Battelle
The Business of Innovation

December 11, 2013

United States Department of State
Attn: Genevieve Walker, NEPA Coordinator
2201 C Street N.W. Suite 2726
Washington, DC 20037

Dear Ms. Walker:

In September 2011, the U.S. Department of State (DoS) requested that Battelle Memorial Institute (Battelle) conduct an independent engineering assessment of the Risk Assessment contained in the Draft Environmental Impact Statement (EIS) for the Keystone XL Pipeline. Where necessary, TransCanada provided additional information to support the results presented in the Risk Assessment. The Battelle report was submitted to the DoS in January 2012. In May 2013, comments on the Engineering Report were received; Battelle revised the Engineering Report and submitted it to the DoS in June 2013. After discussions with the DoS EIS contractor, ERM, Battelle also produced a Risk Assessment Report. That report was submitted to ERM in June 2013; ERM then submitted the report to the DoS. On September 20, 2013, DoS asked Battelle to continue its review of these reports and submit any final comments. Attachment 1 provides a summary of Battelle's review of the Risk Assessment Report, and Attachment 2 provides Battelle's final comments on the Independent Engineering Report.

From our review of the Risk Assessment Report, we determined that the spill volumes and operator reported damage cost data are lognormally distributed. This is a significant finding because the statistical arguments are made to determine whether the pipeline system should be broken up into system components versus not breaking the system into components. The statistical analyses clearly present a compelling basis for breaking the system into the four components used in Battelle's risk assessment and in Appendix K of the Supplemental EIS (SEIS). The basis for this finding is presented in Attachment 1 of this Letter Report and its associated appendices. Appendix B of Attachment 1 shows the resulting revisions to the key system element tables in the Risk Assessment Report.

In Attachment 2, which addresses the Independent Engineering Report, we focused on our key findings and recommendations.

Should you have any questions, please contact me via email or phone (osborner@battelle.org, 614.424.4833).

All the best,

Rodney L. Osborne
Manager, Exploration ~ Production ~ Pipelines
Battelle Energy & Environment

Attachment 1

Comment Response on
"Risk Analysis of Proposed Keystone XL Pipeline Route – Final Report"

Following the completion of the draft Risk Assessment Report, Battelle started an internal review of the report. The first step was to perform a statistical analysis of the data in the Liquid Pipeline Incident Database maintained by the US Department of Transportation (DoT) Pipeline and Hazardous Materials Safety Administration (PHMSA) to determine if the correct statistics had been used and to obtain a better understanding of the uncertainty in the data analysis. The statistical review considered all the reported onshore crude oil incidents from January 2002 to December 2012 (11 years of data). The results of the statistical analyses and the significance of these results are summarized below. The detailed results of these analyses are presented in Appendices A and B of this attachment.

The key findings from the statistical analyses are:

1) The reported onshore crude oil spill volumes conform to a lognormal distribution (see Figure A-1).
2) The operator-reported damage cost data for onshore crude oil spills, used as a performance measure in the Risk Assessment Report, conform to a lognormal distribution (see Figure A-2).
3) If the pipeline system is divided into four system elements—mainline pipe, mainline valves, tanks, and other discrete elements—spill volumes and damage costs conform to a lognormal distribution (see Figure A-3 for mainline pipe).

The plots shown in Figures A-1 through A-4 were generated by the SAS® statistical software package. In Figures A-1 and A-3, "l_PRPTY_2013" is the SAS variable name for "total damage costs". These are the total damage costs expressed in 2013 dollars. In Figures A-2 and A-4, "l_loss_barrel" is the SAS variable name for "total barrels lost." On each figure, a histogram at the top left shows that the data conform to a normal distribution when the spill and damage cost data are plotted on a logarithmic scale. At the top right of each figure is the confidence range; the horizontal line and the diamond in the box are the mean and median, respectively. When the correct distribution is used, the two are equal, as shown in each of the figures. The diagram at the bottom of the figure shows that the probability data with increasing spill size or damage cost are linear, indicating that the correct analysis is being used.

The significance of these findings is that it is now possible to use the right performance measure, the geometric mean spill volume and geometric mean damage cost. Using these measures, it is not possible to demonstrate which subsets of data are statistically different from one another and specify the confidence level associated with these differences. For example, we show that that:

1) For two system components on the pipeline right-of-way, the geometric mean spill and damage costs for mainline pipe and mainline valves are statistically different at the 95 percent confidence level.
2) For two system components on fixed facilities, the geometric mean spill and damage costs for tanks and other discrete elements are statistically different at the 95 percent confidence level.
3) For spills greater than 1,000 barrels, the geometric mean damage cost for spills in high-consequence areas (HCAs) is significantly different from the damage costs in non-HCAs at the 95 percent confidence level. The same can be shown to be true for spills less than 50 barrels but not for medium-sized spills between 50 and 1,000 barrels.
4) For each of the four system components, when the geometric mean damage costs for large (greater than 1,000 barrels), medium (50 to 1,000 barrels) and small (less than 50 barrels) spills are calculated, they are statistically different at the 95 percent confidence level

There is a great deal of variability in the reported spill volumes and damage cost estimates. Now that it has been verified that the data are lognormal, statistical tests can demonstrate differences in the data groupings (two examples considered in the risk assessment are large, medium, and small spills in HCAs and non-HCAs). The tables in Appendix B show the geometric mean damage costs and associated uncertainty ranges for the four system components. The tables in Appendix B include revisions and additions to tables in the June 2013 Risk Assessment Report, as noted in the table titles.

