OCS Study
BOEM 2020-51

Oil Spill Occurrence Rates for Cook Inlet, Alaska Oil and Gas Exploration, Development, and Production

US Department of the Interior
Bureau of Ocean Energy Management
Alaska Region

BOEM
Bureau of Ocean Energy Management

OCS Study
BOEM 2020-051

Oil Spill Occurrence Rates for Cook Inlet, Alaska Oil and Gas Exploration, Development, and Production

October / 2020

Authors:

Tim Robertson, Nuka Research and Planning Group, Lead Author

Lynetta K. Campbell, Statistical Consulting Services, Lead Analyst

Sierra Fletcher, Nuka Research and Planning Group, Editor

Prepared under contract #140M0119F0003
by
Nuka Research and Planning Group, LLC
P.O. Box 175 Seldovia, AK 99663
10 Samoset Street Plymouth, Massachusetts 02360

US Department of the Interior
Bureau of Ocean Energy Management
Alaska Region

BOEM
Bureau of Ocean Energy Management

DISCLAIMER

Study concept, oversight, and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, DC, under Contract Number 140M0119F0003. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REPORT AVAILABILITY

To download a PDF file of this report, go to the US Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2020-051. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

CITATION

Robertson, T., Campbell, L.K. 2020. Oil Spill Occurrence Rates for Cook Inlet, Alaska Oil and Gas Exploration, Development, and Production. Anchorage (AK): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020-051. 78 p.

ABOUT THE COVER

Platform A in sea ice in Central Cook Inlet, photo by Tim Robertson.

ACKNOWLEDGMENTS

This project was funded by the Bureau of Ocean and Energy Management (BOEM) contract #140M0119F0003 Alaska Oil Spill Occurrence Estimators Study. We thank Dr. Heather Crowley and Caryn Smith on the BOEM staff for their review and guidance.

EXECUTIVE SUMMARY

Under contract to the Bureau of Ocean Energy Management (BOEM), Nuka Research and Planning Group, LLC developed statistical methods to estimate oil spill occurrence based on past onshore and offshore spills in the Cook Inlet region. This information was sought for use in future assessment of potential oil and gas leasing, exploration or production in the Outer Continental Shelf managed by BOEM, though the current oil and gas production infrastructure is all based onshore or in state waters.

A dataset of 292 spills was compiled from a several sources of available records covering 1966–2019. Spills were included in the dataset if they were larger than one barrel and could be associated with Cook Inlet oil and gas exploration, development, or production infrastructure or activities. While this included oil field support, it did not include the distribution of natural gas or refining and distribution of refined oil products, nor the shipment of crude oil into Cook Inlet. Spills, as recorded in the data, were consolidated into four types: crude oil, diesel, other refined products, and natural gas liquids.

The full dataset was characterized across oil fields and infrastructure types, as well as presenting the number and volume of spills over time:

- The oil fields with highest numbers of spills are the legacy fields that have been operating the longest: Trading Bay (65), Swanson River (47), and Middle Ground Shoal (37). Likewise, the infrastructure components with the largest number of spills have been operating in Cook Inlet for more than 50 years: Kenai Pipeline (23) and Cook Inlet Pipeline (13).
- The largest number (189) and 79% of the volume (12,421 barrels [bbl]) of recorded spills were attributed to crude oil. The refined oil category accounted for the next highest number (103) and 21% of volume (3,205 bbl).
- The largest number (146) and largest volume (11,485 bbl) of recorded spills were attributed to mechanical failure. Spills caused by human error (66) represented about 45% of the number of spills due to mechanical failure and about 17% of the volume. The cause was unknown for 64 spills, representing 1,502 bbl.
- The largest number (214) and 65% of the volume (10,163 bbl) of recorded spills were attributed to oil production facilities. The crude oil terminal category accounted for the next highest number (29) and 24% of volume (3,726 bbl).
- Most spills (213) were between 1–10 bbl, totaling a volume of 765 bbl. Only 4 spills exceeded 1,000 bbl each, but these totaled 7,100 bbl by comparison. Seventy-five (75) spills were in the range of 10–1,000 bbl totaling 7,770 bbl.

While the full dataset was characterized, only spills from 1996–2019 were used to evaluate trends and develop the occurrence estimators. Gaps in earlier data strongly suggested inconsistencies in the dataset, and familiarity with the context indicated both that industry practices have changed with time (and regulation) and the current and best available data tracking system for the area was initiated in mid-1995. The 1996–2019 dataset also predicted spills from 2009–2019 slightly better than a second potential variation with data from 1988–2019. Although the latter dataset was larger it did not yield better results.

When comparing spills from 1996–2019 to oil production volumes, the total number of spills of all oil types correlates fairly well with production as both generally decline until 2018. That year there is a sharp increase in production but no increase in spills. However, annual spill volume does not correlate with production well at all. Additionally, when broken down by oil type, it is actually the number of crude oil spills that correlates best with production. While both crude and refined spills vary considerably, the trend in crude oil spills more closely follows the trend in oil production. There is no readily discernable trend in the number of refined product spills.

Several approaches were tested to develop occurrence estimators. The dependent variables were the total volume of oil spilled each year and the total number of spills each year. The candidates for inclusion as independent spills were: the annual volume of gas produced from gas wells, the annual volume of crude oil produced from oil wells, the annual volume of water produced from oil wells, the average inflation adjusted price of Alaskan crude each year, and the length of pipelines transporting oil in the region each year. All independent variables, except gas production, resulted in Pearson Correlation Coefficient values significant at the 90% confidence level. Overall, the linear correlations were significantly stronger between the potential independent variables and the number of spills observed than between the volume of oil spilled. This further reinforced the decision to focus the regression work on explaining the number of spills, not the volume spilled.

A suitable regression model was identified for the number of spills using oil production as a single independent variable:

N_tot = 2.1557 + Oil_Prod. x 0.3591

Where: N_tot = total annual number of spills for all spill types and classes

Oil_ Prod. = annual volume of crude oil produced[1] from oil wells in million bbl

The model indicated that for every increase of one million barrels (MMbbl) of crude oil production, the number of annual spills is expected to increase 0.36 units (number of spills) for all spill types and classes. This model explains 23% of the variation observed in the annual number of spills. The model's calculated multivariate power was 0.7199. The power is adequate but not exceptional. This is attributed to the relatively small sample size.

The model's chief weakness stems from an extreme outlier in the data: in 2019, at an annual oil production volume of 5.2 MMbbl, there were 11 spills recorded. The model also was unable to predict spills larger than 1,000 bbl since there were no such spills in the 1996-2019 dataset used. A Poisson distribution was used to estimate the probability of the expected number of large spills for various total production volumes based on all historic Cook Inlet region data.

By contrast, it was not possible to develop a regression model to estimate the annual *volume* of oil spills. Instead, a bootstrapping procedure and Monte Carlo simulation was used to estimate the spill volume. These estimates were then combined in the following formula to estimate the total annual volume expected to be spilled at a given level of oil production:

$$Vol\_tot_y = Pred\_N\_tot_y \times Prop\_B \times Med\_B + Pred\_N\_tot_y \times Prop\_C \times Med\_C + Pred\_N\_tot_y \times Prop\_D \times Med\_D$$

Where: $Pred\_N\_tot_y$ = total number of spills predicted for oil production Y using the regression model with multiple realizations created via a Monte Carol simulation

Prop_X = Proportion of spills from Class X estimated using the bootstrapped procedure

Med_X=Median spill size of Class X estimated using the bootstrapped procedure

This method resulted in an estimated 87 bbl of annual oil spill volume with a 95% confidence interval of 6 to 226 bbl at an annual level of 7.5 MMbbl of oil production.

---

[1] Does not include natural gas liquids.

Occurrence estimates were also sought for crude and refined spills separately. The occurrence model to predict annual number of crude oil spills is very similar to the model developed to predict annual number of all types of oil. Applying the above modeling approach to the Cook Inlet annual crude oil spill data resulted in a regression model with Oil Production as the single independent variable.

The resulting linear regression model was:

N_crude_tot = -0.1432 + Oil Prod. x 0.3209

Where: N_crude_tot = total annual number of crude oil spills

Oil_ Prod. = annual volume of crude oil produced[2] from oil wells in million bbl

The model indicates that for every increase of one million bbl of oil production the number of annual crude oil spills is expected to increase 0.32 units. The model explains 25.58% of the variation observed in the annual number of spills.

The model was not useful for predicting annual numbers of refined spills, however. There was no significant relationship between annual number of refined oil spills and any of the independent variables investigated. The best estimator of the annual number of refined oil spills is the mean value, which is equal to 2.6 refined oil spills per year.

The limitations of the models developed should be noted. These include the small size of the dataset and changes in reporting over time. Occurrence estimates might also be improved by using more independent variables, though in order to be useful these need to be variables that can be estimated or planned on for the future.

[2] Does not include natural gas liquids.

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ADEC	Alaska Department of Environmental Conservation
AIC statistic	Akaike Information Criteria
Bbbl	Billion barrels
bbl	barrel
BOEM	Bureau of Ocean Energy Management
CIGGS	Cook Inlet Gas Gathering System
DOI	US Department of the Interior
mcf	million cubic feet
MMbbl	Million barrels
NGL	Natural Gas Liquids
NRC	National Response Center
OCS	Outer Continental Shelf
RMSE	root mean square error
VIF statistic	Variable Inflation Factor

1 INTRODUCTION

Nuka Research and Planning Group, LLC completed this study under Contract #140M0119F0003 to the Bureau of Ocean Energy Management (BOEM) Alaska Regional Office.

1.1 Purpose

The purpose of project was to develop oil spill occurrence estimators for the Cook Inlet region in Alaska based on available data on past onshore and offshore spills in the region.

The objectives of this analysis were to:

- Develop a dataset of crude and refined oil spill records for Cook Inlet, Alaska;
- Develop a dataset of crude oil and gas production, pipeline mileage, and other possible independent variables for developing an oil spill occurrence rate model for Cook Inlet, Alaska;
- Provide statistical measures of crude and refined oil spills such as mean and median spill sizes with confidence intervals as appropriate;
- Use statistical analysis to identify trends in spill numbers and volumes;
- Categorize Cook Inlet spills into size classes;
- Apply statistical procedures to develop occurrence rate estimator models for crude and refined oil spills, as well as all spills; and
- Develop an appropriate confidence interval for occurrence rate estimators.

Previous studies have provided methodologies for estimating oil spill occurrence rates for both offshore and onshore oil and gas development. However, most of the previous work on Outer Continental Shelf (OCS) historical platform and pipeline crude oil spill occurrence rates relies on data from the Gulf of Mexico and Pacific OCS (ABS Consulting Inc. 2016; ABSG Consulting Inc. 2018; Anderson and LaBelle, 2000; Eschenbach et al., 2010; Anderson et al., 2012). The BOEM Alaska Regional Office contracted this analysis to calculate onshore and offshore spill occurrence based on data collated from Alaska's Cook Inlet region, and to include all spills greater than one barrel.

