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Safety in the Transportation of Oil and Gas: Pipelines or Rail?

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Main Conclusions

- Transporting oil and gas by pipeline or rail is in general quite safe.
- But when the safety of transporting oil and gas by pipelines and rail is compared, taking into consideration the amount of product moved, pipelines are found to be the much safer transportation method.
- Specifically, rail is found to be over 4.5 times *more* likely to experience an occurrence when compared to pipelines.
- Over 70 percent of pipeline occurrences result in spills of 1 m^3 or less, and only 17 percent of pipeline occurrences take place in actual line pipe, meaning that the vast majority of spills occur in facilities, which may have secondary containment mechanisms and procedures.

Introduction

Different modes of oil transport pose different risks, as has been discussed previously in *Intermodal Safety in the Transport of Oil* (Furchtgott-Roth and Green, 2013). That report found, using primarily US data, that while all modes of oil transport have very high safe-delivery rates, there are some differences: on an apples-to-apples basis, there are likely to be more spills when transporting a given quantity of oil a given distance by rail than by pipeline, and there will be still more spills if that volume is moved that same distance by truck.

Since that publication, additional data has been gathered to allow for a more substantive comparison of Canadian transportation modes. In addition, the United States Department of State published more recent data on intermodal safety of oil transportation. This Research Bulletin will summarize our findings from 2013, as well as the newer findings that have been published subsequently. In this update, we will focus mainly on the movement of oil by pipeline versus rail, as that distinction is central to discussions being held today with regard to the movement of oil in North America.

Intermodal safety, Canada

In our previous report, we did not do a head-to-head comparison of rail versus pipeline safety in Canada, as has been done for the US. Recently compiled data allows us to compare the safety of transporting hydrocarbons by pipelines and rail for the years 2003 to 2013, the period for which data is comparable.

For the past few years, the Transportation Safety Board of Canada (TSB) has published an annual statistical summary of pipeline accidents and incidents for Canada's 73,000 kilometres of federally regulated oil and natural gas pipelines (TSB, 2012; TSB, 2014; NR Canada, 2014).[1] These reports provide the pipeline data used below.

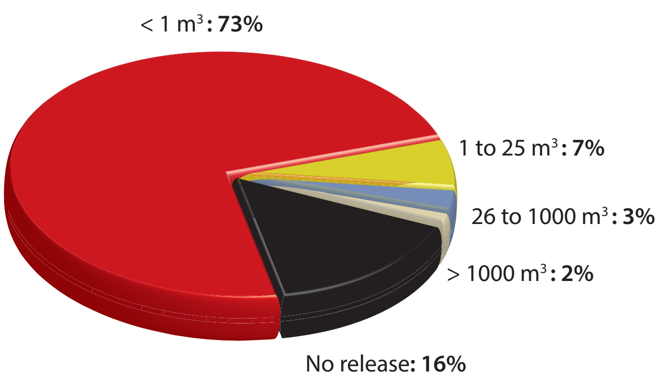
At the outset, an issue with the pipeline data is its fragmentation into accidents and incidents. One reason this poses a problem is that there is overlap between the two definitions. For example, both accidents and incidents can result in the release of product. For this reason we will consider accidents and incidents in their totality, focusing on pipeline "occurrences" which encompasses both.[2] Additionally, from 2003 to 2013, approximately 92 percent of pipeline occurrences were classified as incidents. If we were to only focus on accidents, we would likely overemphasize the safety of pipelines.

1 A reportable commodity pipeline accident occurs when "a person sustains a serious injury or is killed as a result of being exposed to (i) a fire ignition or explosion or (ii) a commodity released from the commodity pipeline" and/or where "the commodity pipeline (i) sustains damage affecting the safe operation of the commodity pipeline as a result of being contacted by another object or as a result of a disturbance of its supporting environment, (ii) causes or sustains an explosion, or fire or ignition that is not associated with normal operating circumstances, or (iii) sustains damage resulting in the release of any commodity" (TSB, 2014). An incident occurs where "(a) an uncontained and uncontrolled release of a commodity occurs, (b) the commodity pipeline is operated beyond design limits, (c) the commodity pipeline causes an obstruction to a ship or to a surface vehicle owing to a disturbance of its supporting environment, (d) any abnormality reduces the structural integrity of the commodity pipeline below design limits, (e) any activity in the immediate vicinity of the commodity pipeline poses a threat to the structural integrity of the commodity pipeline, or (f) the commodity pipeline, or a portion thereof, sustains a precautionary or emergency shut- down for reasons that relate to or create a hazard to the safe transportation of a commodity" (TSB, 2014).

