APPENDIX K

Historical Pipeline Incident Analysis

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HISTORICAL PIPELINE INCIDENT ANALYSIS

The detail within the Pipeline and Hazardous Materials Safety Administration (PHMSA) incident and mileage reports was analyzed to show the distribution of historic spill volumes, incident causes, and frequencies of crude oil pipeline incidents in the PHMSA database. This analysis was done to understand what has occurred historically with respect to pipelines in the United States, and to provide input for spill impact analysis in this report. Although the results are not a direct indicator of how the proposed Project will act, it can provide insight into what could potentially occur with respect to spill volume, incident cause, and incident frequency.

1.0 BACKGROUND

The risk assessment of the previously proposed Project Final EIS (see the Supplemental EIS Appendix O, Pipeline Risk Assessment and Environmental Consequence Analysis) cited 1) the volumetric quantities of crude oil spilled in a pipeline spill event; 2) the frequency that such an event occurs; and 3) the causes of the events. PHMSA collects data on hazardous liquid pipeline systems operating in the U.S. These data can be used to provide insight into these three items.

PHMSA collects information that is available to the general public on both reportable pipeline incidents that have occurred and the total length of pipelines in operation from which the incidents have occurred.

Information collected for each incident includes:

- The date of each reportable incident;
- The hazardous liquid commodity associated with the pipeline involved in the incident;
- The volume of hazardous liquid commodity spilled in the incident;
- The part of the pipeline system from which the spill occurred;
- The diameter of the hazardous liquid pipeline involved in the incident; and
- The cause of the incident.

The total mileage of pipelines in operation in the United States is collected for each of the following:

- The type of hazardous liquid commodity transported; and
- The diameter of the pipeline.

In addition, for each individual pipeline system in operation in the United States, the number of breakout tanks in use is also collected. Defined in this document, linear elements refer to mainline pipe and girth welds and discrete elements are pipeline components such as pumping stations, mainline valves, and breakout tanks.

1.1 OBJECTIVE

The objective of this data analysis is to use PHMSA hazardous liquid pipeline incident data and hazardous liquid pipeline annual (mileage) data to determine the historical spill volumes, incident causes, and incident frequencies of crude oil pipeline spills in the United States. Additionally, this analysis provides separate determinations for pipeline mainline pipe and pipeline system discrete components.

1.2 METHOD

The method is to filter the PHMSA hazardous liquid incident database covering a fixed period of time by commodity type to obtain a subset of data specific to crude oil pipeline systems. Subsequent filtering by pipeline system component, pipeline diameter, and incident cause results in separate subsets of incident counts and associated reported spill volumes for pipeline mainline pipe, mainline valves, pipeline system tanks, and other discrete pipeline components. The historical spill size distributions and incident cause distributions can then be summarized for the time period covered.

By filtering the pipeline mileage data by commodity type and pipeline diameter, an estimate of the total mileage of pipeline in service over the same fixed time period is made. Dividing the number of incidents by the number of mile-years of pipeline in service provides the frequency of historic incidents per mile-year of pipeline. Dividing the pipeline tank incidents by the number of tanks in service over the time period provides the frequency of historic tank incidents per tank-year.

Finally, by estimating the average spacing of mainline valves and pumping stations on pipeline systems in service, the number of mainline valves and pumping stations in service can be approximated. Dividing the number of mainline valve incidents with the approximate number of mainline valves in service results in an approximate frequency of incidents per valve-year. Similarly, dividing the number of pipeline discrete incidents by the approximate number of pumping stations in service results in an approximate frequency of incidents per pumping station-year.

The number of incidents resulting from each filtering set is documented to provide a quick reference for error checking while performing the analysis.

1.3 ASSUMPTIONS

PHMSA incident and mileage data for the period from January 2002 through July 2012 (10.58 years of data) are sufficient for use and are most applicable to these estimates. Data prior to January 2002 had different reporting requirements and may not provide additional useful information.

Annual mileage for 2002 and 2003 is estimated by assuming each year's mileage is the same as that for 2004, the first year for which detailed mileage information is provided in the PHMSA data. Accepting the small discrepancies resulting from this simplification (reflecting only 2 out of 10.58 years of data) is preferable to the alternative of not assessing incidents covering the same period which would then reflect only 8.5 years of data.

The mileage for January through July 2012 is estimated by multiplying the mileage from 2011 by 0.58 (the fraction of a year represented by January through July). Accepting this simplification is preferable to not including the incidents that occurred in January through July of 2012.

All reported database incidents are counted, even if the information was incomplete or unspecified ("blank" or "Unknown", "Miscellaneous", and "Other").

2.0 RESULTS

The summaries show that:

- Spill volumes from the mainline pipeline tend to be larger than spills from discrete elements, other than tanks;
- Spill volumes from larger diameter pipelines tend to be larger than spills from smaller diameter pipelines;
- Spill volumes from pipeline tanks tend to be larger than mainline pipe spills when considering reported pipeline diameters;
- Spill volumes from pipeline tanks tend to be similar to mainline pipe spills for 16-inch and larger diameter pipelines;
- The dominant cause of a release for the mainline pipeline (linear) element is corrosion and outside force;
- Equipment failure is the primary cause for discrete equipment elements; and
- Incorrect operations represent a large proportion of reported incidents for tanks.

The PHMSA liquid incident dataset, which includes incidents from hazardous liquid pipelines, can be filtered to include only crude oil pipeline incidents. The PHMSA hazardous liquid pipeline incident data do not detail the type of crude oil (e.g., dilbit, synthetic crude oil [SCO], etc.) involved with each incident, and so the historic incident summaries cannot be specific to dilbit, SCO, or Bakken crude oil, but rather can only be specific to crude oil in general.

The historic incident data can be subdivided allowing historic spill volumes and incident causes from the mainline pipe to be assessed separately from discrete elements such as pumping stations, breakout tanks, valves, and other associated equipment.

Table 1 is a summary of hazardous liquid pipeline incidents reported to PHMSA for the January 2002 through July 2012 period and shows the incident breakdown by pipeline system element (mainline pipe, tanks, valves, and other discrete equipment items associated with pumping stations or pipeline systems). The incident counts are used to derive historic incident frequencies and spill volume distributions and for referencing incident cause breakdown.

For pipeline components, including the body of the pipeline itself and associated equipment, there were 1,692 reported crude oil incidents out of a total of 3,916 incidents in the entire hazardous liquid pipeline database for the time period referenced. Of the incidents contained in Table 1, the 2,224 incidents not related to crude oil are not salient to this evaluation. The remaining 1,692 incidents involving crude oil are used.

Table 1 Summary of PHMSA Database

Main Categories		Subset	
Description	**Number of Incidents**	**Description**	**Number of Incidents**
Hazardous liquid pipeline incidents	3,916	Non-crude oil pipeline incidents	2,224
		Crude oil pipeline incidents	**1,692**
Crude oil pipeline incidents	1,692	**Crude oil mainline pipe incidents**	**321**
		Crude oil pipeline, equipment incidents (not mainline pipe)	**1,027**
		Crude oil pipeline system, unspecified elements	344
Crude oil mainline pipe incidents	321	**16-inch or greater diameter**	**71**
		8-inch or 15-inch diameter	154
		Less than 8-inch diameter	52
		Diameter not provided	44
Crude oil pipeline, equipment incidents (not mainline pipe)	1,027	**Tanks**	**93**
		Valves	**25**
		Other discrete elements (pumps, fittings, etc.)	**909**

Source: PHMSA Hazardous Liquid Pipeline Incident Database, January 2002 through December 2009 and January 2010 through July 2012.

Notes:
Bold - Subsets of data used in this analysis.