This report represents the first attempt to estimate oil spill occurrence based on historic spills from Cook Inlet oil and gas operations, though estimates of the probability and movement of large spills in the Cook Inlet OCS have been generated based on spill occurrence data from other locations (Anderson et al., 2012, ABS Consulting Inc. 2016; Ji et al., 2016). Previous studies using Alaska-specific oil spill data have focused on Alaska's North Slope (Hart Crowser, 2000; Nuka Research, 2010; Robertson et. al., 2013).

1.2 Project Scope

For the purpose of the study, the project scope was defined by the geographic area and whether the spill was associated with oil and gas exploration or production activities.

1.2.1 Cook Inlet Oil and Gas Operations

Crude oil was first found in the Cook Inlet area in the 1950s, at the Swanson River field (Eastham, 2014). Today, oil and gas are produced both onshore and offshore in multiple units extending as far south as Anchor Point, Alaska (see Figure 1). To date, all of the offshore production has been in State waters and oil production infrastructure is concentrated in Central Cook Inlet (see Figure 2). This infrastructure includes 17 fixed offshore oil production platforms and one terminal loading platform, various production facilities, a refinery, hundreds of miles of pipelines, storage facilities, and marine terminals (one in Nikiski and a second, now inactive, at the Christy Lee Platform at the Drift River Terminal). Pipelines within the project scope transport three-phase liquids (a mix of oil, gas, and water before processing occurs), crude oil, produced water, and, in a few cases, fuel gas that is delivered *to* platforms.

The Marathon refinery in Nikiski processes crude oil from Cook Inlet as well as oil brought by vessel from other areas (notably the Trans-Alaska Pipeline System terminus in Prince William Sound). Crude oil may be shipped out of Cook Inlet from Nikiski as well, although it has not been done in many years. Prior to 2018, crude oil was also shipped *within* Cook Inlet from the Drift River Terminal/Christy Lee Platform to the Kenai Pipeline dock on the east side (or shipped out of the Inlet). Currently, oil produced from the platforms connected to the west side infrastructure is moved to the east side via a repurposed subsea gas pipeline (Boettger, 2018).

In addition to the infrastructure shown in Figure 2, there are natural gas lines and a refined product pipeline to Anchorage. These facilities are outside the scope of this report.

Figure 1. Cook Inlet oil and gas units
The Cook Inlet area has both onshore and offshore production of oil and gas.

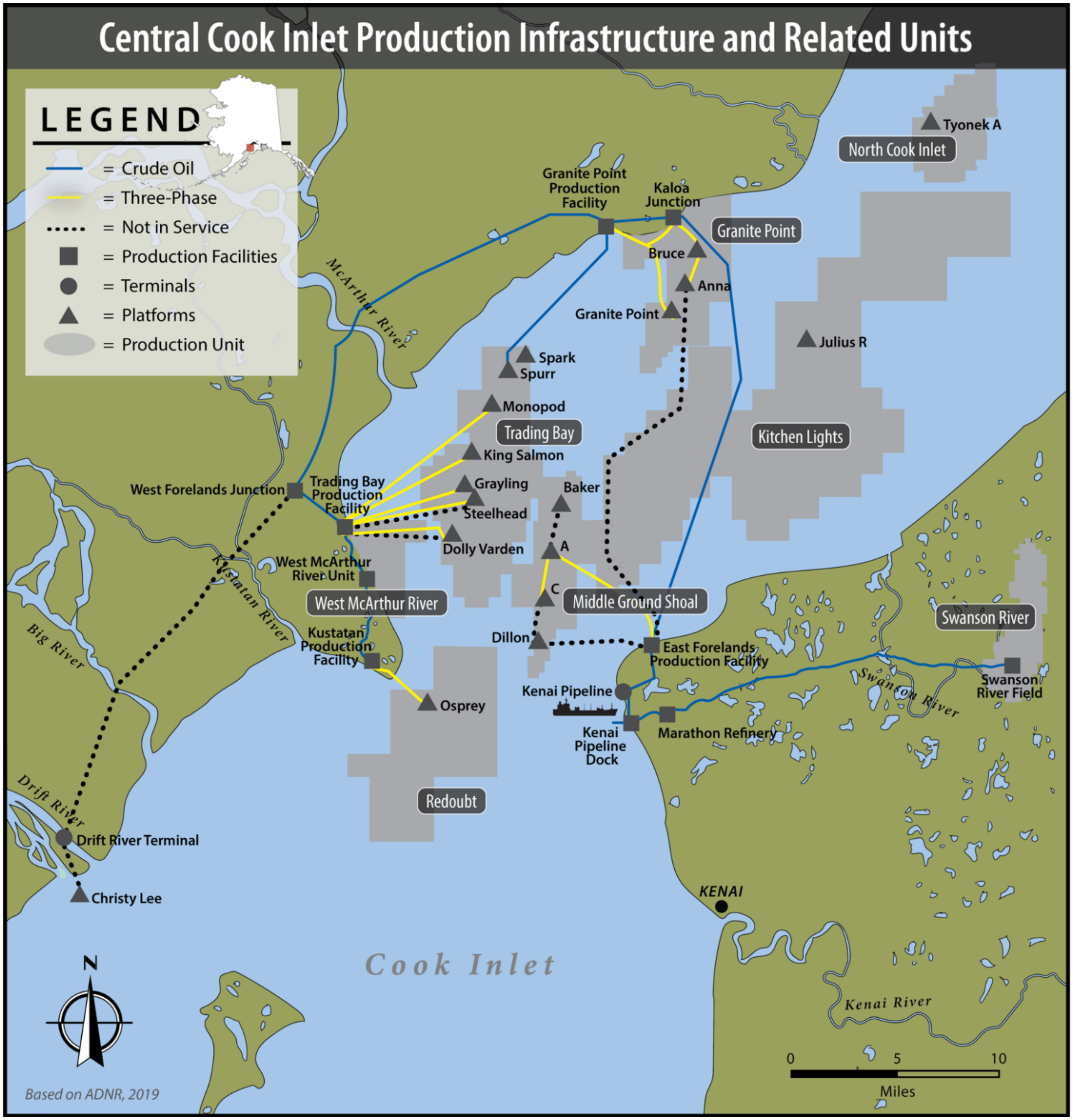

Figure 2. Cook Inlet oil and gas production infrastructure and related units

Oil production in Cook Inlet occurs both onshore and offshore. The East Forelands Production Facility represents the point where subsea pipelines come on shore on the East side as well as the Middle Ground Shoal production facility, Cook Inlet Gas Gathering System (CIGGS), and Furie gas production facility. There are two marine terminals: one at Drift River that is no longer in use but was active for most of the years included in the dataset, and one that remains active at the Kenai Pipeline Dock. In total there are 17 fixed offshore production platforms in Cook Inlet. The Christy Lee platform depicted was used for loading only. Mobile drilling units have been used in the recent past as well.

1.2.2 Spill Source

The study focused on spills associated with oil and gas exploration and production activities. This includes much, but not all, of the oil and gas infrastructure in Cook Inlet. Figure 3 shows the basic process flow and what elements are in or out of the scope of this study. Spills were included in the data analyzed if they were associated with exploration and development activities, production (onshore or offshore), or the transport or processing of crude oil up to the point of either being refined in Nikiski or shipped out of Cook Inlet. Most of the transport among the included elements occurs via pipeline. Spills included in the data did not need to come directly *from* this infrastructure (e.g., a pipeline leak), but simply had to be associated with it. Thus, a diesel spill from a vessel servicing a platform would be included.

As shown in Figure 3, spills were excluded if they were downstream of the refinery (either in a tank vessel or pipeline), or related to the distribution of natural gas. Spills associated with the shipment of crude oil *into* Cook Inlet also were excluded. For example, the spill associated with the grounding of the *T/V Glacier Bay* in 1987 was excluded because it was carrying Alaska North Slope crude oil to the refinery at Nikiski and thus was not associated with oil and gas exploration or production in Cook Inlet.

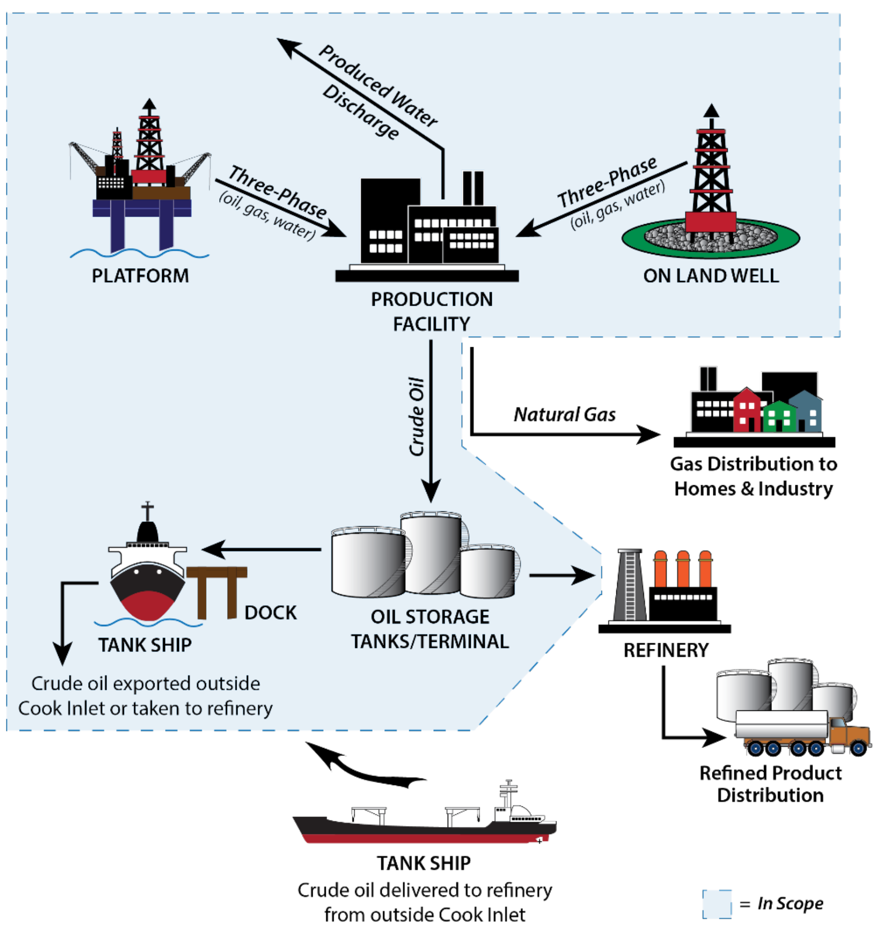

Figure 3. Cook Inlet process flow diagram

2 METHODS AND ASSUMPTIONS

This section describes the methods, inputs, and assumptions applied to the analysis.

2.1 Oil Spill Data Collection and Collation

Nuka Research collated data from various sources including:

- Alaska Department of Environmental Conservation (ADEC) oil spill database
- Reports of oil spills to federal agencies through the National Response Center (NRC)
- Pipeline and Hazardous Materials Safety Administration database report from September 11, 2018, provided by BOEM
- Epstein, 2002
- Roberts, 1996
- Robertson, et. al., 2013
- Sienkiewicz, et. al., 1992
- Whitney, 2002.

