reports used to describe the results of analyses of this nature.

5. REFERENCES CITED

1) Association of American Railroads (AAR). 2014. Freight Railroads Join U.S. Transportation Secretary Foxx in Announcing Industry Crude by Rail Safety Initiative. www.aar.org/newsandevents/Press-Releases/Pages/Freight-Railroads-Join-U-S-Transportation-Secretary-Foxx-in-Announcing-Industry-Crude-By-Rail-Safety-Initiative.aspx#.U4-PmcYYWkR (accessed 2/25/2014).

2) Barkan, C.P.L., M.R. Saat, F. González, III and T.T. Treichel. 2013. Cooperative Research in Tank Car Safety Design, TR News 286: 12-19, Transportation Research Board of the National Academies, Washington, DC.

3) Federal Railroad Administration. 2014. Railroad Equipment Accident/Incident Reporting Threshold 1957–2014. FRA, U.S. Department of Transportation, Washington, DC. http://www.fra.dot.gov/eLib/details/L03622 (accessed 4 June 2014).

4) Liu, X., 2015. Statistical temporal analysis of freight-train derailment rates in the United States: 2000 to 2012. Transportation Research Record, Journal of the Transportation Research Board 2476: 119-125.

5) Liu, X., M.R. Saat, X. Qin, C.P.L. Barkan. 2013. Analysis of U.S. freight-train derailment severity using zero-truncated negative binomial regression and quantile regression. Accident Analysis and Prevention 59: 87–93.

6) Liu, X., M.R. Saat and C.P.L. Barkan. 2014. Probability analysis of multiple-tank-car release incidents in railway hazardous materials transportation. Journal of Hazardous Materials 276: 442-451.

7) Liu, X., M.R. Saat and C.P.L. Barkan. 2016. Freight-train derailment rates for railroad safety and risk analysis. *(In Review)* Accident Analysis and Prevention.

8) Nayak, P.R., D. B. Rosenfield and J.H. Hagopian 1983. Event Probabilities and Impact Zones for Hazardous Materials Accidents on Railroads. Report DOT/FRA/ORD-83/20. Federal Railroad Administration, U.S. Department of Transportation, Washington D.C.

9) Pipeline and Hazardous Materials Administration (PHMSA) and Federal Railroad Administration (FRA). 2015. Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains. Federal Register 80, (89): 26644 - 26750.

10) Treichel, T.T., J.P. Hughes, C.P.L. Barkan, R.D. Sims, E.A. Phillips and M.R. Saat 2006. Safety Performance of Tank Cars in Accidents: Probability of Lading Loss. Report RA-05-02, RSI-AAR Railroad Tank Car Safety Research and Test Project. Association of American Railroads, Washington, D.C.

11) Treichel, T.T. 2014. Tank Car Accident Safety Research for Crude Oil and Ethanol Cars. Presentation in: NTSB Forum - Transportation of Crude Oil and Ethanol, 22-23 April 2014 Washington, DC. http://www.ntsb.gov/news/events/Documents/Panel%201_C_Todd%20Treichel.pdf

APPENDIX

A.1. Derailment Rate Analysis Database and Methodology

The accident database used to develop the statistics for this risk analysis is comprised of a unique combination of Federal Railroad Administration and proprietary Class 1 freight railroad information. The data used to calculate the rates are not limited to trains shipping crude oil; instead they include traffic, infrastructure and accident data for all freight trains operating on U.S. Class 1 railroads. Proper estimation of train accident rates involves analysis of all reportable accidents, divided by the total amount of traffic. By accounting for specific physical and operational conditions where accidents occurred and the amount of rail traffic operating under these same conditions, more refined, accurate estimates of the derailment rate can be developed. The data and analytical method used provides a more robust, reliable database for estimating rail accidents and derailments than is possible using historical accident data for particular segments along an individual route. Following is a more detailed explanation of the data and methodology.

U.S. train derailment rates over the 5-year period 2005–2009 were analyzed using data from the U.S. Department of Transportation, Federal Railroad Administration (FRA) Rail Equipment Accident (REA) database combined with traffic data from the rail industry (Liu et al., 2015). Nayak et al. (1983) conducted research for the US DOT that demonstrated an inverse relationship between FRA track class and derailment rate (i.e. higher track classes have lower derailment rates). Since then, this result has been replicated and updated several times. More recently, as part of his Ph.D. dissertation research, Dr. Xiang Liu conducted a new study in which, in addition to FRA Track Class, he was able to incorporate new data on two other important variables, Traffic Density and Method of Operation (Liu et al., 2015). He found a clear, statistically significant effect of all three variables on freight train derailment rate (see Figure 1 in this report). The additional granularity provided by Liu's analysis allows more accurate, reliable segment-specific estimates of accident rates and these were used in the analysis. Liu's analysis represents the current state-of-the-art in detailed assessment of conditions affecting derailment rate on U.S. railroads.