Of these 1,692 incidents, 321 incidents were associated with the body of the pipeline or the welds connecting mainline pipe sections, and 1,027 incidents were associated with tanks, valves, and equipment at pumping stations. In this analysis, the 321 incidents are referred to as *Mainline Pipe* and the 1,027 are referred to as *Pipeline System*.

Also, 344 incidents were reported in such a way (such as with blank data fields) that it is not clear if they were associated with the mainline pipe of a pipeline or with a discrete element. Based on the low spill volumes of these incidents and the content of the extended descriptions of the item involved, most of these incidents are likely not associated with the body of a transmission pipeline.

The 321 mainline pipe incidents are divided according to the pipeline diameter involved, making three subsets as referenced in Table 1 for this analysis. For 44 of these incidents, the pipeline diameter was missing from the data. For the 1,027 incidents not involving the mainline pipe, subsets include tank incidents (referred to as *Tanks*), valve incidents (referred to as *Mainline Valves*), and incidents involving other discrete elements (referred to as *Other Discrete Elements*). These discrete elements include pumps, fittings, and other equipment items normally found at pumping stations or other fixed locations, and generally not found along the entire pipeline route as is the case of the mainline pipe itself and girth welds used to connect pipeline sections during pipeline installation.

The PHMSA data also include information on the pipelines in service in each calendar year since 2004. This information includes the pipeline length, the commodity transported, the pipeline

diameter, the installation year, and the number of breakout tanks associated with the pipeline. This information is needed to determine the incident rate per mile-year of pipeline and the incident rate per tank-year.

Table 2 contains a summary of the mileage of crude oil pipelines in service during the same period of the incidents shown in Table 1; it is broken down into three size ranges. To apply the incident detail available for 2002 and 2003, the mileage of pipelines in service in 2004 is used as an estimate for those years due to the lack of detail provided in the PHMSA data available. Because the incidents for 2012 only include those through July 30 of the 2012 calendar year (this report being made before the end of the year), the total number of miles in service at the end of 2011 is factored by 0.58 (January through July) to represent only the mile-years of January through July 2012.

Table 2 Estimated Mile-Years of Crude Oil Pipelines, by Diameter

Year	Less than 8-inch Diameter	8-inch to 15-inch Diameter	16-inch or Larger Diameter	Total
2002	*6,109*[1]	*16,606*[1]	*26,549*[1]	*49,264*[1]
2003	*6,109*[1]	*16,606*[1]	*26,549*[1]	*49,264*[1]
2004	6,109	16,606	26,549	49,264
2005	7,512	16,703	24,516	48,732
2006	6,206	14,782	27,464	48,453
2007	6,733	15,491	27,264	49,488
2008	7,124	16,687	27,152	50,963
2009	7,074	15,607	30,043	52,723
2010	4,079	22,455	28,511	55,045
2011	4,231	22,705	28,270	55,206
2012 (through July)	*2,215*[2]	*11,883*[2]	*14,796*[2]	*28,894*[2]
Jan 2002 – July 2012	**63,500 mile-years**	**186,130 mile-years**	**287,665 mile-years**	**537,295 mile-years**

Source: PHMSA Liquid Annual Data, 2004 through 2011.

[1] PHMSA data not available, estimated based on 2004 mileage.
[2] Estimated number of mile-years for January through July 2012 as 0.58 x 2011 mileage.

To estimate the numbers of associated pipeline system equipment in service from January 2002 through July 2012, shown in Table 3, several assumptions are used.

For breakout tanks, the number of breakout tanks in service is taken directly from the PHMSA liquid annuals data, which includes the number of tanks in service for each pipeline system. However, only breakout tanks are included in these numbers and incidents attributed to tanks are not necessarily associated with breakout tanks. The number of tanks over which the incidents are taken is greater than the number of breakout tanks shown in Table 3. Note that using a lower number of tank-years will result in a higher estimated incident frequency as the fixed number of incidents is applied to a smaller number of tanks in service. Thus using the breakout tank count will result in conservatively high tank incident frequencies.

For mainline valves, a rough estimate of the number of valves in service is made by assuming that crude oil pipelines in the PHMSA liquid annual data have a mainline valve every 20 miles, on average; this is half the number that would be used for the proposed Project which will have such a valve roughly every 10 miles. Thus a rough estimate of the number of valve-years is the number of pipeline mile-years divided by 20.

Table 3 Estimated Pipeline Equipment-Years

Crude Oil Pipeline Item	Estimated Exposure January 2002 – July 2012	Comment
Breakout tanks	18,937 tank-years	As reported in PHMSA Liquid Annual Data[1]
Mainline valves	26,865 valve-years	Assumes a valve every 20 miles (half as many as planned for the proposed Project) for 537,295 mile-years of reported crude oil pipeline[2]
Pumping stations	11,647 pumping station-years	Assumes a pumping station every 46 miles for 537,295 mile-years of reported crude oil pipeline[3]

Source (for pipeline mileage and breakout tank numbers): PHMSA Liquid Annual Data 2004 through 2011.

[1] 2002 and 2003 tank count based on 2004 count; 2012 tank count taken as 0.58 x 2011 count.
[2] PHMSA does not detail the number of valves in service. Assumption used results in only a rough estimate.
[3] PHMSA does not detail the number of pumping stations in service. Assumption used results in only a rough estimate.

For pumping stations, a rough estimate of the number of pumping stations in service is made by assuming that crude oil pipelines in the PHMSA liquid annual data have similar distances between pumping stations as the proposed Project's average distance of about 46 miles. Thus a rough estimate of the number of pumping station-years is the number of pipeline mile-years divided by 46.

The estimates of pipeline mile-years shown in Table 2 along with the estimates of pipeline-associated-equipment–years shown in Table 3 allow differentiating the incident rate between linear elements (mainline pipe and girth welds) and discrete elements (such as pumping stations and breakout tanks).

A summary of crude oil pipeline incidents as reported to PHMSA from January 2002 through July 2012, including spill volume, incident frequency, and cause breakdown, is presented in the following tables and plots. These summaries were made by simple filtering of the publicly available PHMSA incident data summarized in Table 1. The incident frequencies contained in the tables are simply the number of incidents divided by the associated mile-years or equipment-years summarized in Table 2 and Table 3.

The remaining tables and figures present summaries of incident data, spill volumes, and incident causes for the data subsets, as follows:

- Pipeline, reported elements: Table 4, Figure 1, and Figure 2;
- Mainline pipe, reported pipeline diameters: Table 5, Figure 3, and Figure 4;
- Mainline pipe, 16-inch and larger diameter: Table 6 and Figure 5, and Figure 6;
- Pipeline system, tanks: Table 7, Figure 7, and Figure 8;
- Pipeline system, mainline valves: Table 8, Figure 9, and Figure 10; and
- Pipeline system, other discrete elements: Table 9, Figure 11, and Figure 12.