Both the spill volumes and operator-reported damage costs are lognormal. In addition, when the data are parsed into system components— mainline pipe, mainline valves, tanks, and other discrete elements—each data subset was found to have a lognormal distribution. A SAS analysis of the uncertainty in the geometric mean spill volume for the four system components shows that only the tanks and mainline pipe are not statistically different at the 95 percent confidence limit. All the others have confidence ranges that do not include the mean value of the other elements. The basis for this statement can be shown using the geometric mean spill volumes and confidence ranges shown in Table 1. While the spill volumes for the mainline pipe and the tanks cannot be shown to have significantly different spill volumes, the others have statistically different spill volumes at the 95 percent confidence level because the geometric mean value for the system element falls outside the confidence range. For example, the geometric mean spill volume for mainline pipe, 33 barrels, falls outside the uncertainty range for both mainline valves and other discrete elements. There is also no overlap between the tanks and the other discrete elements. Since there is justification for treating the facility and the pipe right-of-way elements separately and there is statistical justification for separating those two elements into two additional parts, we stand by our decision to separate the analysis into four component elements. Note that these statistical tests consider the variation in spill volume over the 11-year period from January 2002 to December 2012.

Table 1. Geometric Mean Spill Volume and Uncertainty Range by System Element (January 2002 to December 2012)

System Element	Number of Spills	Geometric Mean Barrels Lost	95 % Confidence Level	
			Lower Limit	Upper Limit
Mainline Pipe	329	33	25	45
Mainline Valves	25	4	1	10
Tanks	92	53	27	104
Other Components	351	10	7	12

The lognormal distribution of the cost data means that any breakout of the damage costs by category can be tested for significance. In Table 2A, for the mainline pipe, the statistical analyses show that the damage costs for small, medium, and large spills are statistically different at the 95 confidence level. For large and small spills, there is a significant difference between the damage costs for HCAs and non-HCAs. For mainline valves, the data in Table 3A shows that the confidence test suggests using one damage cost for all 25 spills. For the two facility system elements, Tables 4 and 5 for tanks and other discrete elements, respectively, there is no significant difference between the damage costs spills occurring in an HCA and non-HCA area. This seems reasonable given that most of the spills at fixed facilities are unlikely to spread beyond the facility boundaries and that most are probably collected in sumps or retained by berms that are required around storage tanks. For tanks, a significant difference in the damage cost was found between large and medium spills, but not between medium and small spills. For other discrete elements, there were significant differences at the 95 percent confidence level between large, medium, and small spills. Considering these numbers to be avoidance costs, that is, costs an individual or company would be willing to spend to avoid the event, it can be concluded that the spill prevention programs should be directed at all three spill size categories.

In the Risk Assessment Report, there was insufficient discussion of the use of damage costs as a risk measure. The findings presented in Sections 5 and 7 of the Risk Assessment Report are particularly affected because in the draft report, by calling them costs, the Report provided an incomplete description of how the dollar values should be interpreted. In Table 2, the term “cost-risk” is now used because these dollar values have a probability term imbedded in them. Thus if two incidents have the same damage costs but one has a probability of occurrence that is one tenth the other, the one with the lower probability will have a ten times lower cost-risk. Cost-risk values are commonly used to identify those system elements where incorporating additional preventative and mitigative measures would be most effective. If selected measures are then incorporated into the operating system, it becomes possible to measure their effectiveness by estimating the change in the overall system level cost-risk value.

Table 2 shows the cost-risk by system element. It is clear that spills at fixed facilities (Tanks and Other Discrete Elements) represent almost half the cost-risk, suggesting that equal attention be placed on the maintenance and prevention activities for components other than mainline pipe.

Table 2. Cost-Risk Values by System Element
(dollar amounts rounded to nearest $1000)

Annual Risk of Pipeline Operation ($/year)		
Pipeline System	**Risk per Year**	**Percentage of Total**
Mainline Pipe	$106,000	48%
Mainline Valves	$1,000	0.28%
Tanks	$1,000	0.40%
Other Discrete Elements	$114,000	51%
All	**$221,000**	