2 Indeed, TSB (2014) describes a pipeline occurrence to be "[a]ny accident or incident associated with the operation of a pipeline."

Pipelines transport most of the hydrocarbons in Canada, doing so in a safe and efficient way. Between 2003 and 2013, the average yearly number of occurrences involving pipelines was approximately 111. While this appears to be a large number, the reality is somewhat different when taking into consideration how much product actually gets released. Just over 80 percent of pipeline occurrences result in some release of product. However, as shown in **figure 1**, the vast majority (73 percent) of occurrences result in releases of less than 1 m^3, with only about 5 percent of accidents resulting in releases greater than 26 m^3.

Figure 1: Percentage of pipeline accidents and incidents by quantity released, 2003–2013



Sources: TSB, 2012, 2014; calculations by authors.

To understand the nature and safety of pipelines, it is also necessary to understand where accidents occur. During the period 2003 to 2013, only 17 percent of occurrences took place within the actual line pipe (see table 4, below). The majority of pipeline accidents occurred at facilities, which include, for example, compressor stations, gas processing plants, pump stations, terminals, transmission line pig traps, etc. Spills that occur in these areas are often contained within the facility, which may have secondary containment mechanisms and procedures (Furchtgott-Roth and Green, 2013).

In addition, over this time period only 8 of 1226 occurrences (less than 1 percent) resulted in environmental damage according to the Transportation Safety Board (TSB, 2013, 2014).

The relative safety of pipelines is further strengthened by this NR Canada (2014) statistic: between 2011 and 2013, 99.999 percent of crude oil and petroleum products arrived at their destination.

To compare the relative safety of transporting oil and gas by pipelines and rail, we converted data from governmental sources on oil transport to a common metric of million barrels of oil equivalent (Mboe). Unfortunately, the data for the goods transported by pipelines and rail are not perfectly comparable. The data for pipelines includes both petroleum products and natural gas products. These categories are rather broad and include many different types of products. In order to determine which commodity groupings to use in our calculation of a comparable measure of the amount of hydrocarbon transported by rail, we analyzed which commodities had been involved in pipeline occurrences over the last decade as cataloged in TSB (2014) (**table 1**).

Table 1: Product types involved in pipeline occurrences

Acid Gas
Condensate
Liquefied Petroleum Gas
Natural Gas
Natural Gas Liquids
Sour Gas
Petroleum Crude Oil
Refined Products
Sour Crude Oil

By assessing which types of hydrocarbon commodities were involved in pipeline occurrences, we were able to get a better idea of which commodities make up petroleum products and natural gas products, the categories containing the data on the amount of product moved by pipeline. Thus, we selected fuel oils and crude petroleum (includes bituminous mineral oil and tar sands), gaseous hydrocarbons including liquid petroleum gas (LPG's), and gasoline and aviation turbine fuel for rail. These categories should allow for the best comparison of the amount of hydrocarbons being transported by pipeline and rail.[3]

Table 2 presents the amount of oil and gas transported by both pipelines and rail. As it shows, pipelines have always transported the majority of hydrocarbons in Canada. Of particular interest though is the growth in the amount of fuel oils and crude petroleum transported by rail between 2003 and 2013, amounting to an increase of 166 percent. This growth will likely continue in the absence of new pipeline infrastructure (see CAPP, 2015).

Like the data on the amount of goods transported by rail, the rail accident data is also fragmented. Statistics Canada (2015) provides rail accident data for dangerous goods by dangerous goods classes. This presents a problem since the hydrocarbons that are comparable with pipelines fall under both Class 2-gases and Class 3-flammable and combustible liquids, and these categories have products in them that are not hydrocarbons transported by pipelines.[4]

3 Additional categories of hydrocarbons recorded by Statistics Canada include coal (e.g., non-agglomerated bituminous, anthracite, lignite, and agglomerated coal); coal coke and petroleum coke; and other refined petroleum and coal products (Statistics Canada, 2012).