The summaries show that:

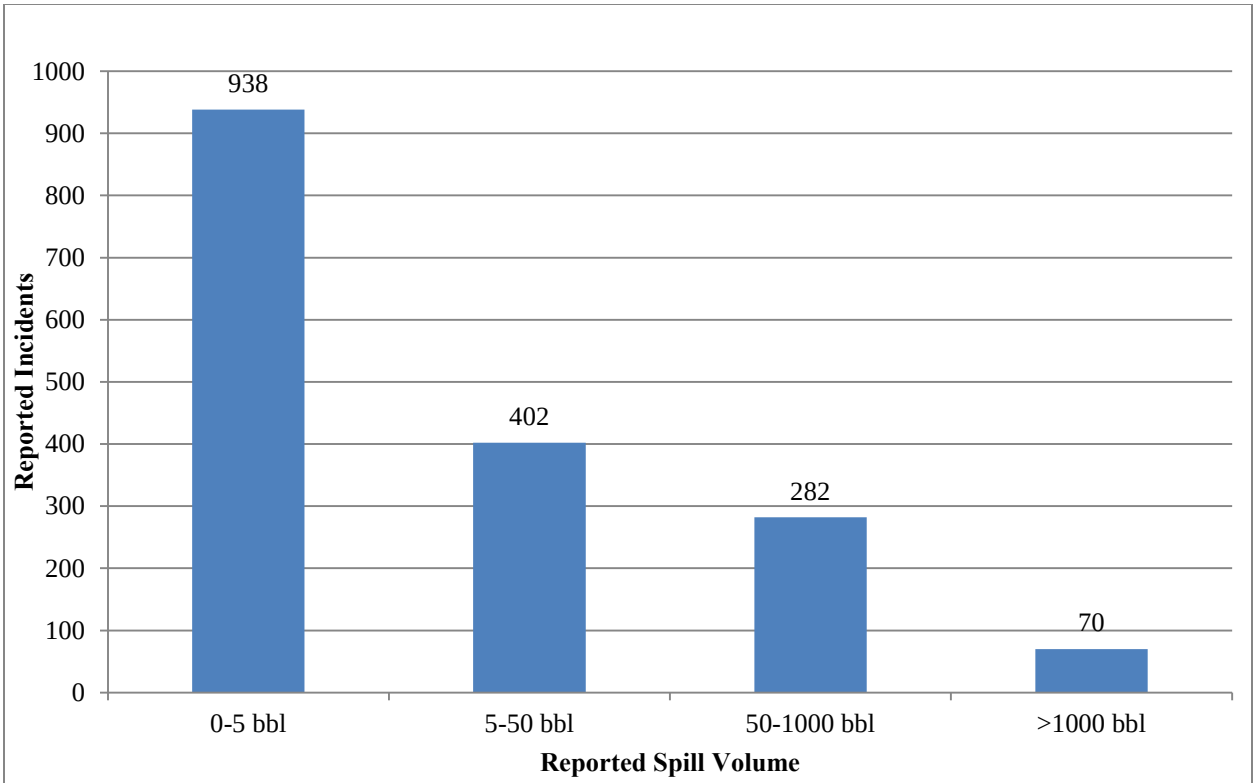
- Spill volumes from the mainline pipeline tend to be larger than spills from discrete elements, other than tanks;
- Spill volumes from larger diameter pipelines tend to be larger than spills from smaller diameter pipelines;

- Spill volumes from pipeline tanks tend to be larger than mainline pipe spills when considering reported pipeline diameters;
- Spill volumes from pipeline tanks tend to be similar to mainline pipe spills for 16 inch and larger diameter pipelines;
- The dominant cause for a release for the mainline pipeline (linear) element is corrosion and outside force;
- Equipment failure is the primary cause for discrete equipment elements; and
- Incorrect operations represent a large proportion of reported incidents for tanks.

Table 4 Historic Incident Summary, Onshore Crude Oil Pipeline, and Reported Elements

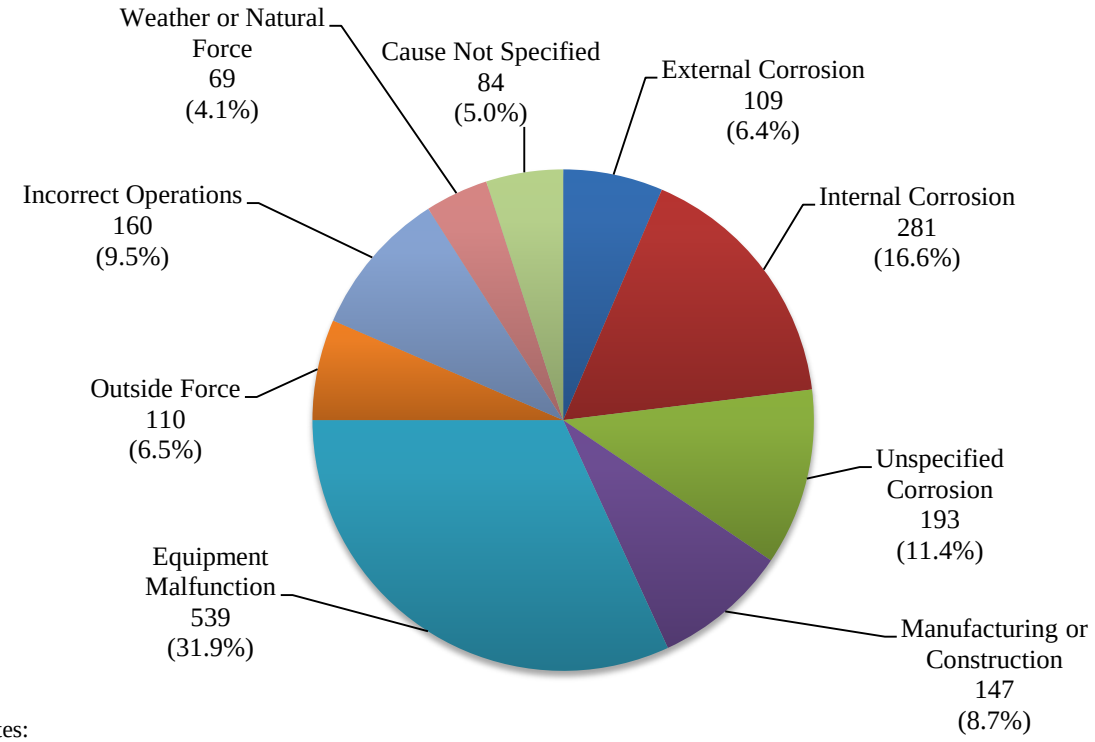
Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	1,692	Reported incidents
Pipeline Mileage	537,295	Mile-years
Incident Rate per Mile-Year	0.00313	Reported incident per mile-year
Equipment exposure	-	Not applicable
Incident Rate per equipment-year	-	Not applicable
Maximum Incident Volume Reported	49,000	Barrels
Median Incident Volume Reported	3	Barrels
Average Incident Volume Reported	264.6	Barrels
0-50 barrels	79%	Percentage of incidents
50-1000 barrels	17%	Percentage of incidents
1000 – 20,000 barrels	4%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
1,692 reported incidents between January 2002 and July 2012 (PHMSA)
Pipeline elements include mainline pipe, valves, breakout tanks, and pumping station equipment, and unspecified elements.

Figure 1 Historic Incident Spill Volumes, Onshore Crude Oil Pipeline, Reported Elements