We would like to clarify the link between the cost-risk reported in Section 5 of the Risk Assessment Report and the cost-risk discussion in Section 7 (the summary section). In Section 5, the cost-risk was calculated for a pipeline with a total length and number of components similar to the proposed northern section of the Keystone XL pipeline; however, since the cost-risk is based on historical data, its performance will be the same as the aggregate performance of all operating pipelines. The average age of the operating pipeline in the United States, based on mileage, is more than 40 years. That the data presented in Section 5 did not incorporate the safeguards discussed in Section 6 might not have been obvious to the reader of Section 5. The concept of presenting the data without the safeguards that will be used by TransCanada to prevent or minimize spill consequences first, and then qualitatively address the possible improvements to performance, is a common risk assessment approach. The vast majority of the currently operating pipeline, whose performance is used to develop the cost-risk numbers in Section 5, was not designed and constructed using current standards. The performance of a pipeline designed and constructed to the standards being used for the Keystone XL pipeline is anticipated to be much better than the performance demonstrated by the cost-risk numbers in Section 5. However, this conclusion must be tempered with another finding from the risk assessment. The mainline pipe represents only half the cost-risk, as shown in Table 2. Thus, completely effective performance of the main pipeline prevention and surveillance programs will only reduce the cost-risk by half; the other half of the cost-risk is at the fixed facilities and is controlled by different design and construction standards and different maintenance and surveillance programs. Section 7 states that the pipeline prevention and surveillance programs might be up to 90 percent effective, thereby reducing the frequency of spills by up to a factor of 10, if the TransCanada surveillance and maintenance programs are run in an effective manner.

One of the biggest uncertainties in the Risk Assessment Report is the number of facility components and mainline valves. The risk assessment results in Section 5 rely on the analysis of a system (1) whose number of components is based on the 875-mile length of the northern segment of the Keystone XL pipeline and (2) whose performance is no better than a composite of all currently operating pipeline. These results show that the facilities components represent half the cost-risk. The number of pumping stations is well known, as is the number of miles of pipe. Therefore, this 50/50 cost-risk ratio for facility components versus right-of-way components is quite certain. Because tanks and mainline valves have such a small contribution to the total, if they were increased by an order of magnitude, their contribution to the risk would still be below the cost-risk for the mainline pipe and other discrete elements by a factor of more than four. Thus considering the statistical uncertainty in the cost-risk numbers for the four system elements, the relative differences shown in Table 2 are believed to be robust.

As discussed in Section 7 of the Risk Assessment report spill prevention programs at both fixed facility and along the pipeline right-of-way are clearly a priority. It should be noted that although the numbers in the Risk Assessment Report have changed significantly, and can now be based on a much better understanding of the data, the conclusion s remain the same.

Appendix A: Detailed Summary of Statistical Analysis

Figure A-1. Damage Costs Plotted as Log (Damage Costs in 2013 Dollars) - Test for Lognormal Distribution)