4 See the appendix for a list of the commodities in dangerous goods classes 2 and 3.

Table 2: Amount of oil and gas transported (Mboe), 2003–2013

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Pipelines												
Total (petroleum products and natural gas products)	2,252	2,269	2,252	2,287	2,287	2,182	2,165	2,165	2,252	2,322	2,479	**24,909**
Rail												
Fuel oils and crude petroleum	37	36	37	36	40	38	38	39	40	67	99	**507**
Gaseous hydrocarbons, inc. liquid petroleum gas (LPG's)	58	57	53	52	52	49	48	46	46	50	52	**564**
Gasoline and aviation turbine fuel	18	17	19	21	22	21	25	26	28	23	16	**235**
Total rail	113	110	109	109	114	108	111	110	115	140	167	**1,307**

Sources: TSB, 2012, 2014; calculations by authors.

We made a special data request to Transport Canada (2015b) in order to pull out rail accident statistics comparable to pipelines from dangerous goods Classes 2 and 3. This request also allowed us to compile additional data for rail about where the accident occurred and whether product was released, allowing for a better comparison with rail.[5] Rail accidents for the following goods were used in the comparison:

Class 2

- Liquefied Petroleum Gases
- Liquefied Natural Gas or Methane
- Propane

Class 3

- Gasoline
- Petroleum Crude Oil
- Petroleum Crude Distillates
- Petroleum Sour Crude
- Fuel, Aviation, Turbine Engine

These goods should allow for the closest possible comparison with pipelines (goods transported by pipelines were listed in table 1).

Without considering the amount of product transported, rail initially appears to be the safer method for transporting oil and natural gas products (**table 3**). The average number of occurrences in a year for rail, based on data from 2003 to 2013, was 27, compared to 111 for pipelines. It is also worth noting that the percentage of accidents that resulted in the release of product was lower for rail in this period, at 73 percent, while approximately 84 percent of pipeline occurrences experienced some sort of product release. However, the percentage of occurrences with releases is much more stable over time for pipelines than for rail.

But a simple overview of occurrences does not convey the whole story. **Table 4** shows that the vast majority of occurrences for both rail and pipelines occur at facilities and not in transit or within the actual line pipe. This is encouraging, given safety and environmental concerns over the transportation of hydrocarbons, since 83 and 85 percent of respective pipeline and rail occurrences occur in areas that likely have secondary containment mechanisms (Furchtgott-Roth and Green, 2013).

Broad comparisons of the simple number of accidents over a given period do not take into consideration the amount of product being transported. In 2013, pipelines moved just under 15 times more product than did rail (2,479 Mboe transported by pipelines versus 167 Mboe by rail, see table 2). In order to determine the relative safety of each method, occurrences should be considered in relation to the amount of product transported. **Table 5** contains the occurrence statistics per Mboe transported for the years 2003 to 2013. In terms of both occurrences per Mboe and releases per Mboe, in every year, pipelines are *less* likely than rail to experience an occurrence in the transportation of hydrocarbons.

Overall, both methods of transportation appear to be quite safe. But data compiled on the safety of pipelines and rail in the transportation of hydrocarbons suggests that pipelines will experience approximately 0.049 occurrences per Mboe transported, while rail will experience about 0.227 occurrences per Mboe transported, making pipelines the safer method of transportation (**table 6**). These results suggest that rail is just over 4.5 times *more* likely to experience an occurrence per Mboe of hydrocarbon transported.

5 Note that, as per Transport Canada (2015a), an accident with the release of product only has to be reported as such if, for Class 2, it involves "[a]ny quantity that could pose a danger to public safety or any sustained release of 10 minutes or more", and for Class 3 if the release is greater than 200L.