Each spill record was reviewed. Spills of larger than 1 bbl were included in the data if they were deemed to originate from infrastructure or activities within the project scope. Spills were then categorized based on the information available and the best professional judgement of the Principle Investigator. Ten percent of records were randomly selected and verified back to the original source.

The original oil spill datasets also each had different data structures. The collation process involved transforming each dataset into a common format that would facilitate the merging of records from a single spill. In all cases, spill volumes were converted to barrels. In some datasets, multiple variables from a single record were concatenated into a single variable. Table 1 presents the data scheme for the final dataset with notes about how these variables relate to the original datasets. The final dataset (Appendix A) consists of 292 records with each representing a single spill event covering calendar years 1966 through 2019.

Table 1. Variables for each spill record

Variable	Information
Spill ID	Unique identifier for this dataset. Cook Inlet spill beginning with "CI –"
Primary Source	The primary source record for the spill.
Source ID	The identifier from the primary source.
Additional Sources	Other sources where a record of the spill was found.
Spill Date	The date that the spill occurred, if it was known.
Spill Year	The calendar year that the spill occurred.
Spill Size (bbl)	The best or maximum estimate of the spill size in barrels (42 US gallons). In most instances, tables in this report round to the nearest barrel, but fractions of a barrel are preserved in the dataset and used in calculations.
Spill Size Class	Spill size category. See Section 2.1.1.
Substance	The category of the oil substance spilled. See Section 2.1.2.
Consolidated Substance	A consolidation of oil substances. See Section 2.1.2.
Facility/Activity Type	The category of facility type. See Section 2.1.3.
Consolidated Facility/Activity Type	A consolidation of facility types. See Section 2.1.3.
Location	The category of the location of the spill, either Offshore, Onshore, or Unknown.
Oil Field/Infrastructure	The oil field or infrastructure where the spill occurred. See Section 3.2.1.
Spill Source	The category of the source of the spill. See Section 2.1.4.
Spill Cause	The category of the spill cause. See Section 2.1.5.
Consolidated Spill Cause	A consolidation of spill causes. See Section 2.1.5.

2.1.1 Spill Size Classes

Only spills larger than one barrel (bbl) were included. The following spill size classes, as defined in Robertson et al. 2013, were used for this study:

- A = oil spills > 1,000 bbl
- B = oil spills > 200 bbl and ≤ 1,000 bbl
- C = oil spills > 10 bbl and ≤ 200 bbl
- D = oil spills > 1 bbl and ≤ 10 bbl
- E = oil spills ≤ 1 bbl (excluded from this analysis)

Spills less than or equal to one barrel were not considered because of the historical inconsistency in reporting of small spills.

2.1.2 Spill Substance

The following consolidated spill substances were used:

- Crude Oil
- Crude Oil and Produced Water
- Refined: Diesel
- Refined: Natural Gas Liquids
- Refined: Other

Consolidated spill substances were developed based on the categories used:

- Crude Oil
- Crude Oil and Produced Water
- Refined: Asphalt
- Refined: Aviation
- Refined: Ballast Water with Oil
- Refined: Bunker Oil
- Refined: Diesel
- Refined: Gasoline
- Refined: Hydraulic Oil
- Refined: Jet Fuel
- Refined: Lube/Gear Oil
- Refined: Naphtha
- Refined: Natural Gas Liquids
- Refined: Turbine Oil
- Refined: Unknown
- Refined: Unknown and Water

Where spills were of a mixed substance type, such as crude oil and produced water, only the oil portion of the mixture was included in the final dataset. For spills of produced water and oil where the proportion of oil and water was not identified, the total volume of the mixture was recorded and the proportion was estimated during the analysis, given the best information available from the data source.

2.1.3 Activity/Facility

The following consolidated activity/facility types were used:

- Oil Production
- Oil Exploration
- Support Facility/Services
- Unknown

Consolidated activity/facility types were developed based on the categories used: Crude Oil Terminal (Oil Production)

- Natural Gas Production (Oil Production)
- Oil Exploration (Oil Exploration)
- Oil Production (Oil Production)
- Pipeline (Oil Production)
- Support Dock (Support Facility/Services)
- Transmission Pipeline (Oil Production)
- Unknown (Unknown)
- Vehicle (Support Facility/Services)
- Vessel (Support Facility/Services)

2.1.4 Spill Source

The following spill source categories were used:

- Coiled Tubing Unit
- Container, Other
- Drill activities
- Drum(s)
- Equipment Failure, Vehicle
- Flare
- Fuel Pump
- Heavy Equipment
- Hydraulic System
- J TUBE
- Loading Arm
- Other
- Pipe or Line
- Tank, Aboveground
- Tank, Mobile
- Tank, Other
- Unknown
- Vehicle
- Vessel
- Vessel Transfer
- Well

2.1.5 Spill Cause

The following consolidated spill causes were used:

- Human Error: Other
- Human Error: Overfill
- Human Error: Unknown
- Mechanical Failure: Corrosion
- Mechanical Failure: Other
- Mechanical Failure: Overpressure
- Mechanical Failure: Unknown
- Mechanical Failure: Valve/Seal
- Other
- Unknown

Consolidated spill causes were developed based on the categories used:

- Cargo Not Secured
- Collision/Allision/Grounding
- Containment Overflow
- Corrosion
- Crack
- Dumping
- Equipment Failure, Gauge/Site Glass Failure
- Equipment Failure, Line Failure
- Equipment Failure, Other
- Equipment Failure, Seal Failure
- Equipment Failure, Tank Failure
- Equipment Failure, Unknown
- Equipment Failure, Valve Failure
- Equipment Failure, Vehicle
- Erosion
- External Factors
- Fire/Explosion
- Freezing
- Hull Failure
- Human Error
- Human Error, Overfill
- Miss-injection
- Other
- Over Pressure
- Puncture
- Rollover/Capsize
- Unknown
- Weld Failure

2.1.6 Spill Records and Years Included in Final Dataset

The final oil spill dataset from 1966–2019 included 292 spills larger than one barrel. As discussed in Section 4 however, a shorter time period was used for the development of the occurrence estimator.

2.2 Exposure Variable Data

Data on crude oil production for all years from 1958 through 2019 by month was compiled from the Alaska Oil and Gas Conservation Commission's records and combined into a workbook with a separate spreadsheet for each of the 11 distinct producing Cook Inlet oil fields. Data for each month includes barrels of oil produced, barrels of water produced, million cubic feet of gas produced, and number of producing wells. Note that natural gas liquids were not included in these data.

Data on pipeline mileage were taken from the Cook Inlet Infrastructure Assessment conducted by Nuka Research for ADEC in Fletcher et. al. (2020). Because the price for Cook Inlet crude oil is based on the price of Alaska North Slope crude, the adjusted Oil Price data for Alaska North Slope crude oil were taken from U.S. Energy Information Administration (EIA, 2020) and adjusted for the Consumer Price Index[3] to 2020 US dollars.

These data, which are included in Appendix B, were screened as independent variables for developing occurrence estimators.

3 SUMMARY OF HISTORICAL SPILL OCCURRENCE DATA

This section summarizes the spill data from 1966–2019 by the number of spills, spill volume, oil field, facility/activity type and cause, examining each of these factors as related to the spill size categories.

3.1 Total Spills Over Time

There were 292 spills recorded in the final dataset for Cook Inlet. The earliest spill in the dataset occurred on March 5, 1966 and the last spill occurred on December 27, 2019. The year was recorded for every spill, though the month and day were missing from 88 of the spill events recorded prior to 1994.

3.2 Overview of Recorded Spills

This section summarizes oil spill occurrence for all spills in the dataset from 1966–2019. It presents the spill data based on oil field, cause, facility type, and substance spilled, including a breakdown by size class. Figure 4 shows the number and volume of recorded spills for each cause, activity, substance, and oil field/infrastructure. Each of these factors will be discussed independently in sections below.

[3] Consumer Price Index for all Urban Consumers (CPI-U) as presented by the Bureau of Labor Statistics

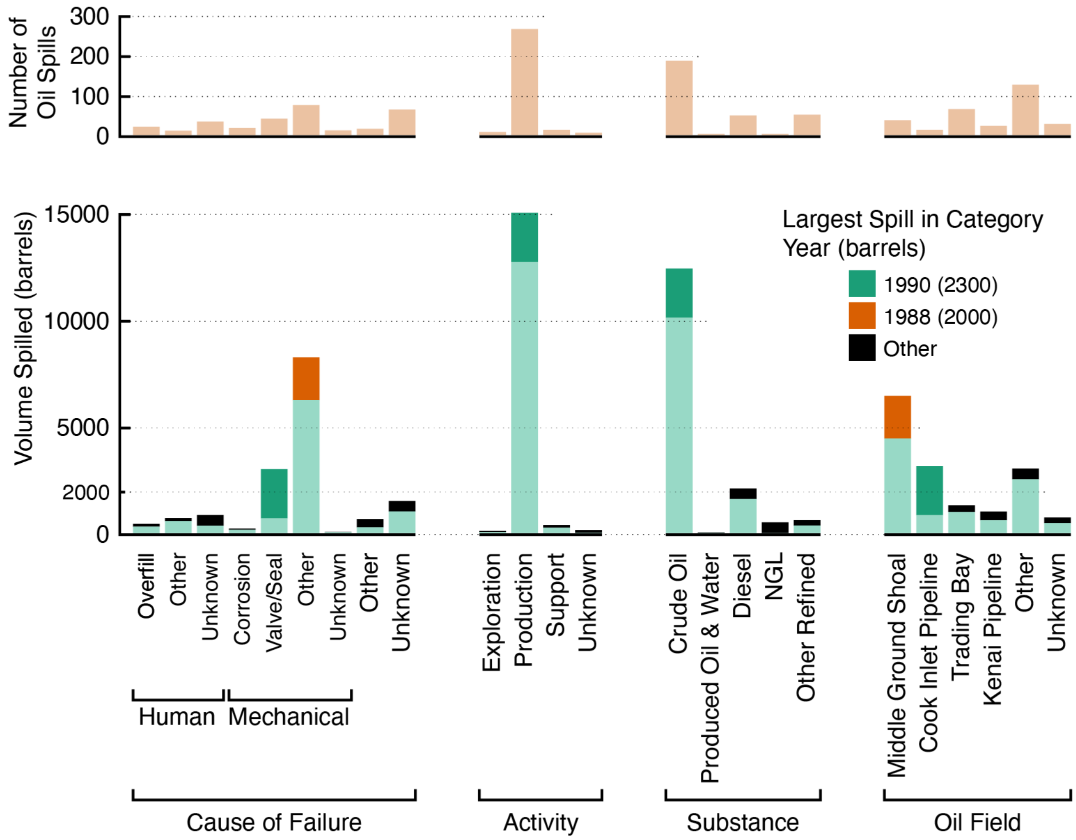

Figure 4. Spill number and volume by cause, activity/facility, substance and oil field/infrastructure in Cook Inlet, 1966–2019

3.2.1 Spill Occurrence by Oil Field or Infrastructure Component

Oil was first produced in Cook Inlet in 1958 as shown in Table 2. This section presents spill occurrence by oil field or infrastructure component, as shown in Table 3. The oil fields with highest numbers of spills are the legacy fields that have been operating the longest: Trading Bay (65), Swanson River (47), and Middle Ground Shoal (37). Likewise, the infrastructure components with the largest number of spills have been operating in Cook Inlet for more than 50 years: Kenai Pipeline (23) and Cook Inlet Pipeline (13).