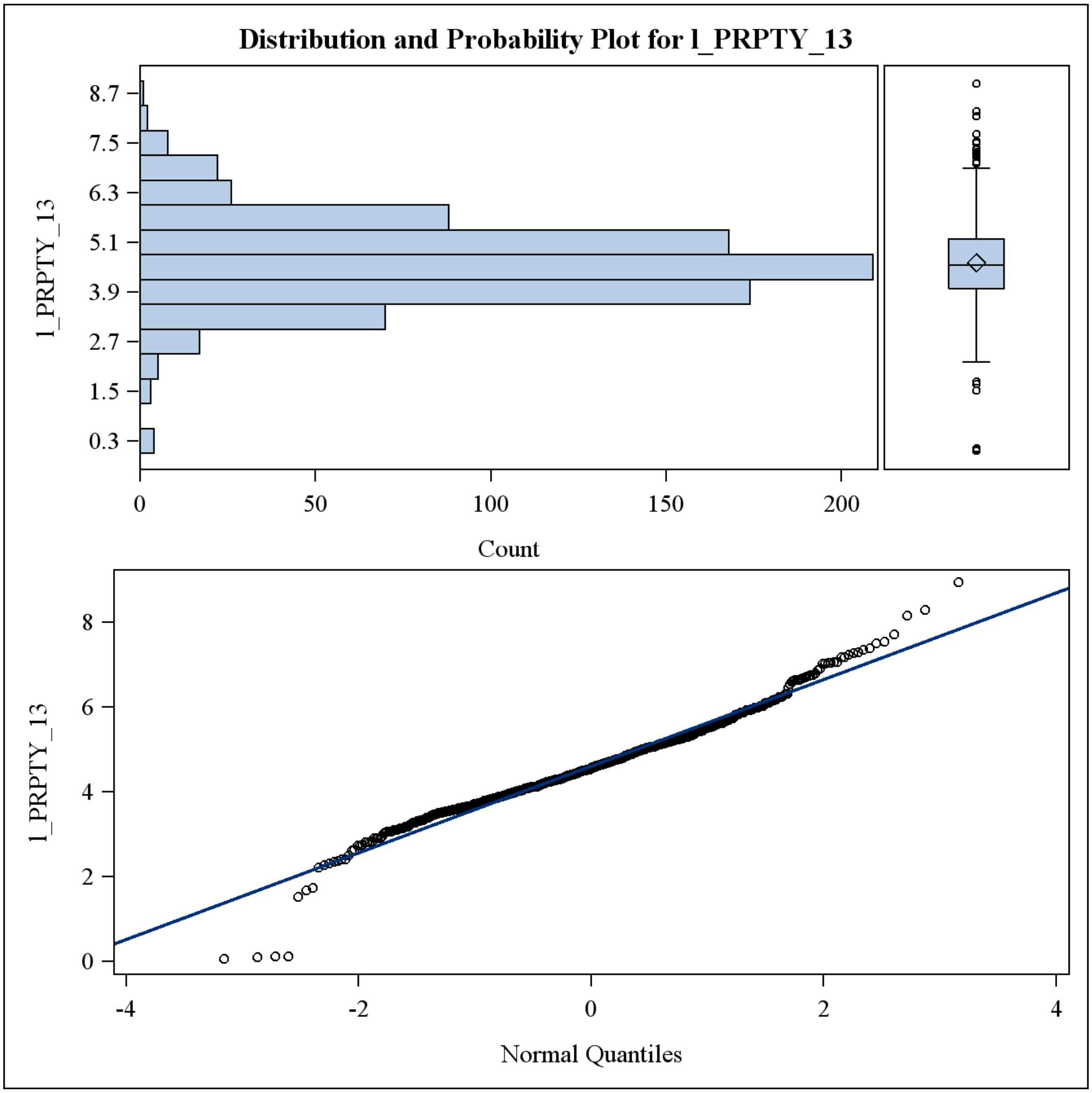


Figure A-2. Barrels Lost Plotted as Log (Barrels Lost) – Test for Lognormal Distribution

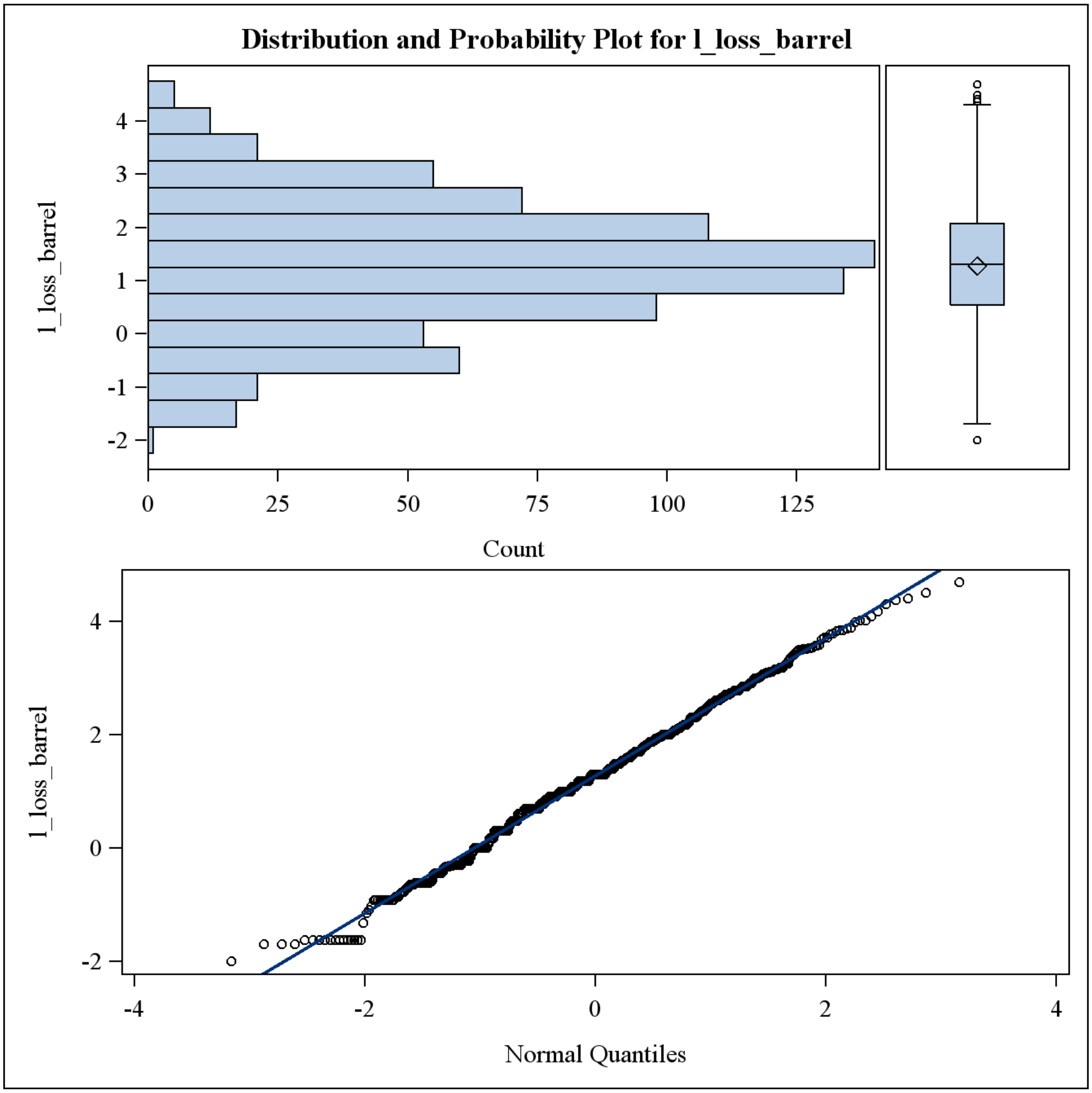


Figure A-3. Mainline Pipe Damage Costs Plotted as Log (Damage Costs in 2013 Dollars) - Test for Lognormal Distribution)