Table 3: Overview of pipeline and rail occurrences, 2003–2013

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Pipelines												
Number of occurrences (accidents and incidents)	59	81	84	71	71	90	133	156	172	180	129	**1,226**
Number of occurrences with release of product	48	71	74	58	58	72	104	137	151	157	105	**1,035**
Percentage of occurrences with release of product	81%	88%	88%	82%	82%	80%	78%	88%	88%	87%	81%	**84%**
Rail												
Number of occurrences	50	31	45	24	27	18	17	16	18	20	30	**296**
Number of occurrences with release of product	45	23	34	9	21	10	11	8	13	15	28	**217**
Percentage of occurrences with release of product	90%	74%	76%	38%	78%	56%	65%	50%	72%	75%	93%	**73%**

Sources: TSB, 2012, 2014; Statistics Canada, 2015; Transport Canada, 2015b; calculations by authors.

Table 4: Pipeline and rail occurrences by location, 2003–2013

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Pipelines												
Occurrences – line pipe	9	25	23	12	16	13	26	17	20	19	23	**203**
Occurrences – facilities	50	56	61	59	55	77	107	139	152	161	106	**1,023**
Percentage of occurrences in line pipe	15%	31%	27%	17%	23%	14%	20%	11%	12%	11%	18%	**17%**
Rail												
Occurrences – transit	1	2	5	3	5	4	7	4	5	2	7	**45**
Occurrences – facilities	49	29	40	21	22	14	10	12	13	18	23	**251**
Percentage of occurrences in transit	2%	6%	11%	13%	19%	22%	41%	25%	28%	10%	23%	**15%**

Sources: TSB, 2012, 2014; Statistics Canada, 2015; Transport Canada, 2015b; calculations by authors.

Table 5: Pipeline and rail occurrences per Mboe transported, 2003–2013

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pipelines											
Occurrences per Mboe	0.026	0.036	0.037	0.031	0.031	0.041	0.061	0.072	0.076	0.078	0.052
Occurrences with release of product per Mboe	0.021	0.031	0.033	0.025	0.025	0.033	0.048	0.063	0.067	0.068	0.042
Rail											
Occurrences per Mboe	0.441	0.282	0.412	0.220	0.236	0.167	0.154	0.145	0.157	0.142	0.179
Occurrences with release of product per Mboe	0.397	0.209	0.312	0.083	0.183	0.093	0.100	0.073	0.113	0.107	0.167

Sources: TSB, 2012, 2014; Statistics Canada, 2015; Transport Canada, 2015b; calculations by authors.

Table 6: Overall comparison between pipelines and rail

	Totals, 2003–2013
Pipelines	
Pipeline Accidents and Incidents	1,226
Pipeline Goods Transported (Mboe)	24,909
Overall Occurrences per Mboe	0.049
Rail	
Rail Accidents	296
Rail Goods Transported (Mboe)	1,307
Overall Occurrences per Mboe	0.227

Sources: TSB, 2012, 2014; Statistics Canada, 2015; Transport Canada, 2015b; calculations by authors.

Intermodal safety, United States

The above calculations, comparing the safety of pipelines and rail in Canada, add to an already established literature in the United States that has explored this issue. Below we present many of the conclusions of various US studies that have examined the relative safety of pipelines and rail for the transportation of hydrocarbons.

State Department

Most recently, the United States State Department (2014a) evaluated the safety of oil pipelines versus railroads (and tankers) specifically in the context of the Keystone XL pipeline, which if constructed would deliver up to 830,000 barrels of oil per day from Canada's oil sands and Bakken shale.

Based on historical data in the US and a comparison of spill frequencies, a few of the general conclusions of the State Department were that:

> Overall, pipeline transport has the highest number of barrels released per ton-mile (Figures 5.1.3-5 and 5.1.3-6) and barrels released per barrels transported (Figures 5.1.3-7 and 5.1.3-8) for both crude oil and petroleum products … [c]omparing the number of incidents per ton-miles reported between 2002 and 2009, rail transport had the highest incident frequency for both crude oil and petroleum products of all modes of transport. (State Department, 2014a: 84; 87)

In specific relation to the proposed Keystone XL pipeline project, the State Department (2014b) also considered what the effects would be of moving the same amount of oil by other scenarios including rail transport. They concluded that moving the oil by non-pipeline means would result in more total releases and barrels released per year, while also emitting more CO^2 emissions during transport.