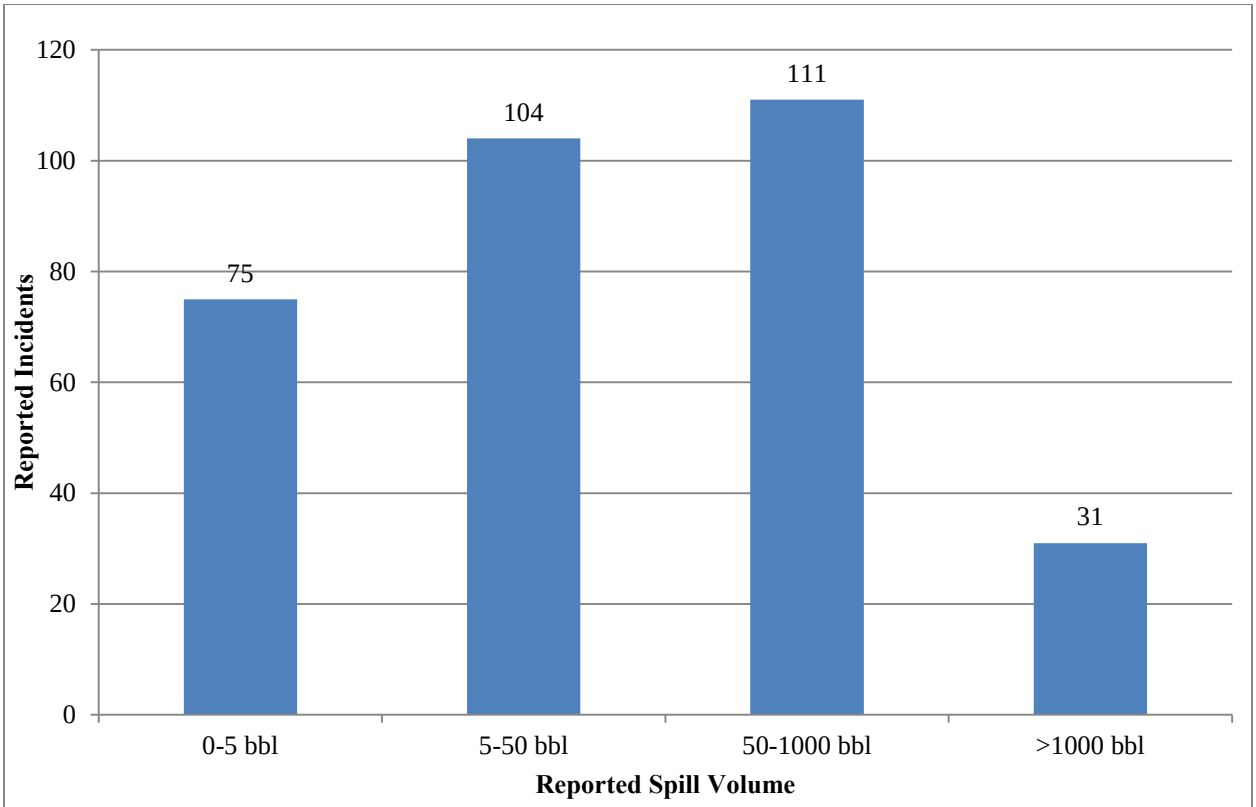
Notes:
1,692 incidents reported between January 2002 and July 2012 (PHMSA).
Pipeline elements include mainline pipe, valves, breakout tanks, and pumping station equipment.

Figure 2 Historic Incident Cause, Onshore Crude Oil Pipeline, Reported Elements

Table 5 Historic Incident Summary, Onshore Crude Oil Mainline Pipe, Reported Pipeline Diameters

Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	321	Reported incidents
Pipeline Mileage	537,295	Mile-years
Incident Rate per Mile-Year	0.00059	Reported incident per mile-year
Equipment exposure	-	Not applicable
Incident Rate per equipment-year	-	Not applicable
Maximum Incident Volume Reported	20,082	Barrels
Median Incident Volume Reported	30	Barrels
Average Incident Volume Reported	401.7	Barrels
0-50 barrels	56%	Percentage of incidents
50-1000 barrels	35%	Percentage of incidents
1000 – 20,000 barrels	9%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
321 reported incidents between January 2002 and July 2012 (PHMSA)
Pipeline elements include mainline pipe, and associated girth welds only.

Figure 3 Historic Incident Spill Volumes, Onshore Crude Oil Mainline Pipe, Reported Pipeline Diameters

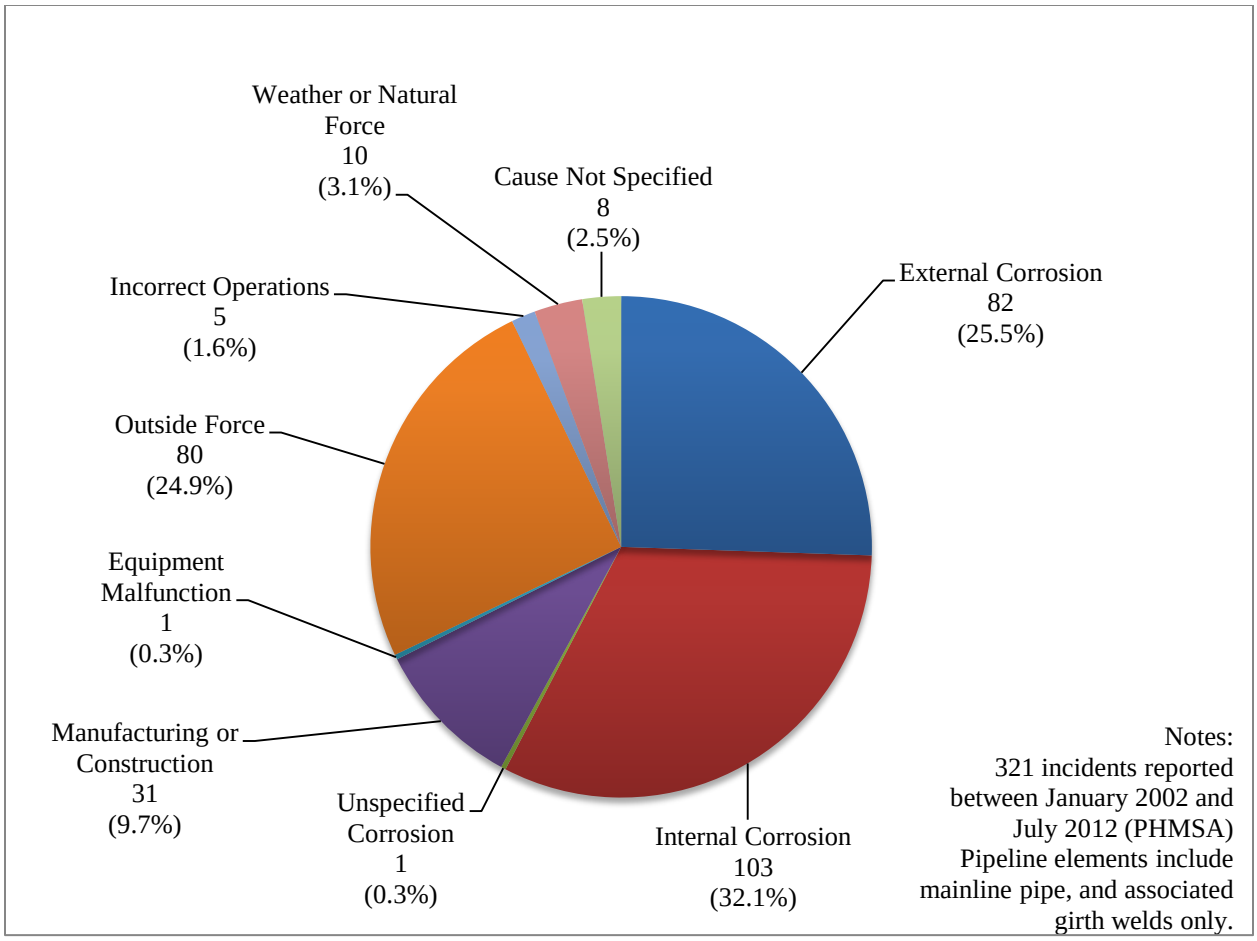
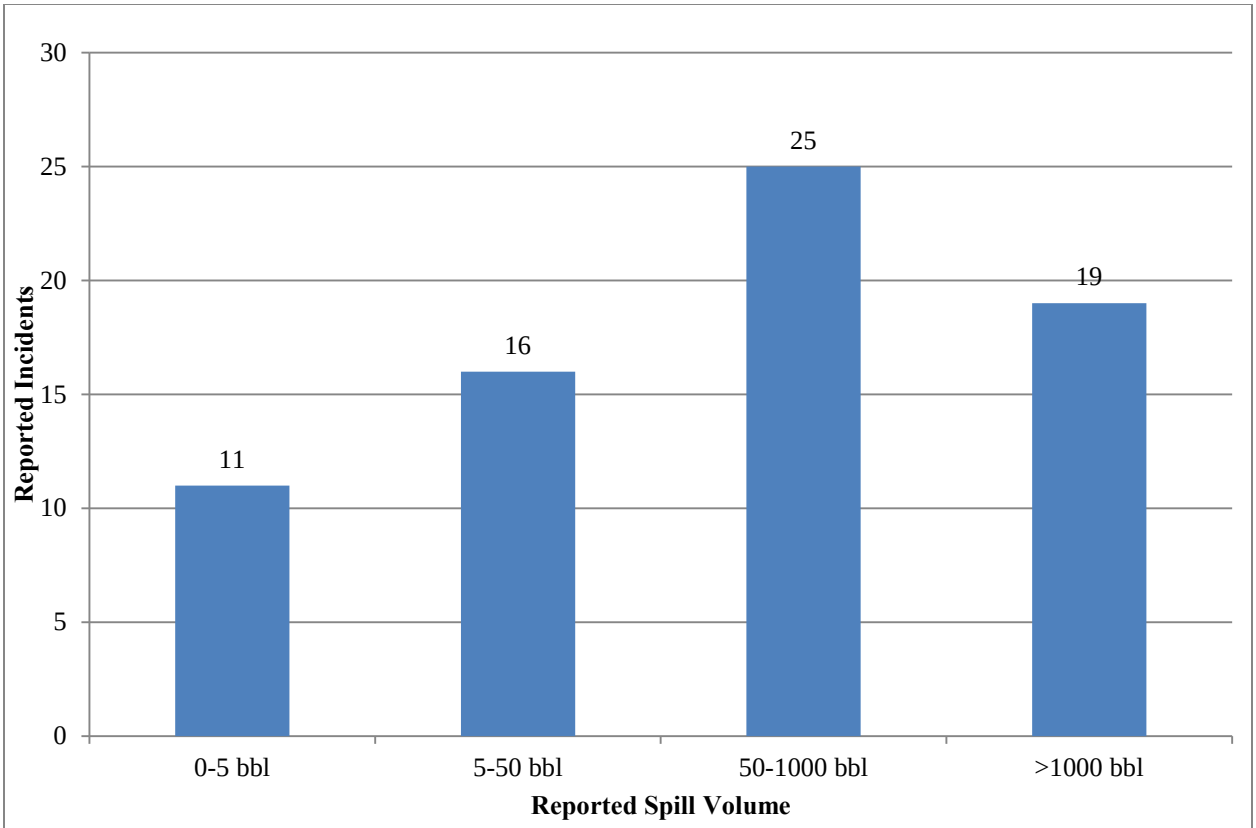