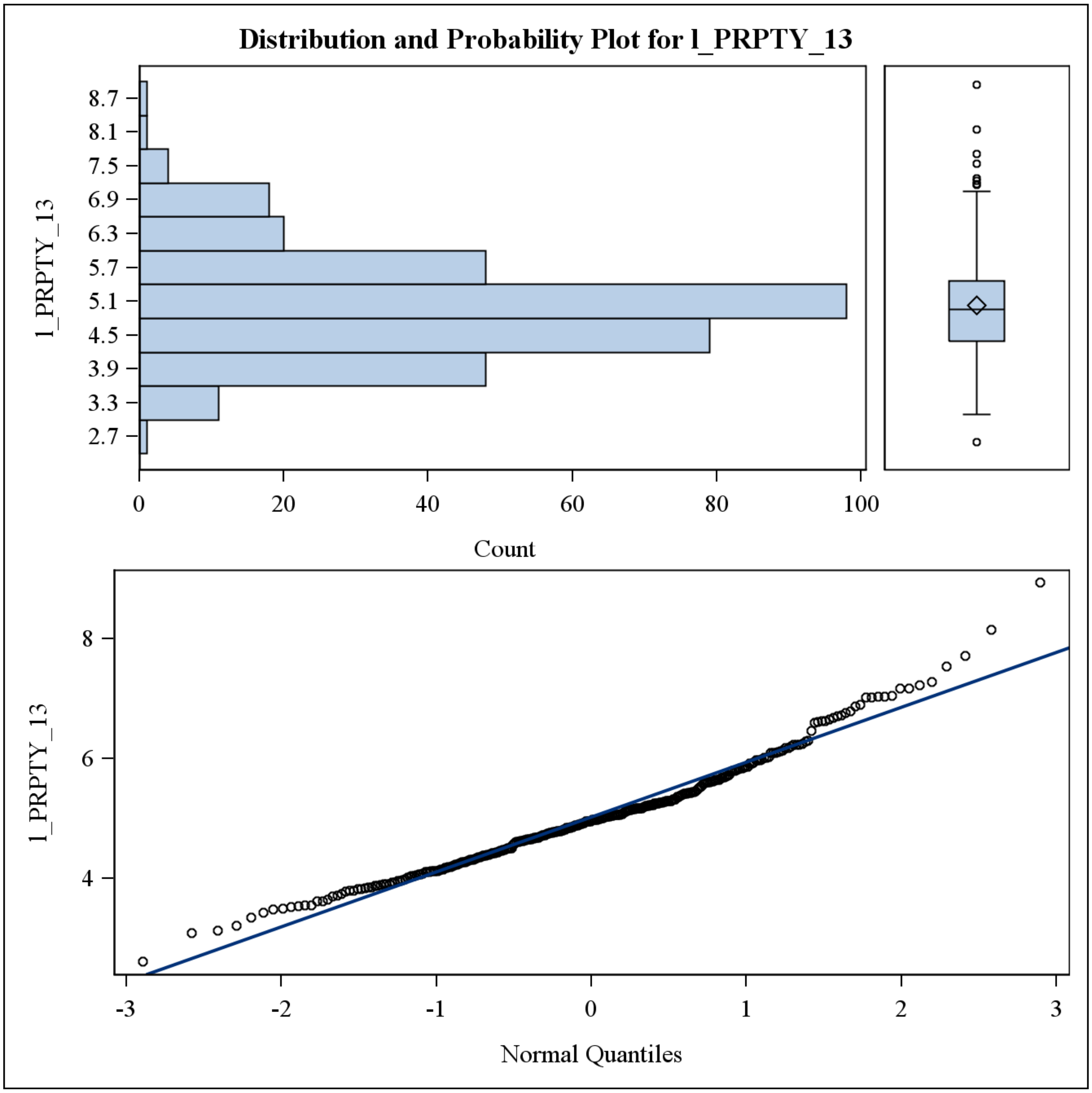
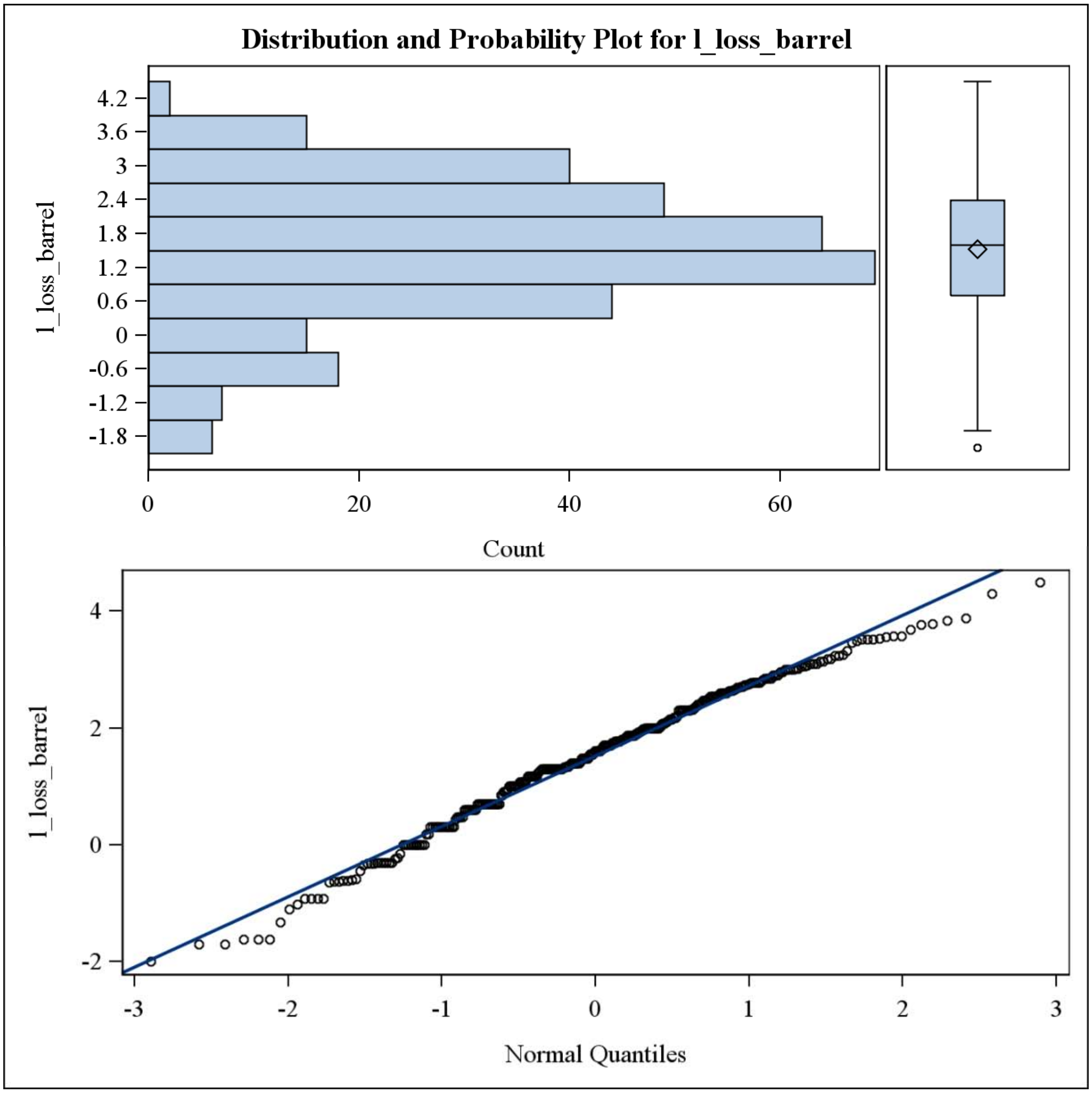