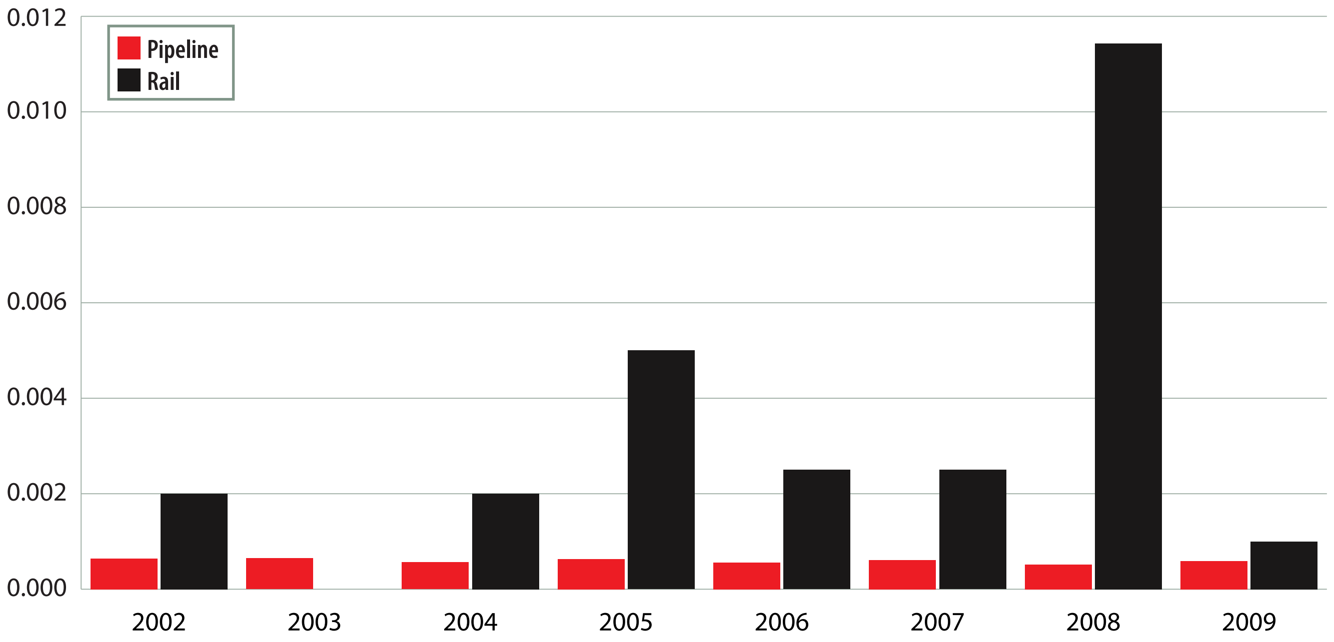
As **figure 2** shows, between 2002 and 2009, the number of releases per million ton-miles transported by rail has greatly exceeded the number of releases for pipelines. The average number of year releases per million ton-miles for pipelines and rail were 0.0006 and 0.0033, respectively, making rail roughly 5.5 times as likely to experience a release.

As **figure 3** shows, from 2002 to 2009, the volumes spilled per million ton-miles of petroleum transport was generally larger for pipelines than for rail (though in 2008 rail edged out pipelines on quantity spilled).