The volume of recorded oil spills is dominated by the Middle Ground Shoal oil field (6,431 bbl) with 41% of the total volume spilled. Almost 75% of the Middle Ground Shoal total is from the three Class A oil spills described below and if the 1,000 bbl Class B spill, which is just below the cut off for Class A, is considered, the proportion of Middle Ground Shoal oil spills accounted for by large spills is 90%. Cook Inlet Pipeline infrastructure (3,139 bbl) holds the second highest volume with 20% of the total for the whole area. Almost 75% of the Cook Inlet Pipeline total is accounted for by the 2,300 bbl spill in 1990. The only other infrastructure and oil field components that exceed 1,000 bbl in total volume spilled were the Trading Bay oil field (1,301 bbl) and the Kenai Pipeline (1,007 bbl).

Table 2. Year of first production from Cook Inlet productions units

Production Unit	Year of First Production
Swanson River	1958
Kenai	1960
Beluga River	1963
Granite Point	1965
Middle Ground Shoal	1965
Trading Bay	1965
Ninilchik	1966
Redoubt Shoal	1968
North Cook Inlet	1969
Beaver Creek	1972
West McArthur River	1991

Table 3. Cook Inlet area spills by oil field/infrastructure category, 1966–2019

Oil Field - Infrastructure	Number	Percent Number	Total Volume (bbl)	Percent Total Volume
Middle Ground Shoal	37	13%	6,430	41%
Cook Inlet Pipeline	13	4%	3,139	20%
Trading Bay	65	22%	1,301	8%
Kenai Pipeline	23	8%	1,007	6%
Granite Point	24	8%	770	5%
Unknown	28	10%	727	5%
Swanson River	47	16%	525	3%
Beaver Creek	1	<1%	500	3%
North Cook Inlet	4	1%	498	3%
Support Services	15	5%	386	2%
Kenai Gas	8	3%	156	1%
Exploration	8	3%	107	1%
West McArthur River	11	4%	55	<1%
Beluga River	3	1%	10	<0.1%
Cosmopolitan	2	1%	7	<0.1%
Redoubt	2	1%	6	<0.1%
Ninilchik	1	<1%	2	<0.1%
Grand Total	**292**	**100%**	**15,626**	**100%**

Table 4 shows the percentage of the total volume spilled accounted for by the largest oil spill in each oil field/infrastructure category. Excluding unknowns, the largest oil spill accounted for more than 50% of the total volume spilled in eight of the 16 categories.

Table 4. Largest recorded spill at each Cook Inlet oil field and percent of total volume of spills from that field represented by the largest spill, 1966–2019

Oil Field - Infrastructure	Maximum Spill (bbl)	% Total Volume
Beaver Creek	500	100%
Ninilchik	2.2	100%
North Cook Inlet	490	98%
Kenai Gas	123.8	80%
Redoubt	4.8	79%
Cook Inlet Pipeline	2,300	73%
Cosmopolitan	4	60%
Exploration	60	56%
Granite Point	380	49%
Beluga River	4.8	47%
West McArthur River	25	45%
Kenai Pipeline	400	40%
Swanson River	200	38%
Unknown	261.9	36%
Support Services	126.1	33%
Middle Ground Shoal	2,000	31%
Trading Bay	315	24%

3.2.2 Overall Spill Occurrence by Cause

Table 5 shows the number and volume of oil spills by cause. Half of the spills (146) were due to mechanical failure accounting for 74% of the volume. Spills caused by human error (66) represented about 23% of the number of spills and about 13% of the volume. The cause was unknown for 64 spills, representing 1,502 bbl.

Table 5. Cook Inlet spill occurrence and percent of total spill volume by cause, 1966–2019

Consolidated Cause	Number	Percent Number	Total Volume (bbl)	Percent Total Volume
Mechanical Failure	**146**	**50%**	**11,485**	**74%**
Mechanical Failure: Other	75	26%	8,229	53%
Mechanical Failure: Valve/Seal	41	14%	2,993	19%
Mechanical Failure: Corrosion	18	6%	211	1%
Mechanical Failure: Unknown	12	4%	52	<1%
Human Error	**66**	**23%**	**1,989**	**13%**
Human Error: Unknown	34	12%	846	5%
Human Error: Other	11	4%	707	5%
Human Error: Overfill	21	7%	436	3%
Unknown	**64**	**22%**	**1,502**	**10%**
Other	**16**	**5%**	**650**	**4%**
Grand Total	**292**	**100%**	**15,626**	**100%**

3.2.3 Spill Occurrence by Activity/Facility Type

Table 6 shows the number and volume of oil spills by activity/facility type. The largest number (214) and 65% of the volume (10,163 bbl) of recorded spills were attributed to oil production facilities. The crude oil terminal category accounted for the next highest number (29) and 24% of volume (3,726 bbl). All other facility categories only accounted for a total of 49 spills and 11% of the volume (737 bbl). It is likely that there is overlap and inconsistency in reporting of facility type in these data. For instance, spills from pipelines may be recorded under oil production.

Table 6. Cook Inlet spill occurrence and percent of total spill volume by facility type, 1966–2019

Activity/Facility Type	Number	Percent Number	Total Volume (bbl)	Percent Total Volume
Oil Production	214	73%	10,163	65%
Crude Oil Terminal	29	10%	3,726	24%
Natural Gas Production	16	5%	545	3%
Pipeline	2	1%	420	3%
Vessel	8	3%	358	2%
Transmission Pipeline	4	1%	147	1%
Unknown	6	2%	139	1%
Oil Exploration	8	3%	107	1%
Support Dock	3	1%	19	<1%
Vehicle	2	1%	2	<1%
Grand Total	**292**	**100%**	**15,626**	**100%**

3.2.4 Spill Occurrence by Substance Type

Table 7 shows the number and volume of oil spills by substance. The largest number (189) and 79% of the volume (12,421 bbl) of recorded spills were attributed to crude oil. The refined oil category accounted for the next highest number (103) and 21% of volume (3,205 bbl). The relationship between crude oil and refined product is likely proportional to the volume of products available to spill. Crude oil is the product produced and transported by infrastructure, diesel is a primary fuel to run the process (natural gas is also used), and other refined products are used in many other processes, but in relatively small quantities. Natural gas liquids are a product of processing natural gas and are thus treated as a refined product.

Table 7. Cook Inlet spill occurrence and percent of total spill volume by substance, 1966–2019

Substance	Number	Percent Number	Total Volume (bbl)	Percent Total Volume
Crude	**189**	**65%**	**12,421**	**79%**
Crude Oil	186	64%	12,390	79%
Crude Oil and Produced Water	3	1%	31	0%
Refined	**103**	**35%**	**3,205**	**21%**
Refined: Diesel	49	17%	2,089	13%
Refined: Other	51	17%	613	4%
Refined: Natural Gas Liquids	3	1%	503	3%
Grand Total	**292**	**100%**	**15,626**	**100%**

3.2.5 Summary Spill Data by Size Class

Figure 5 presents the volume of recorded oil spills by size class for cause, activity/facility type, substance, and oil field/infrastructure.

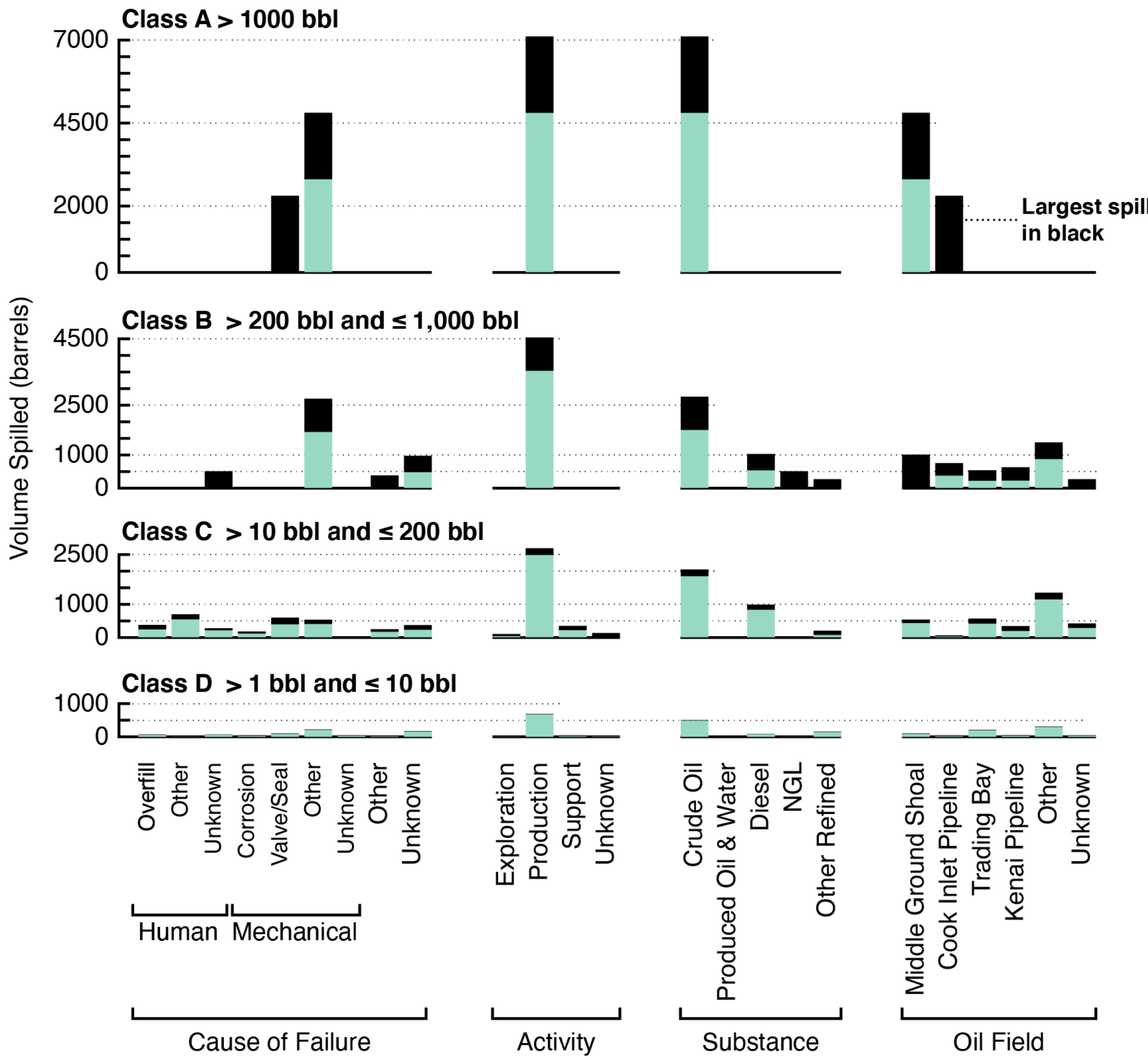

Figure 5. Overview of Cook Inlet spills by size class, cause, activity, substance, and oil field, 1966–2019

Table 8 shows the number and volume of recorded oil spills by size class. Notice that the relationship between number and volume is inverse. The Class A contains the lowest number (4) and the largest volume (7,100). The smallest spill size category contains 73% of the number of spills (213), but represents only 5% of the total volume spilled (756 bbl).