Figure 4 Historic Incident Cause, Onshore Crude Oil Mainline Pipe, Reported Pipeline Diameters

Table 6 Historic Incident Summary, Onshore Crude Oil Mainline Pipe, 16-inch Diameter and Larger

Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	71	Reported incidents
Pipeline Mileage	287,665	Mile-years
Incident Rate per Mile-Year	0.00025	Reported incident per mile-year
Equipment exposure	-	Not applicable
Incident Rate per equipment-year	-	Not applicable
Maximum Incident Volume Reported	20,082	Barrels
Median Incident Volume Reported	100	Barrels
Average Incident Volume Reported	1,116	Barrels
0-50 barrels	38%	Percentage of incidents
50-1000 barrels	36%	Percentage of incidents
1000 – 20,000 barrels	26%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
71 reported incidents between Jan 2002 and July 2012 (PHMSA).
Pipeline elements include mainline pipe, and associated girth welds only.

Figure 5 Historic Incident Spill Volumes, Onshore Crude Oil Mainline Pipe, Diameters 16-inch and Larger

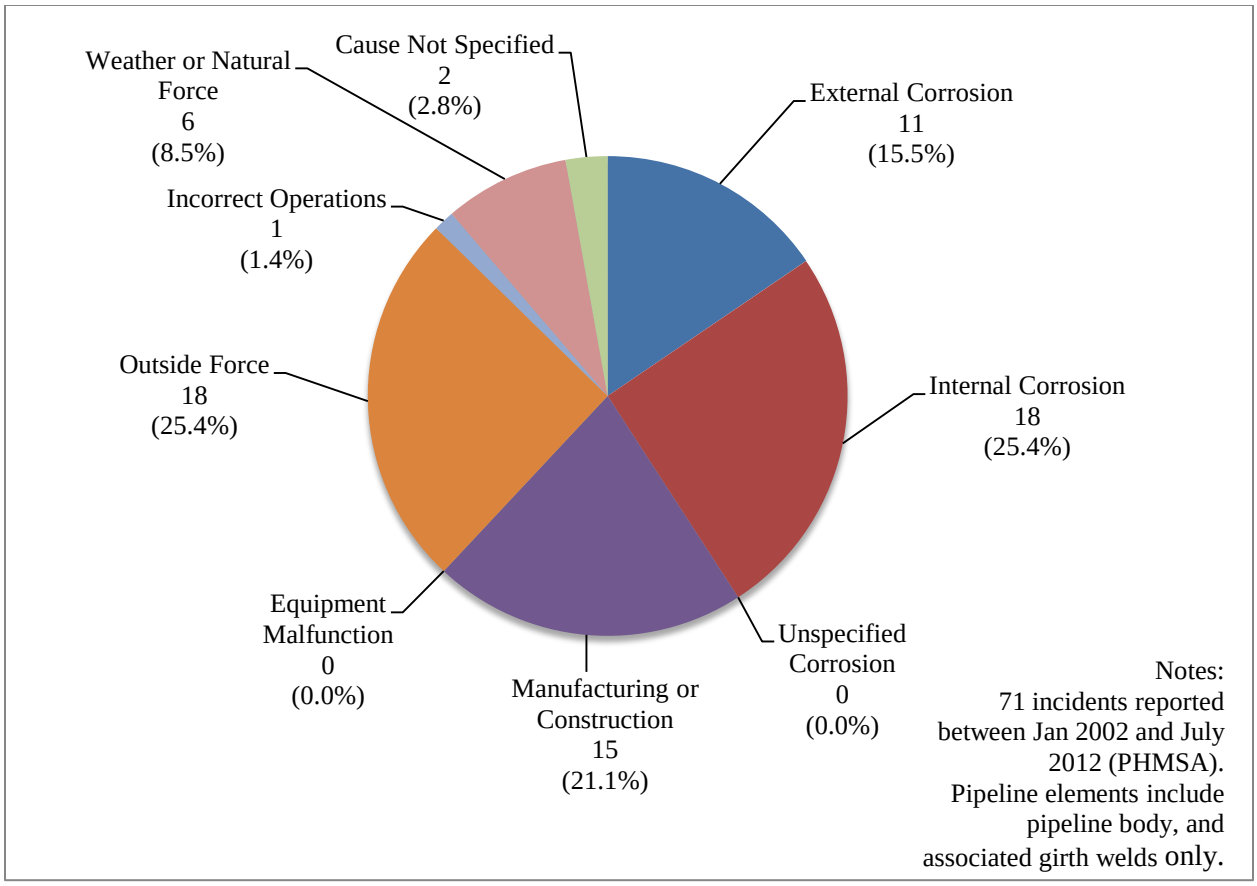
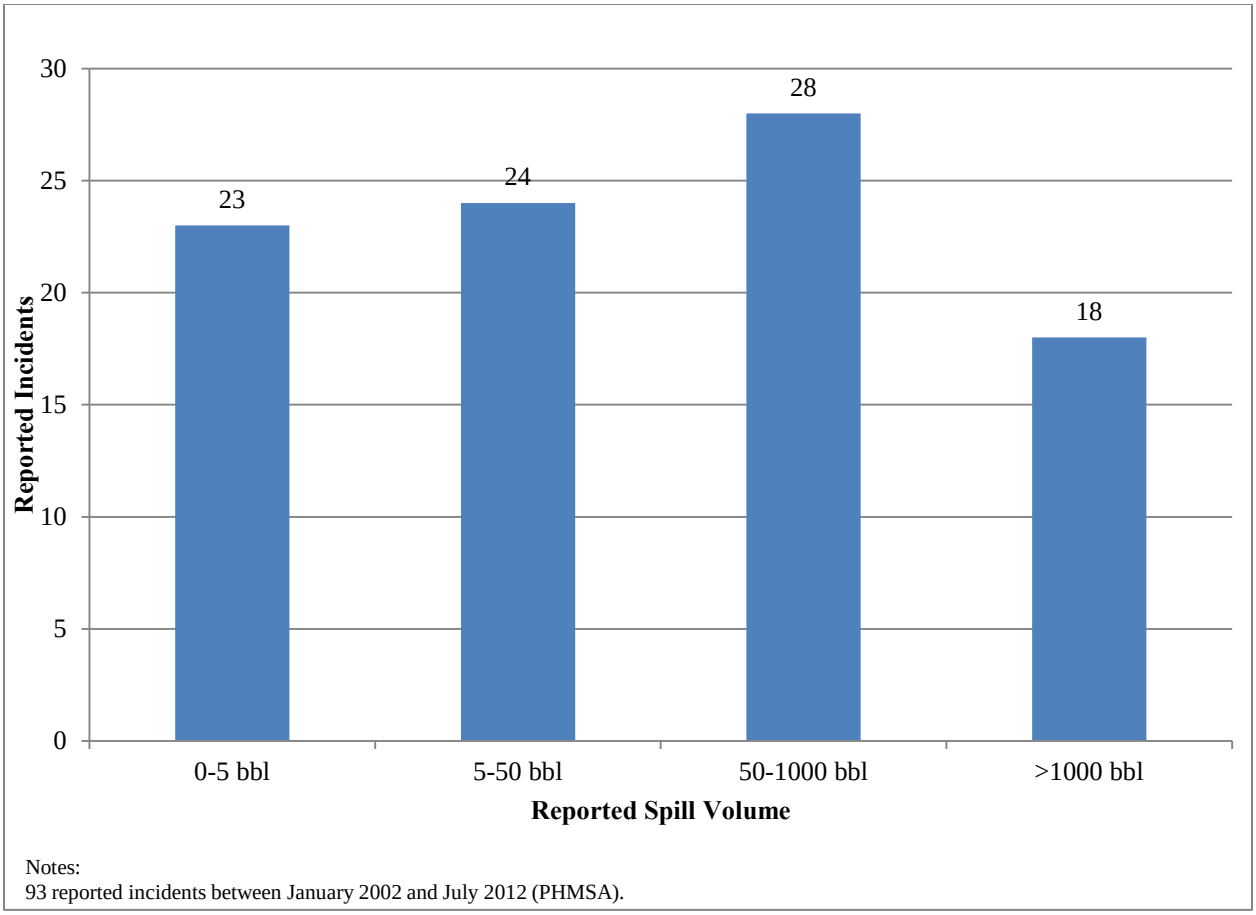