Potential corrosiveness of bitumen in pipelines

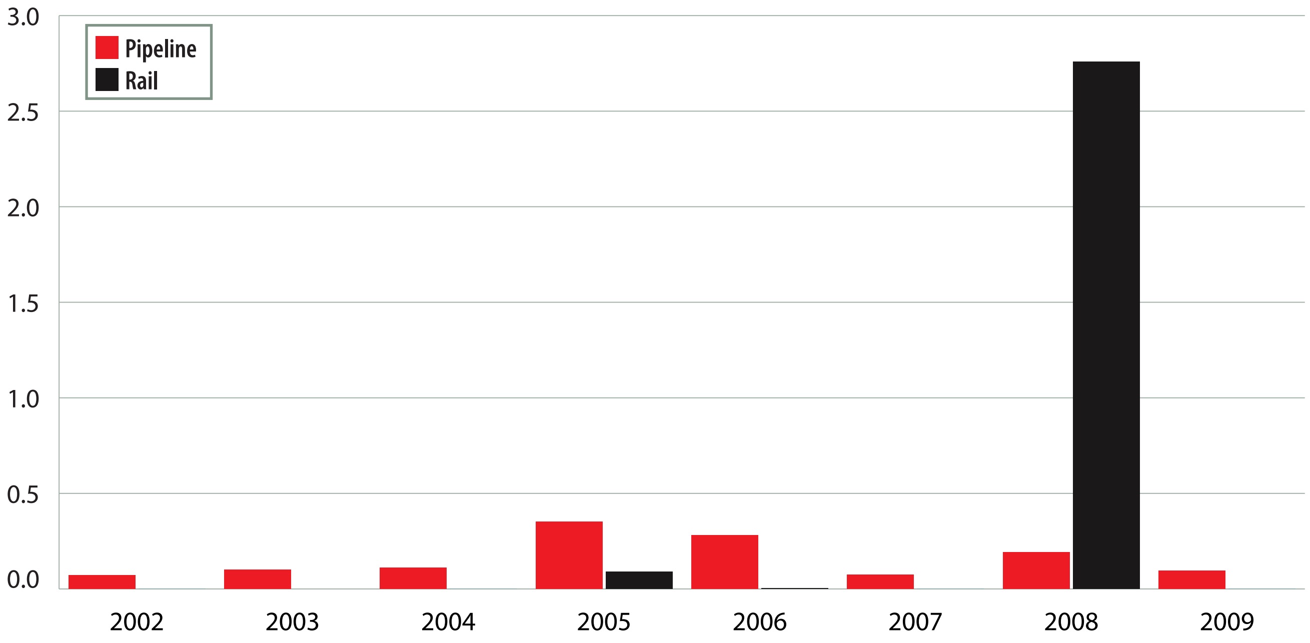
One of the recurring concerns about the safety of pipelines which carry bitumen from Canada's oil sands is that this type of oil is more corrosive than others, perhaps resulting in a greater incidence of pipeline failure. However, the concern remains unfounded. In June 2013, the National Academy of Sciences released a study entitled "Effects of Diluted Bitumen on Crude Oil Transmission Pipelines," which was required as part of the Pipeline Safety, Regulatory Certainty and Jobs Creation Act of 2011. The report found no evidence that diluted bitumen, the type of crude oil that would flow through the proposed Keystone XL pipeline, would contribute to pipeline failures or corrosion (National Academy of Sciences, 2013).

Figure 2: Number of releases per million ton-miles transported per year, crude oil: pipeline and rail



Sources: Bureau of Transportation Statistics, 2012; United States Department of State, 2014a; PHMSA, 2015; calculations by authors.

Figure 3: Barrels released per million ton-miles per year transported, crude oil: pipeline and rail



Sources: Bureau of Transportation Statistics, 2012; United States Department of State, 2014a; PHMSA, 2015; calculations by authors.

However, the State Department (2014b) noted that the differences in total volume spilled between rail and pipelines could be offset at least somewhat by the increased likelihood that a spill will occur when oil is transported by rail.