Table 8. Cook Inlet spill occurrence and percent of total spill volume by size class, 1966–2019

Size Class	Number	Percent	Total Volume (bbl)	Percent Total Volume
A > 1,000 bbl	4	1%	7,100	45%
B > 200 bbl & ≤ 1,000 bbl	11	4%	4,529	29%
C > 10 bbl & ≤ 200 bbl	64	22%	3,241	21%
D > 1 bbl & ≤ 10 bbl	213	73%	756	5%
Grand Total	**292**	**100%**	**15,626**	**100%**

Table 9 presents the four Class A (> 1,000 bbl) and the 11 Class B (>200 and ≤1,000 bbl) oil spills recorded in Cook Inlet. The largest spill of 2,300 bbl (March 1990) was from a mechanical failure of a pipeline at Drift River Terminal which was then operated by Cook Inlet Pipeline. The second largest spill of 2,000 bbl (December 1988) was from a mechanical failure of a tank at the Middle Ground Shoal production facility in Nikiski operated by Shell Western. The third and fourth largest spills of 1,400 bbl each occurred in 1967 and 1968 from subsea pipelines connecting offshore platforms to the Middle Ground Shoal production facility operated at the time by Amoco. Both of these spills were likely caused by current-induced vibrations causing the pipeline to fail (Belmar, 1993). It should also be noted that there was a spill of 1,000 bbl, just below the Class A threshold, in 1968 at Middle Ground Shoal. This 1968 spill was also used in the calculation of large spill occurrence rate in Section 5.2.1.

Table 9. Class A and Class B spills

Date	Spill Volume (bbl)	Oil Field	Location	Source	Cause
Class A Spills					
12/13/66	1,400	Middle Ground Shoals	Offshore	Pipe or Line	Mechanical Failure: Other
8/11/67	1,400	Middle Ground Shoals	Offshore	Pipe or Line	Mechanical Failure: Other
12/8/88	2,000	Middle Ground Shoals	Onshore	Tank	Mechanical Failure: Other
3/10/90	2,300	Cook Inlet Pipeline	Onshore	Pipe or Line	Mechanical Failure: Valve/Seal
Class B Spills					
4/17/68	315	Trading Bay	Offshore	Pipe or Line	Mechanical Failure: Other
6/6/68	380	Granite Point	Offshore	Pipe or Line	Mechanical Failure: Other
10/23/68	1,000	Middle Ground Shoals	Offshore	Pipe or Line	Mechanical Failure: Other
6/10/05	400	Unknown	Onshore	Unknown	Unknown
6/14/05	370	Kenai Pipeline	Onshore	Pipe or Line	Mechanical Failure: Other
1/4/92	214	Kenai Pipeline	Onshore	Pipe or Line	Mechanical Failure: Other
6/15/05	500	Cook Inlet Pipeline	Onshore	Pipe or Line	Other
12/28/93	490	Cook Inlet Pipeline	Onshore	Unknown	Mechanical Failure: Other
3/6/97	378	Trading Bay	Offshore	Unknown	Unknown
11/30/04	220	Beaver Creek	Onshore	Tank	Human Error: Unknown
11/19/16	262	North Cook Inlet	Onshore	Pipe or Line	Unknown

4 TREND ANALYSIS

4.1 Choosing a Timeframe for Trend and Occurrence Analysis

Review of the 1966-2019 dataset compiled for this project (and summarized in Section 3) indicated that data prior to 1996 appeared less reliable than 1996–2019. While the first production data for Cook Inlet occurred in November 1958, the first spill record in the dataset did not occur until more than six years later (March 1966). The March 1966 spill was 100 bbl. The first small spill (Class D ≤ 10 bbl) identified did not occur until 1967. No spill records were found for some years (1973, 1979–1985; see Figure 6). This was believed to be attributed to inconsistent early reporting and databasing procedures.

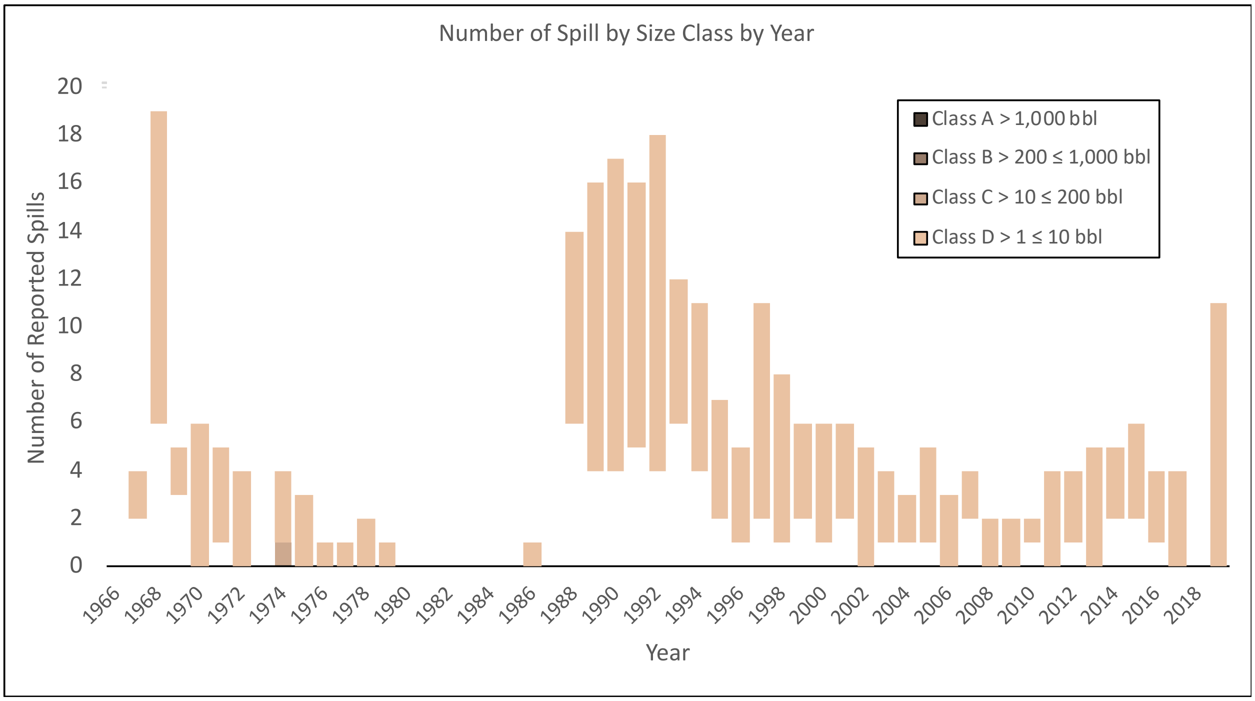

Figure 6. Number of recorded oil spills by size class in Cook Inlet, 1966–2019

While the full dataset was characterized, only spills from 1996–2019 were used to evaluate trends and develop the occurrence estimators. Gaps in earlier data strongly suggested inconsistencies in the dataset, and familiarity with the context indicated both that industry practices have changed with time (and regulation) and the current and best available data tracking system for the area was initiated in mid-1995.

The under-counting of spills prior to 1988 would render any computed mean spill volumes highly inaccurate. For this reason, these numbers were not useful in efforts to predict mean volumes or expected numbers of spills.

Two timeframes were considered for a trend analysis: 1988-2019 and 1996-2019. The earlier time frame was initially considered desirable because it would offer a larger sample size (31 vs. 23 years) and thus more statistical power to the model. However, data from 1996 onward was collected after improvements to the State of Alaska reporting system had been established in 1995. A final decision on which timeframe to use for the trend analysis was made based on comparing models constructed using both timeframes. Each model's ability to predict the last decade’s (2009-2019) spill numbers was then compared. A statistic called the root mean square error (RMSE) was used. RMSE is computed by averaging the squared deviations (predicted value - observed value) and then taking the square root of that figure. When comparing models, the one with the lowest RMSE is generally better. It was found that:

- The RMSE using a model built from 1988-2019 data was 2.6
- The RMSE using a model built from 1996-2019 data was 2.55

This difference between the two models is considered small, but it indicates that using a model built from the smaller dataset (1996–2019) will not be inferior to the larger dataset of 1988–2019. Thus, it was decided that data from 1996–2019 (23 years) would be used for trend analysis and occurrence rate estimates. This decision was also supported by the following aspects of the operational context:

- Inconsistency in spill databases before 1995 (the current State of Alaska database was begun mid-year that year)
- Inconsistency in spill reporting and reporting requirements in early years
- Industry spill prevention practices improved after 1990 and thus spills since that time reflect current practices.

4.2 Annual Data vs. Monthly Data

It was also necessary to decide whether to focus on a model built using monthly data or annual data. Monthly data would have provided a much greater sample size and consequently more power if a valid model could be achieved. However, data on the number of spills per month has some features that make it unsuitable for modeling. First, the distribution is highly non-normal with most months having zero or a single spill occurring in them. Second, even those months with spills generally have a very small number of spills for statistical purposes. So, the interval variable ‘spills per month’ does not begin to approximate a continuous variable suitable for modeling. For annual data there were no years with zero spills. Most years had four or five spills, with a range from 1 to 11. In short, the distribution using annual data was closer to normal. A prerequisite for linear regression modeling is that the observed data will be normally distributed at each treatment level, in this case by calendar year. For this reason, we chose to use annual data for our modeling efforts.

Figure 7 compares the distributions of the monthly spills vs. annual spills.