Figure 6 Historic Incident Cause, Onshore Crude Oil Mainline Pipe, Diameters 16-inch and Larger

Table 7 Historic Incident Summary, Onshore Crude Oil Pipeline System, Tanks

Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	93	Reported incidents
Pipeline Mileage	537,295	Mile-years
Incident Rate per Mile-Year	0.00017	Reported incident per mile-year
Equipment exposure	18,937	Tank-years
Incident Rate per equipment-year	0.0049	Incident per tank-year
Maximum Incident Volume Reported	49,000	Barrels
Median Incident Volume Reported	38	Barrels
Average Incident Volume Reported	1,720	Barrels
0-50 barrels	51%	Percentage of incidents
50-1000 barrels	30%	Percentage of incidents
1000 – 20,000 barrels	17%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
93 reported incidents between January 2002 and July 2012 (PHMSA).

Figure 7 Historic Incident Spill Volumes, Onshore Crude Oil Pipeline System, Tanks

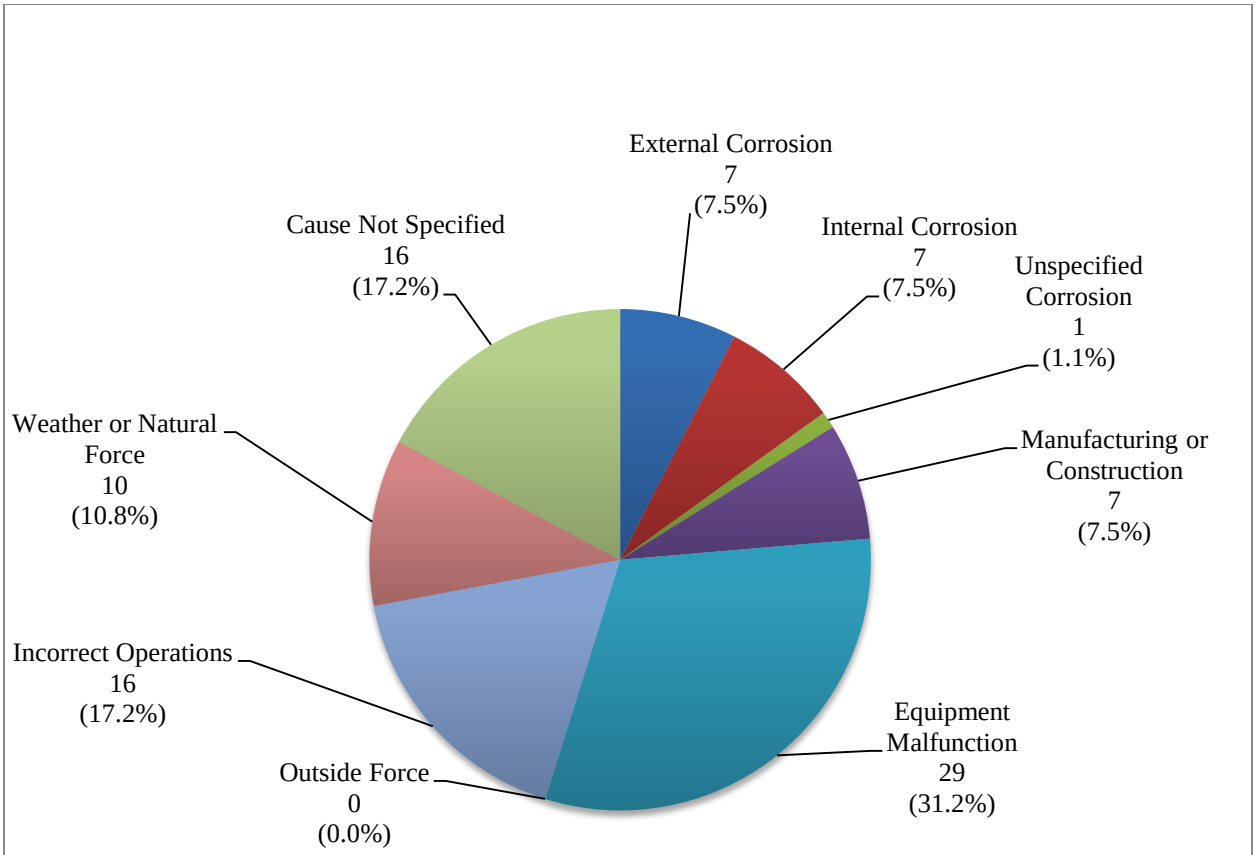
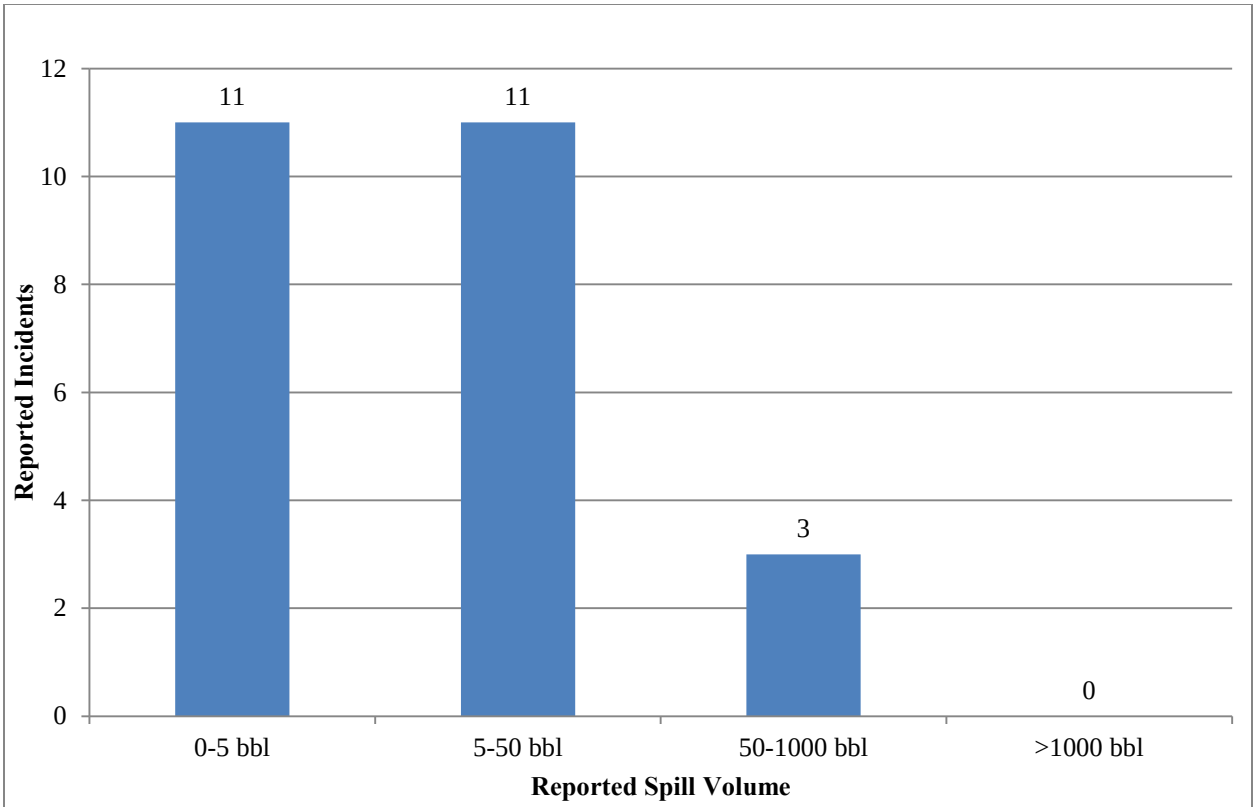