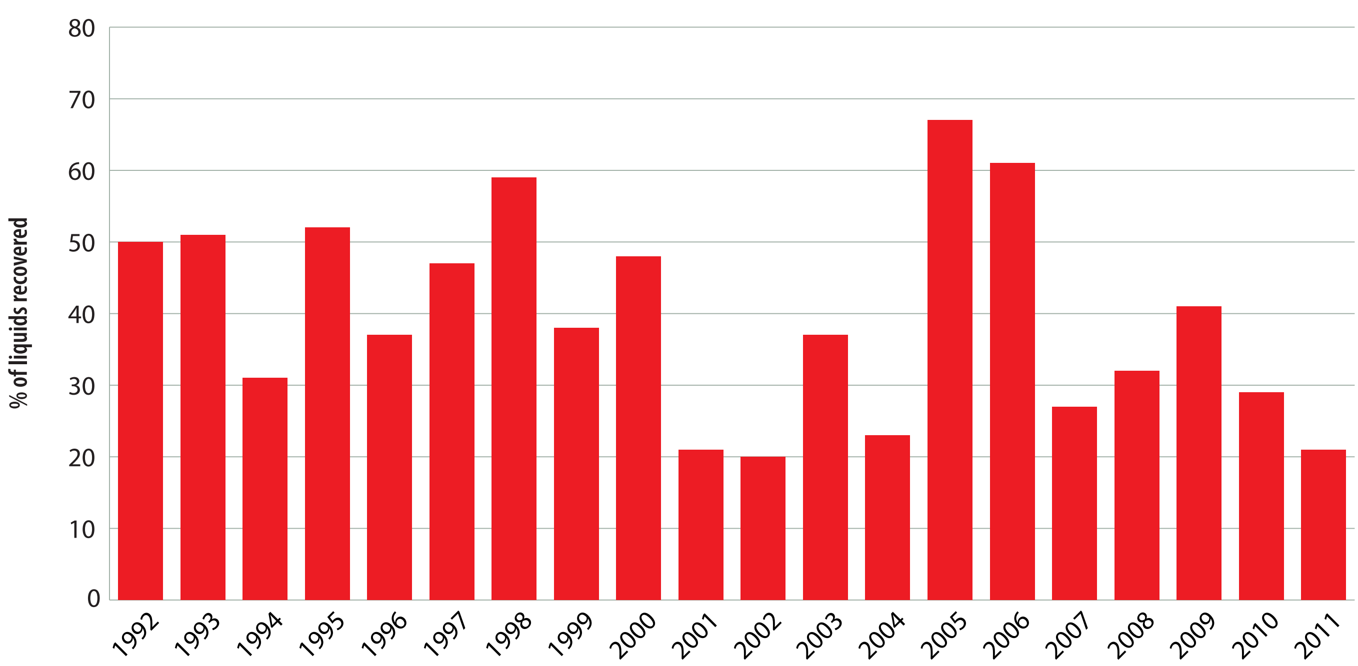
One important factor needs to be considered with regard to volumes spilled in pipeline accidents: a lot of the oil can be recovered. **Figure 4** shows the trend in volumes recovered after pipeline spills from 1992 to 2011 in the United States. The average amount of liquid recovered during this period was 40 percent.

With regard to health and safety, the State Department (2014a) data also gives a clear advantage to pipelines. Its analysis found that injuries and fatalities per ton-mile transported by rail far exceeded those associated with pipelines.

Comparing these known rates against two scenarios, one in which Keystone XL is built, and one in which it is not built, the State Department estimates that "[a]nnual baseline injuries and fatalities without an increase in transport volume from rail transport or pipeline are projected to be approximately 712 injuries and 94 fatalities compared to three injuries and two fatalities for petroleum pipeline. Using the frequency rates based on these incidents … and adding an annualized 830,000 bpd from the proposed Project to the yearly transport volume indicates a potential additional 49 injuries and six fatalities for rail alternative compared to one additional injury and no additional fatality for the proposed Project on a yearly basis" (2014a: 96).

The general conclusions of the State Department in regards to the relative safety of pipelines compared to rail were echoed in a recent Congressional Research Service report on rail transportation of crude oil in the US. The report noted that "pipelines could provide safer, less expensive transportation than railroads" (Frittelli et al., 2014: 23). As was the case with

Figure 4: Percent of liquids recovered from reported pipeline incidents, 1992–2011



Source: Furchtgott-Roth and Green, 2013.

the Canadian data, in the United States the data suggests that, overall, pipelines are a safer method of transporting hydrocarbons.

Manhattan Institute

In a study for the Manhattan Institute (incorporated into a 2013 Fraser Institute study on intermodal safety of oil transport: see Furchtgott-Roth, 2013; Furchtgott-Roth and Green, 2013), Diana Furchtgott-Roth compared the safety of road, rail, and pipeline hydrocarbon transportation. She found that transport of oil by roadway "… had the highest rate of incidents, with 19.95 per billion ton miles per year" (Furchtgott-Roth and Green, 2013: 11). This was followed by rail, with 2.08 per billion ton miles. She also found that "[o]il pipelines were the safest, with 0.58 serious incidents per billion ton miles" (2013: 12).