Figure 7. Comparison of the frequency distribution for spills per month vs. spills per year for Cook Inlet spills, 1996–2019

4.3 Seasonal Variation in Cook Inlet Spill Rates

We examined the 1996–2019 spill data to determine whether or not there is a seasonal pattern inherent in Cook Inlet spills. More spills were recorded in late summer (July and August) than any other months. One possible explanation of this observation is that more maintenance and construction activities may occur during these months of long daylight and mild temperatures. We used the Kruskal-Wallis test to determine if this variation by month in the median number of recorded spills was statistically significant and found that it was not.[4]

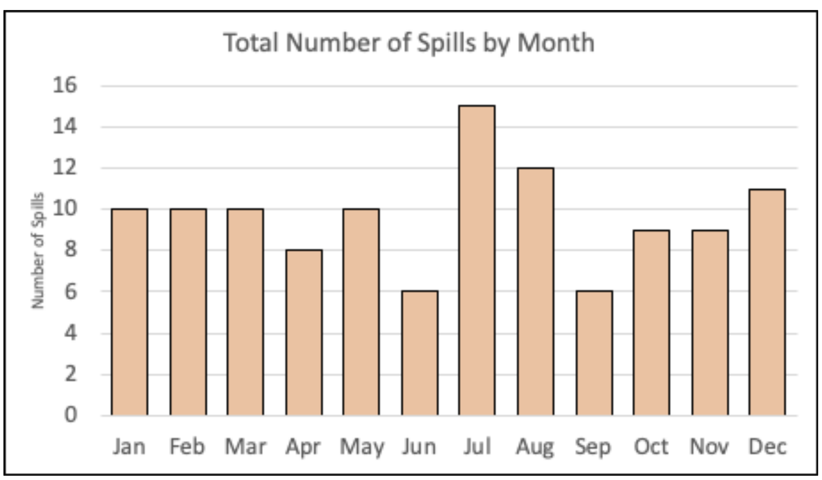

Figure 8. Total number of oil spills by month in Cook Inlet, 1996–2019

[4] Kruskal-Wallis chi-squared = 8.1564, df = 11, p-value = 0.6992

4.4 Spill Trends by Year

Figure 9 shows the annual recorded number of spills plotted against the annual oil production for Cook Inlet from 1996–2019. The graph suggests that for this time range the number of spills roughly follows the production curve when annual values for each are plotted simultaneously. Clearly as production dropped over time, so did the total number of spills recorded. However, the 11 spills that occurred in 2019 appears to be an anomaly.

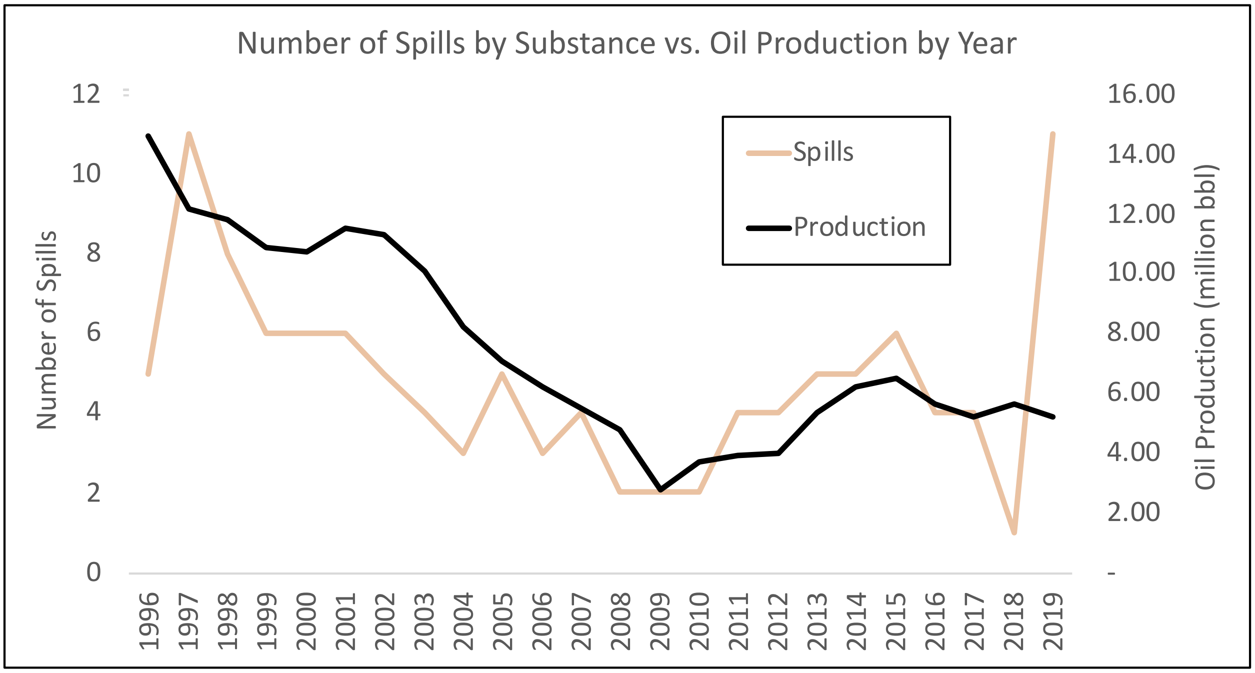

Figure 9. Annual recorded number of oil spills plotted against the annual crude oil production for Cook Inlet, 1996–2019

Figure 10 shows the annual volume of recorded oil spills compared to annual oil production for Cook Inlet from 1996-2019. Spill volumes of near 500 bbl in the years 2004 and 2016 are anomalies. In contrast to the number of spills, the spill volume, however, does not closely follow the production profile. This indicated that predicting the number of spills will be easier than predicting the volume spilled.

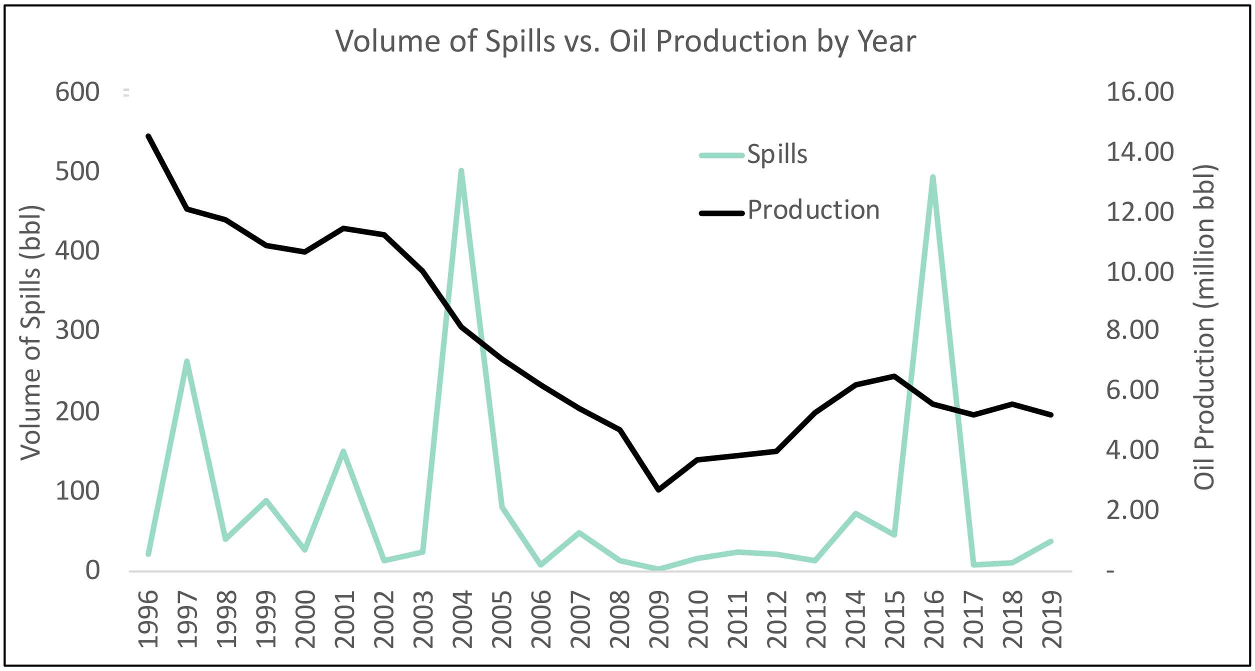

Figure 10. Annual recorded volume of oil spills plotted against the annual oil production for Cook Inlet, 1996–2019

4.5 Spill Trends by Product Type

Figure 11 shows the yearly annual recorded number of crude and refined oil spills plotted against the annual oil production for Cook Inlet from 1996–2019. While both crude and refined spills vary considerably, the trend in crude oil spills more closely follows the trend in oil production. There is no readily discernable trend in the number of refined product spills.

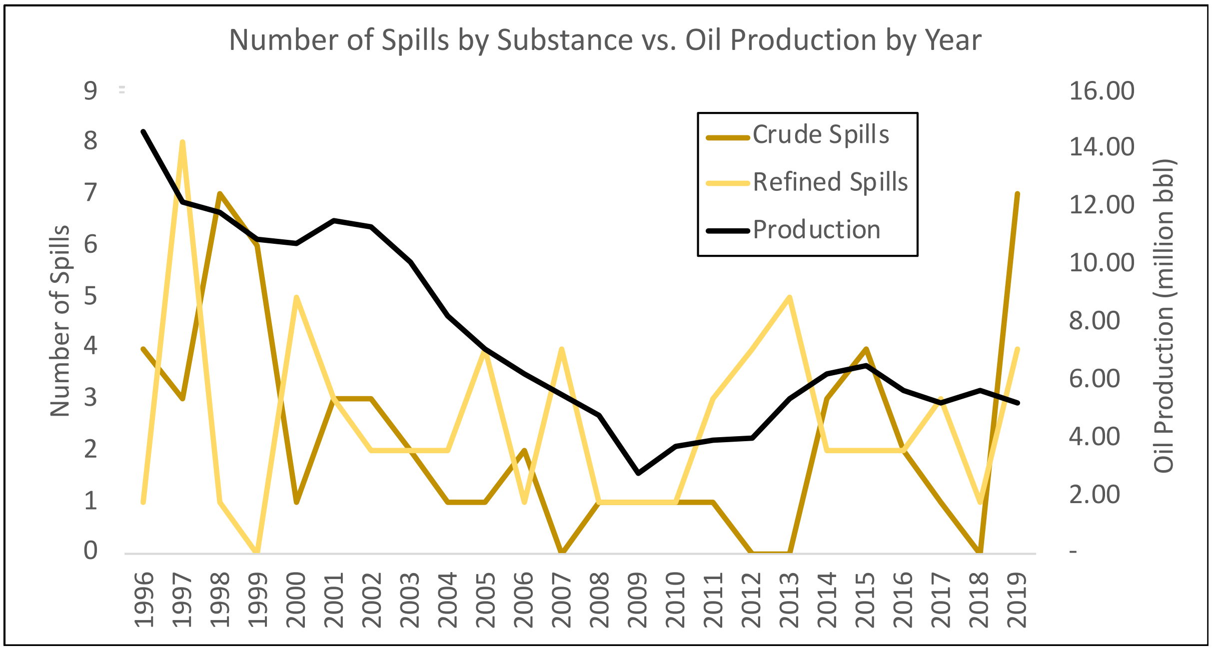

Figure 11. Annual recorded number of oil spills for crude oil and refined oil plotted against the annual oil production for Cook Inlet, 1996–2019

Figure 12 shows the annual volume of recorded crude and refined oil spills plotted against the annual oil production for Cook Inlet in the years from 1996-2019. Neither the crude nor the refined spill data follows the trend in annual oil production. The variability in refined oil spill volume appears much greater than for crude oil spill volume.