Figure 8 Historic Incident Cause, Onshore Crude Oil Pipeline System, Tanks

Table 8 Historic Incident Summary, Onshore Crude Oil Pipeline System, Mainline Valves

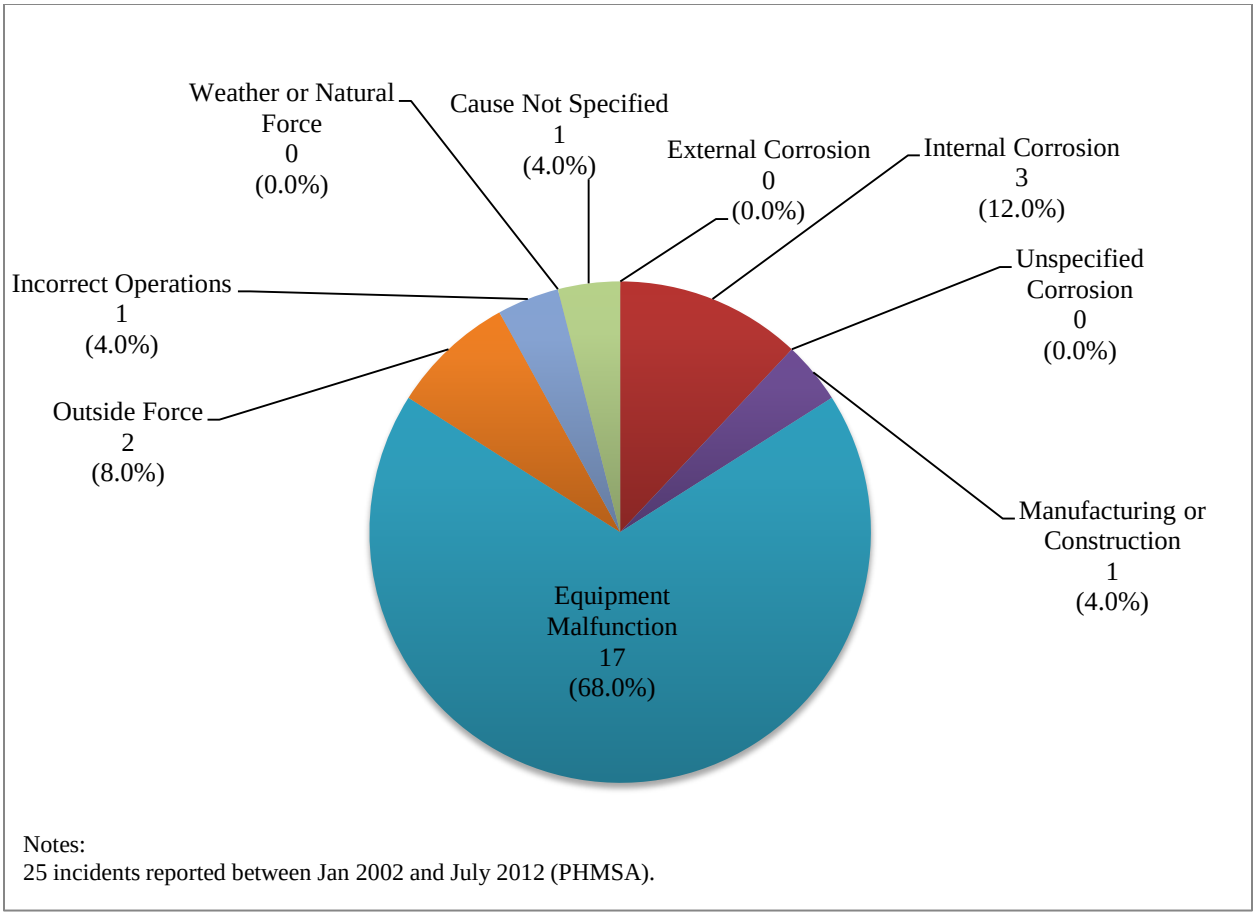
Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	25	Reported incidents
Pipeline Mileage	537,295	Mile-years
Incident Rate per Mile-Year	0.00005	Reported incident per mile-year
Equipment exposure	26,865	Valve-years
Incident Rate per equipment-year	0.00093	Incident per valve-year
Maximum Incident Volume Reported	500	Barrels
Median Incident Volume Reported	5.5	Barrels
Average Incident Volume Reported	33.7	Barrels
0-50 barrels	89%	Percentage of incidents
50-1000 barrels	11%	Percentage of incidents
1000 – 20,000 barrels	0%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
25 reported incidents between January 2002 and July 2012 (PHMSA).