In terms of oil volumes released to the environment, not surprisingly, pipelines have significantly larger spill volumes on an annual basis, some 6.6 million gallons per year. However, it is possible that the total amount of product released is related to the overall amount of product transported, and thus should not be taken as an indicator of the relative safety of pipelines. Indeed, when comparing released product per billion ton-miles, Furchtgott-Roth and Green (2013) found that actual release rates for roads and pipelines were somewhat comparable at 13,707 gallons and 11,286 gallons, respectively. Oil spilled in railway accidents was considerably lower, at 3,504 gallons released per billion ton-miles. Furchtgott-Roth and Green (2013) observed that these values noticeably change when product-recovery rates for pipelines are factored into the equation.

Furchtgott-Roth and Green also looked into the health and safety elements of intermodal oil transport, finding that "[o]n average, annual injuries for 2005 through 2009 were lowest for hazardous liquid pipeline, at 4 people with injuries requiring hospitalization per year. The rate was higher for rail, at 4.6 such injuries per year, although for rail this number was heavily biased by the 2005 observation. Road accidents hospitalized 8.8 people per year, and natural gas pipelines hospitalized 45 people each year" (2013: 12).

With regard to the absolute number of fatalities over the 2005–2009 period studied, Ms. Furchtgott-Roth (2013) found that there was an average of 10 fatalities involved in moving oil by roadway, compared to 2.4 fatalities when moving oil by either railway or onshore pipeline.

Of course, the simple number of accidents does not tell the full tale. When examined on the same kind of apples-to-apples comparison discussed earlier—but this time, expressed as the rate of injuries that would occur when moving one ton of oil over one mile, a standard US metric—"… oil pipeline outperforms rail and road by a wide margin, causing just 0.00687 injuries requiring hospitalization per billion ton-miles. Rail causes nearly 40 times that many injuries requiring hospitalization on a per-ton-mile basis. Rail is also outperformed by natural gas pipelines on this measure, causing almost twice as many serious injuries per ton-mile. Road is the worst performer on this measure, averaging one serious injury per billion ton-miles. This is 145 times the oil pipeline rate" (Furchtgott-Roth and Green, 2013: 12).

Conclusion

Rising oil and natural gas production in both the US and Canada is outpacing the transportation capacity of our pipeline infrastructure. As has been discussed in a previous study, Canada is poised to dramatically increase production of bitumen from oil sand deposits in Western Canada (Angevine and Green, 2013). For Canada to realize the massive economic benefits from the development of those oil sands, the transport conundrum must be solved. At present, resistance to pipeline transport is sending oil to market by modes of transport that pose higher risks of spills and personal injuries, such as rail and road transport. While different data sets are not directly comparable, an examination of studies from the US and our analysis of the Canadian data strongly suggest that pipelines are the safer way to move oil compared to railways or roadways.

Appendix

This is the list of commodities that make up dangerous goods classes 2 and 3. Goods that are bolded were used to compare rail and pipeline safety in the transport of hydrocarbons.[6]

Table 7: Commodities in dangerous goods Classes 2 and 3

Class 2 commodities	*Class 3 commodities*
Anhydrous Ammonia	Flammable Liquids NOS
Butadienes, Stabilized	**Gasoline**
Butane	Diesel Fuel
Chlorine	Kerosene
Oxygen, Refrigerated Liquid	**Petroleum Crude Oil**
Liquefied Petroleum Gases	**Petroleum Crude Distillates**
Propylene	**Petroleum Sour Crude**
Sulphur Dioxide	Methanol
Vinyl Chloride, Stabilized	Turpentine
Argon, Refrigerated Liquid	Alcohols, NOS
Isobutane	Ethyl Acrylate, Stabilized
Liquefied Natural Gas or Methane	Methyl Methacrylate Monomer, Stabilized
Propane	Acetone
Carbon Dioxide	Xylenes
	Adhesives Containing Flammable Liquid
	Resin Solution, Flammable
	Isopropanol
	Toluene
	Fuel, Aviation, Turbine Engine
	Methyl, Tert-Butyl Ether
	Ethanol (more than 24 percent ethanol, by volume)
	Paint
	Styrene Monomer, Stabilized
	Flammable Liquids NOS

6 Note that while pipelines carry refined products which could potentially include diesel fuel, diesel fuel was not included in the railway accident data because we could not get exact data on the volume transported. The inclusion of diesel fuel in the rail data would likely only result in very minor changes.

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