Figure A-4. Mainline Pipe Barrels Lost Plotted as Log (Barrels Lost) – Test for Lognormal Distribution



Appendix B: Revised Risk Assessment Report Tables

In order to assess the effect of using the geometric mean damage cost and barrels lost, the analyses in the June 2013 report were completely redone and new tables developed. The new tables consider the statistical significance of each cost number and only break out the costs when the differences are significant. Thus, the geometric mean damage costs for mainline pipe show that the differences between spills in HCAs and non-HCAs are significantly different for large and small spills, but not for medium spills (between 50 and 1,000 barrels). The uncertainty ranges on those costs are shown in Table B-1 (an addition to Risk Assessment Report Table 2). Table B-2, a revised Table 2 from the Risk Assessment Report, follows. If the mean value for a particular risk component does not fall into the confidence range for another component, then these two components have damage costs that are statistically different at the 95 percent confidence range.

Table B-1 (Addition to Risk Assessment Report Table 2). Confidence Ranges for Average Damage Costs for Mainline Pipe Sections by Spill Category for HCA and non-HCA (dollar amounts rounded to nearest $1000)

Spill Size	Mainline Pipe			
	HCA	Geometric Mean Damage Costs	95 % Confidence Limit	
			Lower Limit	Upper Limit
Large (>1000)	YES	$5,484,000	$1,471,000	$20,447,000
Large (>1000)	NO	$1,288,000	$570,000	$2,914,000
Medium (50-999)	YES	$179,000	$90,000	$356,000
Medium (50-999)	NO	$137,000	$97,000	$194,000
Small (<50)	YES	$78,000	$53,000	$115,000
Small (<50)	NO	$44,000	$34,000	$55,000

Table B-2 (Revision to Risk Assessment Report Table 2). Average Damage Costs for Mainline Pipe Sections by Spill Category for HCA and non-HCA (dollar amounts rounded to nearest $1000)

Spill Size	Mainline Pipe			Spill Probability
	HCA	Non HCA	Combined	
Large (>1000)	$5,484,000	$1,288,000	$2,498,000	11%
Medium (50-999)	Not significant	Not significant	$148,000	37%
Small (<50)	$78,000	$33,000	$44,000	52%

For mainline valves, there are only 25 datapoints; therefore, the statistical analyses show a much different result. The table showing the confidence ranges is shown below (Table B-3). In this case, there are no large spills, and the difference between medium and small spills in HCA and non-HCA is not statistically significant. Therefore one damage cost ($20,000) should be used for all spills.