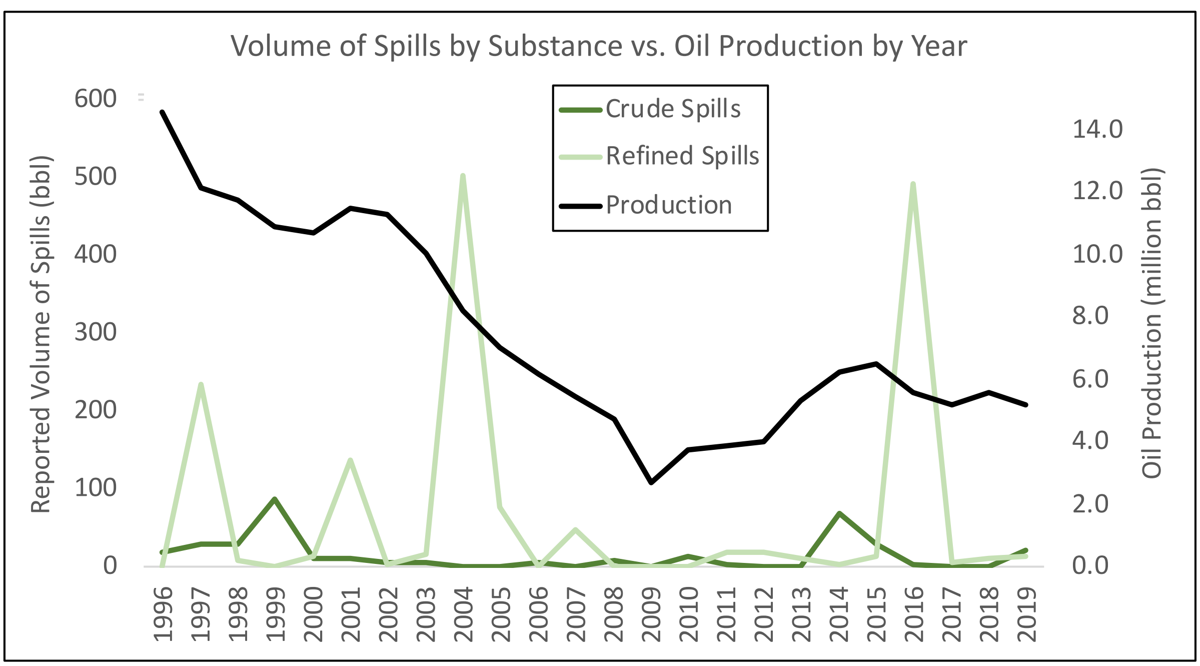

Figure 12. Annual recorded volume of oil spills for crude oil and refined oil plotted against the annual oil production for Cook Inlet, 1996–2019

5 SPILL RATE OCCURRENCE ESTIMATES

The overall purpose of this project was to develop a method to estimate oil spill rates based on independent variables. This section describes the process and results of that effort.

5.1 Annual Number of Spills Over Time

5.1.1 Screening Independent Variables

The first step in building an occurrence rate estimation model is to screen independent variables. The initial screening was done using scatterplots and Pearson Correlation Coefficients. Scatterplots give an indication graphically of whether or not a relationship exists between two variables. That relationship may be linear, quadratic, or some other shape. The Pearson Correlation Coefficient, also referred to as r, measures the strength of the observed linear relationship. A relationship that is perfectly linear will have an r value of 1 or -1, the sign indicating whether the relationship is direct or inverse. A completely uncorrelated pair of variables would have an r of zero. In real situations the observed r lies between these extremes.

It was decided *a priori* that model building would start by including as potential independent variables all of those having a correlation relationship significant at 75% confidence (i.e. a p-value of 0.25 or less).

The dependent variables being screened were the total volume of oil spilled each year (Spill Vol.) and the total number of spills each year (No. Spills). The candidates for inclusion in a model as independent variables were: the annual volume (million cubic feet) of gas produced from gas wells (Gas Prod.), the annual volume (million barrels) of oil produced from oil wells (Oil Prod.), the annual volume (million barrels) of water produced from oil wells (Water Prod.), the average inflation adjusted price (US $) of Alaskan crude each year (Adj. Price), and the length (miles) of oil carrying pipelines (Pipeline Mi.) in the region each year.

Figure 13 presents a scatterplot matrix, distribution, and the Pearson Correlation Coefficient for each variable considered for inclusion in the modeling process.

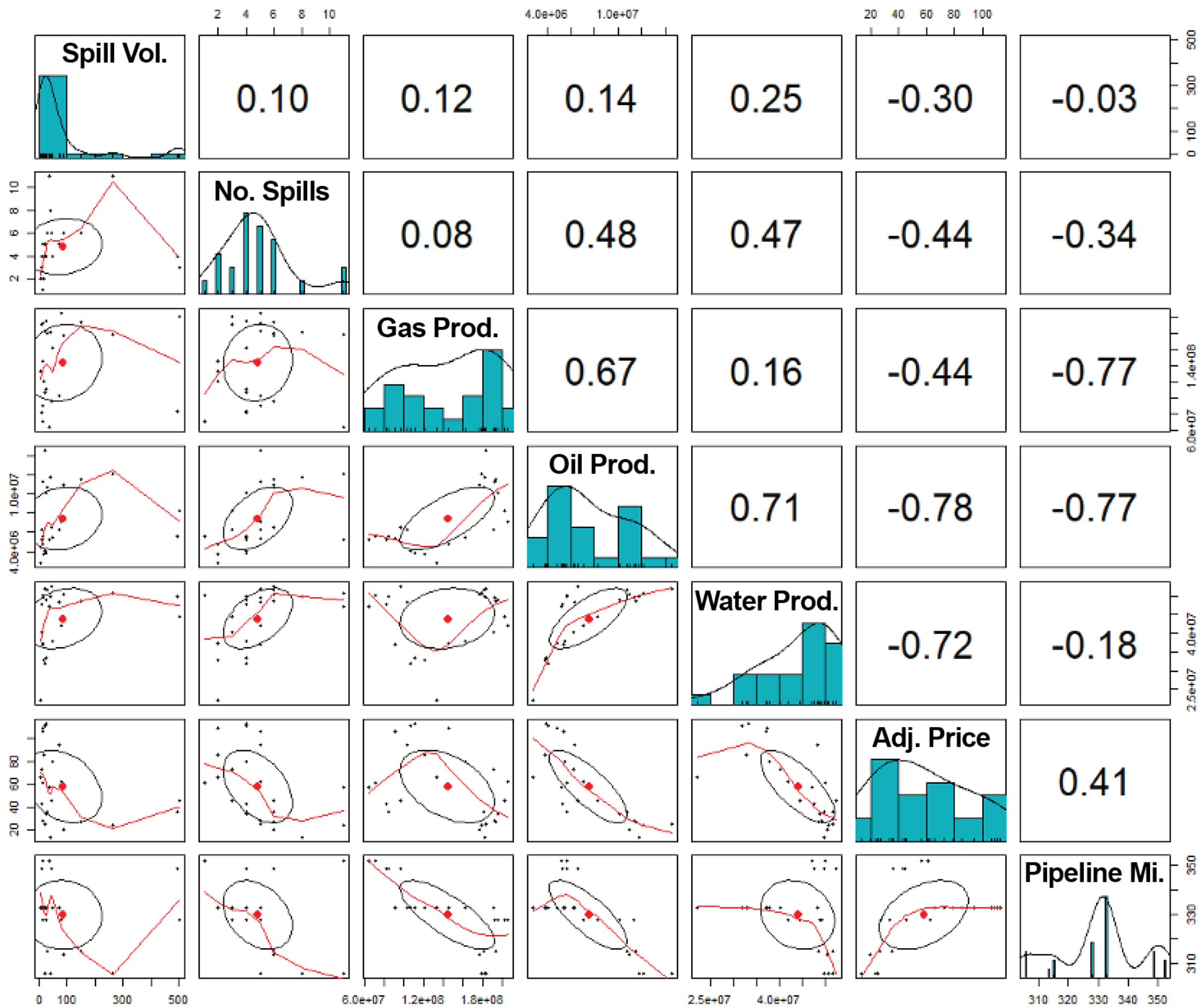

Figure 13. Scatterplot matrix, distribution, and the Pearson Correlation Coefficient for each variable considered for inclusion in the Cook Inlet modeling process

Considering the p-values for the correlations between annual number of spill and each independent variable in Table 9, all Pearson Correlation Coefficient values are significant at the 90% confidence level, with the exception of gas production. See Table 10.

Table 10. Pearson Correlation Coefficient and p-value for independent variables related to annual number and volume of spills recorded in Cook Inlet, 1996–2019

Dependent Variable	Annual number of spills	
Independent Variable	**Pearson Correlation Coefficient**	**p-value**
Gas production	0.08	0.712
Oil production	0.48	0.018
Water production	0.47	0.019
Adjusted price	-0.44	0.032
Pipeline miles	-0.34	0.108

Overall, the linear correlations were significantly stronger between the potential independent variables and the number of spills observed than between the volume of oil spilled. This further reinforced the decision to focus the regression work on explaining the number of spills, not the volume spilled.

Natural gas production was the only variable that had a correlation coefficient with number of spills that was so weak that it was dropped from consideration.

5.1.2 Modeling Approach

We used the following approach to select a suitable model:

1. All candidate independent variables meeting the 0.25 p-value selection criteria were placed in a regression model as main effects (i.e. appearing alone as a term) and in all possible 2-way interactions (i.e. appearing as a term multiplying the variable with another variable).
2. The statistical software program "R" was used to develop regression models. R's automatic step-wise variable selection procedure was run to find the model that minimized the Akaike Information Criteria (AIC statistic).
3. This procedure did not account for multicollinearity existing between the variables, so starting with the model suggested in the step-wise approach, a manual backward variable selection process was employed that removed terms based on which had the highest non-significant p-value and/or the highest Variable Inflation Factor (VIF statistic). The goal was to keep only models for which all terms had a VIF less than 10.

5.2 Predicting Annual Spill Numbers from Crude Oil Production Using Linear Regression

Applying this modeling approach to the Cook Inlet annual spill data resulted in a regression model with a single independent variable - Oil Production. Other independent variables were eliminated through the modeling process due to a high degree of multicollinearity between variables.

The resulting linear regression model was: $N\_tot = 2.1557 + Oil\_Prod. \times 0.3591$

Where: N_tot = total annual number of spills for all spill types and classes

Oil_ Prod. = annual volume of crude oil produced from oil wells in million bbl

The relevant statistics for this model are shown in Table 11.

Table 11. Statistics for the linear regression model predicting annual spills number from oil production

Coefficients	Estimate	Standard Error	t value	p-value	Significance
Intercept	2.1557	1.1454	1.882	0.0731	
Oil Prod.	0.3591	0.1410	2.547	0.0184	0.05
Residual Standard Error		2.226	Degrees Freedom		22
Multiple r-squared		0.2227	Adjusted r-squared		0.1926
F-statistic		6.47	on 1 and 22 degrees of freedom		
p-value		0.1838			

The model indicated that for every increase of 1 MMbbl of oil production, the number of annual spills is expected to increase by 0.36 units (number of spills) for all spill classes. The model explains 22.77% of the variation observed in the annual number of spills. Figure 14 shows the model's predicted value, the 95% confidence interval, and the 95% prediction interval for the range of oil production values studied. The confidence interval is the range that one would expect the mean value of the spill number to fall in 95% of the time when a given production level occurs a large number of times. The prediction interval is the range that one would expect any one value of the spill number to lie in for a given oil production level 95% of the time.