Figure 9 Historic Incident Spill Volumes, Onshore Crude Oil Pipeline System, Mainline Valves



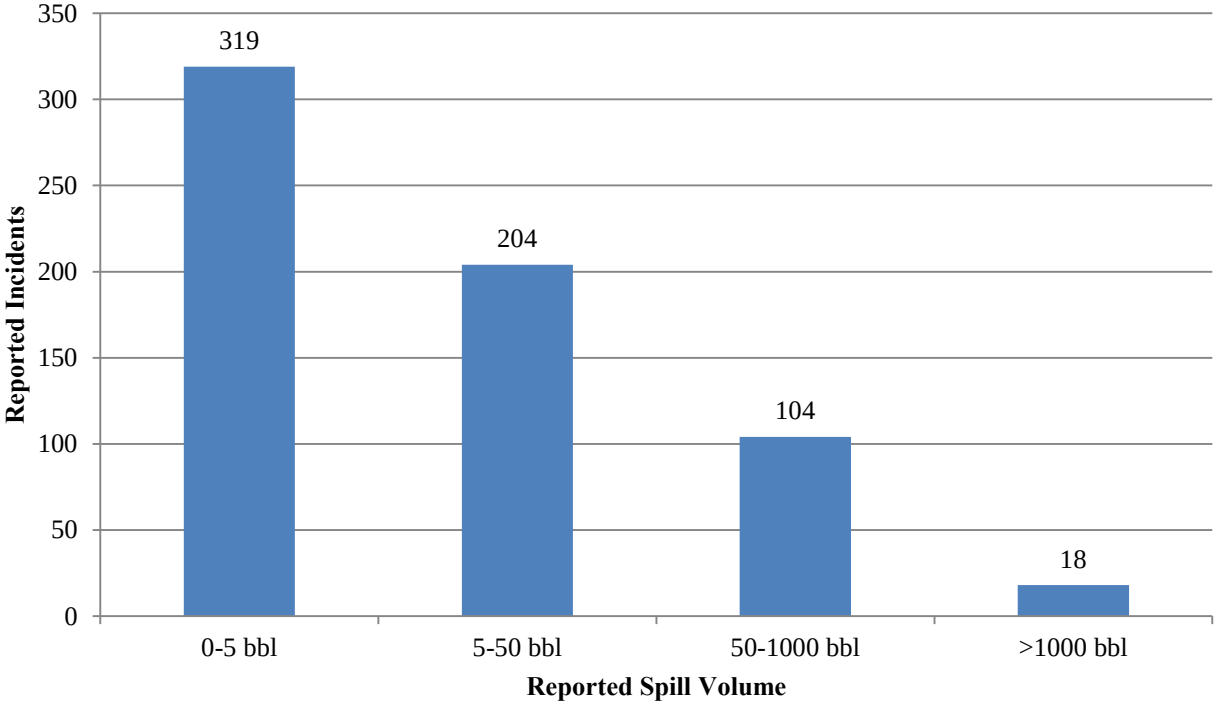
Notes:
25 incidents reported between Jan 2002 and July 2012 (PHMSA).

Figure 10 Historic Incident Cause, Onshore Crude Oil Pipeline System, Mainline Valves

Table 9 Historic Incident Summary, Onshore Crude Oil Pipeline System, Other Discrete Elements

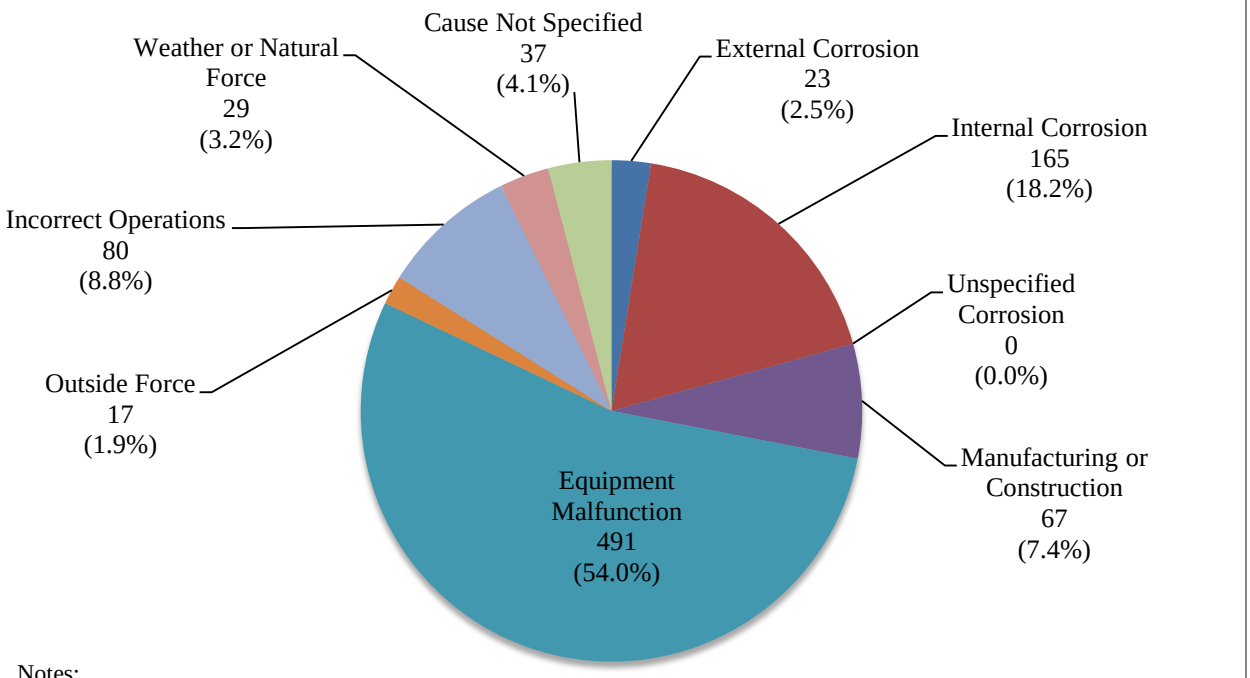
Item	Value	Unit
January 2002 – July 2012	10.58	Years of data
Total Incidents	645	Reported incidents
Pipeline Mileage	537,295	Mile-years
Incident Rate per Mile-Year	0.00168	Reported incident per mile-year
Equipment exposure	11,647	Pumping station-years
Incident Rate per equipment-year	0.055	Incident per pumping station-year
Maximum Incident Volume Reported	31,322	Barrels
Median Incident Volume Reported	5.0	Barrels
Average Incident Volume Reported	206.8	Barrels
0-50 barrels	81%	Percentage of incidents
50-1000 barrels	16%	Percentage of incidents
1000 – 20,000 barrels	3%	Percentage of incidents

Sources: PHMSA Hazardous Liquid Pipeline Incident Data 2002 – July 2012, and PHMSA Liquid Annual Pipeline Data 2004 – 2011.



Notes:
645 reported incidents between January 2002 and July 2012 (PHMSA).
Pipeline elements include pumping station equipment, but excludes tanks, valves, and mainline pipe.

Figure 11 Historic Incident Spill Volumes, Onshore Crude Oil Pipeline System, Other Discrete Elements



Notes:
909 incidents reported between January 2002 and July 2012 (PHMSA).
Pipeline elements include pumping station equipment, but excludes tanks, valves, and mainline pipe.

Figure 12 Historic Incident Cause, Onshore Crude Oil Pipeline System, and Other Discrete Elements

3.0 REFERENCES

PHMSA. See Pipeline and Hazardous Materials Safety Administration.

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2002-2012. Hazardous Liquid Pipeline Incident Database, January 2002 through December 2009 and January 2010 through July 2012.

_____. 2004-2011. PHMSA Liquid Annual Pipeline Data, 2004 through 2011. Website: http://phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print.

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