Table B-3 (Addition to Risk Assessment Report Table 3). Confidence Ranges for Average Damage Costs for Mainline Valves by Spill Category for HCA and non-HCA (dollar amounts rounded to nearest $1000)

Spill Size	Mainline Valves			
	HCA	Geometric Mean Damage Costs	95 % Confidence Limit	
			Lower Limit	Upper Limit
Medium (50-999)	YES	$858,000	$0	**
Medium (50-999)	NO	$76,000	*	*
Medium (50-999)	COMBINED	$383,000	$0	**
Small (<50)	YES	$21,000	$7,000	$68,000
Small (<50)	NO	$9,000	$3,000	$28,000
Small (<50)	COMBINED	$13,000	$6,000	$28,000
COMBINED	COMBINED	$20,000	$8,000	$48,000

* Only one spill was reported, therefore no confidence limits can be assigned.
** The upper limit numbers calculated by SAS are unrealistically high due to the small sample size.

The following tables from the Risk Assessment Report summarize the geometric mean damage costs for tanks (Tables B-4 and B-5) and other discrete elements (Tables B-6 and B-7). Where the data show significant differences, these differences have been factored into the cost-risk calculation.

Table B-4 (Addition to Risk Assessment Report Table 4). Confidence Ranges for Average Damage Costs for Tanks by Spill Category for HCA and non-HCA (dollar amounts rounded to nearest $1000)

Spill Size	Tanks			
	HCA	Geometric Mean Damage Costs	95 % Confidence Limit	
			Lower Limit	Upper Limit
Large (>1000)	YES	$605,000	$118,000	$3,109,000
Large (>1000)	NO	$225,000	$73,000	$689,000
Large (>1000)	COMBINED	$324,000	$137,000	$765,000
Medium (50-999)	YES	$91,000	$13,000	$614,000
Medium (50-999)	NO	$35,000	$10,000	$120,000
Medium (50-999)	COMBINED	$45,000	$17,000	$120,000
Small (<50)	YES	$49,000	$24,000	$101,000
Small (<50)	NO	$13,000	$5,000	$34,000
Small (<50)	COMBINED	$25,000	$14,000	$46,000

Table B-5 (Revision to Risk Assessment Report Table 4). Average Damage Costs for Tank Incidents in HCAs and outside HCAs (dollar amounts rounded to nearest $1000)

Spill Size	Tanks			Spill Probability
	HCA	Non HCA	Combined	
Large (>1000)	Not Significant	Not Significant	$324,000	21%
Medium (50-999)	Not Significant	Not Significant	$45,000	30%
Small (<50)	Not Significant	Not Significant	$25,000	49%

Table B-6 (Addition to Risk Assessment Report Table 5). Confidence Ranges for Average Damage Costs for Other Discrete Elements by Spill Category for HCA and non-HCA (dollar amounts rounded to nearest $1000)

Spill Size	Other Discrete Elements			
	HCA	Geometric Mean Damage Costs	95 % Confidence Limit	
			Lower Limit	Upper Limit
Large (>1000)	YES	$11,561,000	$1,014,000	$131,825,000
Large (>1000)	NO	$1,603,000	$188,000	$13,658,000
Large (>1000)	COMBINED	$2,748,000	$557,000	$13,549,000
Medium (50-999)	YES	$72,000	$31,000	$167,000
Medium (50-999)	NO	$38,000	$24,000	$59,000
Medium (50-999)	COMBINED	$43,000	$29,000	$64,000
Small (<50)	YES	$13,000	$8,000	$21,000
Small (<50)	NO	$9,000	$7,000	$11,000
Small (<50)	COMBINED	$10,000	$8,000	$12,000

Table B-7 (Revision to Risk Assessment Report Table 5). Estimated Damage Costs for Other Discrete Elements – HCA and non-HCAs (dollar amounts rounded to nearest $1000)

Spill Size	Other Discrete Elements			Spill Probability
	HCA	Non HCA	Combined	
Large (>1000)	Not Significant	Not Significant	$2,748,000	3%
Medium (50-999)	Not Significant	Not Significant	$43,000	22%
Small (<50)	Not Significant	Not Significant	$10,000	75%

The damage costs shown to be significant in Tables B-2, B-5, and B-7 were used to recalculate the summary risk assessment results shown in Table 2 in the main body of this attachment (Attachment 1).

Attachment 2

Comment Response on
"Keystone XL Pipeline: Independent Engineering Assessment – Final Report"

As discussed in Attachment 1, above, the spill volume reported for onshore crude oil spills to PHMSA is lognormally distributed, and therefore the geometric mean is used to evaluate the spill volume distribution.

1) The Final EIS (FEIS) discusses the typical spill volume to be expected should a release occur from the Keystone XL pipeline. In the FEIS, TransCanada recommended 3 barrels; in the Independent Engineering Assessment prepared by Battelle, a 100-barrel figure was suggested as a typical spill volume. The TransCanada value was based on the median and the Battelle value was based on the arithmetic mean. As we now interpret the spill distribution to be lognormal, the value for the typical spill should be the geometric mean. The geometric mean value for all spills that occurred between January 2002 and December 2012 is 33 barrels for the mainline pipe section of the system. The discussions on Page ES-3 and ES-4 and in Section 3.3 of the Engineering Assessment should now be based on the geometric mean value.
2) The recommendation on page ES-6 of the Engineering Assessment that the system be divided into four components—mainline pipe, mainline valves, tanks, and other discrete elements —can now be justified using the uncertainty analyses for the lognormal distribution, as discussed in Attachment 1. It can be stated at the 95 percent confidence level that mainline pipe and mainline valves have significantly different spill volume distributions. The same is true for tanks and other discrete elements. While the statistical difference between tanks and mainline pipe is not statistically different, these components are separated by geography; therefore, it makes sense to separate them as well. In the Executive Summary of the Engineering Assessment, page ES-5, Key Finding 1 under Risk Assessment, it is recommended that the following sentences be added at the end:

> As a result of an internal review of the Risk Assessment Report, Battelle performed a statistical analysis of both the onshore crude oil spill volumes and total damage costs reported to PHMSA. The statistical analyses revealed that both the spill volumes and total damage cost estimates were found to be lognormally distributed. As a result of this finding, it was shown that there is a statistically significant difference, at the 95 percent confidence level, between the spill volumes and total damage costs for the four system components used in the Risk Assessment and in Appendix K of the SEIS. Thus, statistical analyses now provide even more justification for breaking the pipeline system into the subsystems.

3) On page 37 of the Engineering Assessment, Section 2.2.3.4 discusses PHMSA cause codes. The PHMSA list of general cause codes is longer than the list of cause codes TransCanada developed using ASME-B31.8S and API 1160. The differences are shown in Table 4 on page 38; ASME-B31.8S and API 1160 list more sub-elements under fewer cause codes. In the Executive Summary, Battelle summarized the proper role of these lists—the PHMSA list for an EIS and the ASME and API lists for developing the Integrity Management Program (IMP). The proper use of these lists is stated in the Executive Summary. Battelle stands by this finding. To clarify this position, it is suggested that the first two sentences under Risk Assessment - Key Finding 2 be replaced with the following statement.

> For the EIS assessments, the damage codes used in the PHMSA database should be used. Over time, the damage codes from standards will supplement these damage codes, but because the codes are more focused, they should not be used for EIS assessments.

4) In the original (January 2012) and the final (June 2013) reports, Battelle recommended increased aerial surveillance of the pipeline beyond what is currently required by PHMSA regulations. We believe this recommendation is a valid one. This recommendation was based on the following information (as noted on page 70 of the January 2012 report:

> "10. survey/patrol frequency even at the nominal two-week interval is largely ineffective based on some analysis:
>
> a. analysis done by Battelle staff over the years indicates that the likelihood of missing an encroachment action at a two-week patrol frequency was quite high.
>
> b. work done CFER (Reliability Based Prevention of Mechanical Damage to Pipelines) likewise indicates about a 90% chance of non detection at two week intervals."

In addition, an expert panel commissioned by the Alaska Department of Environmental Conservation[1] found that 92 percent of all spills they analyzed were detected visually, 5 percent were detected by odor, and 3 percent were detected both visually and by a leak detection system combined. The expert panel concluded that "to date, only a single North Slope oil transmission pipeline or flowline leak had been detected by leak detection systems; every other spill to date had been detected by a person, either through visual or olfactory observation." The panel also concluded that "There seemed to be agreement among the Expert Panel, regulators, and operators that human detection was thus far the most effective, proven technology for leak detection."

[1] *Alaska North Slope Spills Analysis: Final Report on North Slope Spills Analysis and Expert Panel Recommendations on Mitigation Measures*, Nuka Research and Planning Group, for the Alaska Department of Environmental Conservation, November 2010.

In a 2009 report entitled *Mechanical Damage--- Final Report* commissioned by DOT - PHMSA[2], the authors catalogued the experience of 10 pipeline operators, representing a diverse cross-section of industry professionals in the United States, Canada, and Europe, to gain a better understanding of the significance of the mechanical damage threat to pipeline system integrity and assess common practices for mechanical damage prevention, detection, assessment, and mitigation. Several of the pipeline companies interviewed for the report said they conducted aerial surveillance of pipelines greater than once every 2 weeks. For example, in the report, Company J maintains that "[t]he mainline is flown weekly where construction activity is less frequent and twice weekly in more active locations."

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[2] *Mechanical Damage – Final Report*, Michael Baker Jr., Inc. for the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, Office of Pipeline Safety, Under Delivery Order DTRS56-02-D-70036, April 2009.