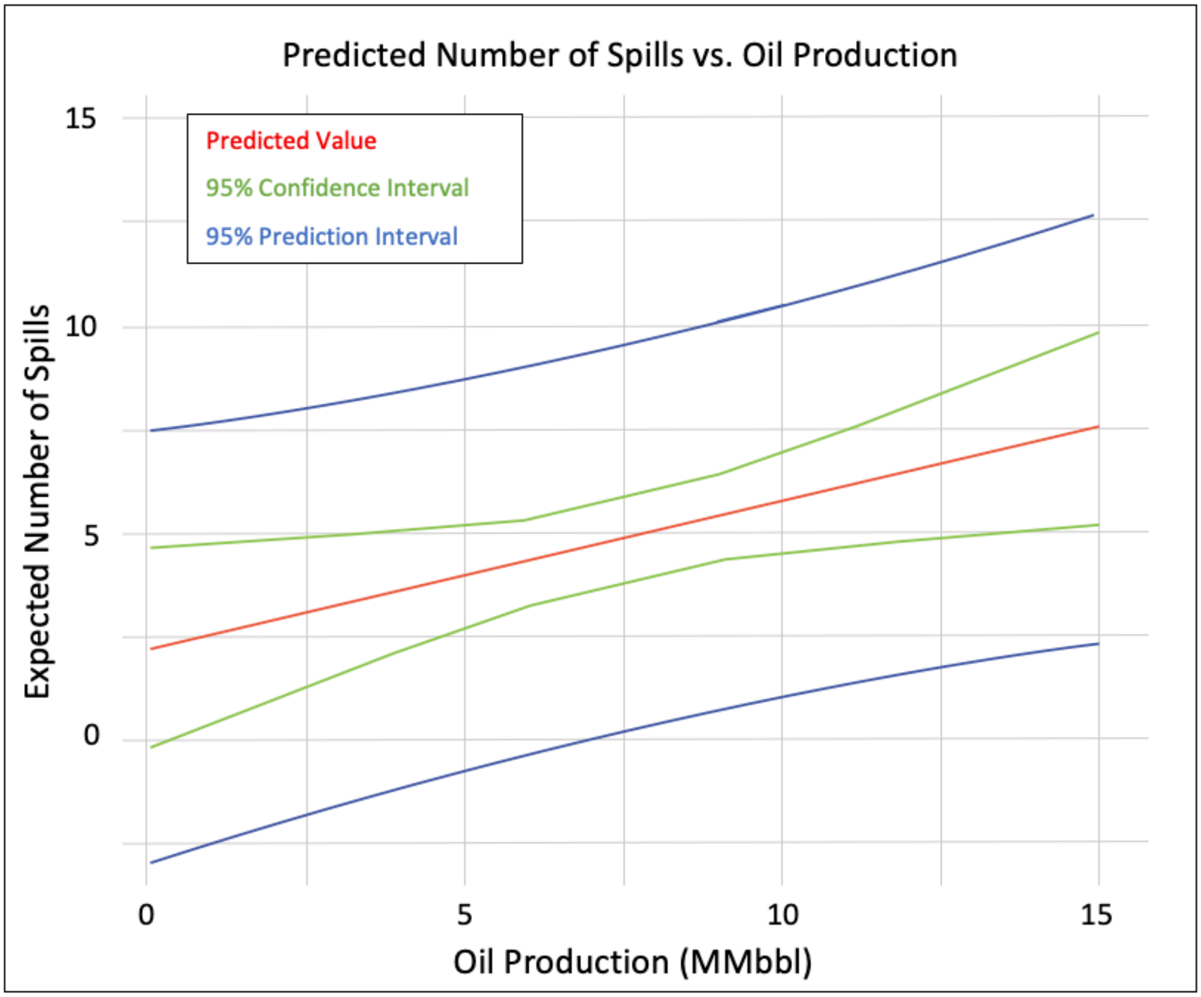

Figure 14. Predicted value, 95% confidence interval, and 95% prediction interval for the expected number of all Cook Inlet oil spills for the range of oil production values studied

The model's calculated multivariate power was 0.7199.[5] The power is adequate but not exceptional. This is attributed to the relatively small sample size.

The model had reasonably normally distributed residuals (i.e. predicted value - observed value), and the equal variance assumption for linear regression was satisfied. Both of these factors indicate the validity of the model.

The model's chief weakness stems from the inclusion of an extreme outlier in the data: in 2019, at an annual oil production level of 5.2 MMbbl, there were 11 spills recorded. Some problematic points are almost always present when building regression models, and statisticians speak of outliers and leverage points which may exert undue influence on the coefficients of a model. In this model, the diagnostic software indicated that two outliers (point 2 - 1997 and point 24 - 2019) and one leverage point (point 1 -

[5] Where u=1, v=22, f2=0.2948, significance level = 0.5 (i.e. 95% confidence)

1996). Only the 2019 point was believed to exert “undue influence” – i.e. significantly affect the value of the coefficients. We went back and examined the spills from 2019 and there was no practical reason for excluding the data, so it was kept in the model.

5.2.1 Predicting Large Spills

Since no Class A spill of greater than 1,000 barrels occurred during the 23-year timeframe chosen to develop occurrence estimates (1996–2019) it is not possible to predict their occurrence using the methods that we used to predict other spills. Table 8 in Section 3.2.5 shows four spills greater than 1,000 bbl were identified in the history of the Cook Inlet oil fields. Another spill was recorded as 1,000 bbl in October 1968, so there have been five large spills (defined here and by MMS/BOEM as ≥1,000 bbl) in or adjacent to Cook Inlet since its beginning. The time interval between these large spills ranged from less than eight months to 20 years. No time pattern was observed. At the end of 2019, 263 million barrels of crude oil had been produced since the last Class A spill almost 30 years before.

Other researchers have used a Poisson distribution to estimate the probability of a large spill as a function of estimated total volume of production (Anderson et al., 2012, Ji et al., 2016). The distribution is based on the rate of large spills per Bbbl of oil production (lambda).

As such the probability of a given number (n) of spills being observed can be calculated using the formula: *P(n) = (lambda * t)^n * exp(-1 * lambda * t) / n!*

Where: P(n) is the probability of a given number of large spills
lambda is the rate of large spills per give volume of oil production
t is the level of total oil production of interest
n! is the factorial of the given number large spills

For the purposes of this work the value of lambda was computed as the number of spills divided by the total production in Cook Inlet at the time that the last large spill occurred. The value of lambda is calculated as $4.45e^{-9}$ dividing 5 (the number of large spills observed through 1990) by the amount of oil produced up until that time[6] (1.1 Bbbl). This is conservative because at the time of this report there are 5 large spills total and oil production is now 1.4 billion barrels, which would result in a lambda of $3.63e^{-9}$. As such, the estimates presented here can be considered to be maximum estimates.

Note that the expected value of the number of spills for a given distribution is computed as:

E(n) = P(0) * 0 + P(1) * 1 + P(2) * 2 + P(3) * 3 …

Table 12 shows the resulting expected number of large for various levels of oil production.

Table 12. Expected number of large spills over the total production volume of a Cook Inlet Oil

Production Level (Bbbl)	Expected Number of Large Spills
1.1 (1990 level)	5.0
1.4 (2019 level)	6.1
1.5	6.7
2.0	8.9
2.5	11.1

[6] 1958 to 1990

It is important to note that expected number was based on large spills over the lifetime of the field and that the lambda calculated for Cook Inlet is dependent on large spills that occurred over 30 years ago and thus does not reflect current oil spill prevention practices.

5.3 Predicting Annual Spill Volume from Crude Oil Production

Attempts to develop a regression model to estimate the annual volume of oil spills in Cook Inlet failed for two reasons. First, as seen in Figure 4, the distribution of the dependent variable, annual volume of spills has a strong positive skew, meaning that there are many more small spills and the mean value is highly influenced by a few larger spills. This suggests that the assumption of a normal distribution required for regression analysis is not appropriate. Second, the individual correlations of the independent variables with Spill Volume are all weak as seen in Table 13 and Figure 15. No variable has a significant linear relationship with the total volume spilled at 95% confidence level or even the 90% confidence level.

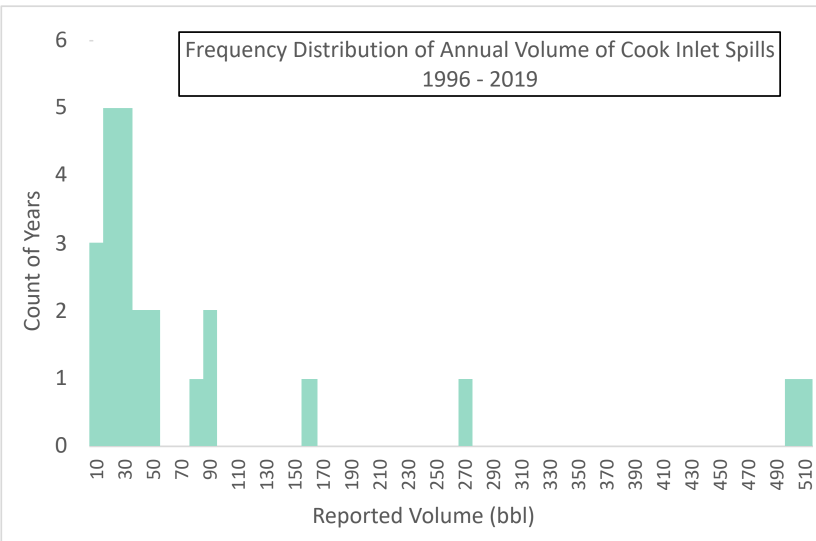

Figure 15. Distribution of volume of recorded oil spill in Cook Inlet, 1996–2019

Table 13. Pearson Correlation Coefficient and p-value for independent variables related to annual volume of spills recorded in Cook Inlet, 1996–2019

Independent Variable	Pearson Correlation Coefficient	p-value
Gas Production	0.12	0.577
Oil Production	0.14	0.52
Water Production	0.25	0.244
Adjusted Price	-0.30	0.152
Pipeline Miles	-0.03	0.903

Still we attempted to use regression techniques to develop a model to predict annual oil volume spilled. Using an automatic variable selection approach, we developed a multivariate model containing all independent variables. However, with an adjusted R-square of 0.037, only about 4% of the variability in annual spill volume was explained by the model. The p-value was 0.3343 which is not significant at a

90% or 95% confidence level and there was a high degree of multicollinearity. For all these reasons, the model was deemed unusable to predict annual spill volume.

An alternate simulation approach was used to arrive at estimates of spill volumes. This approach used a bootstrap technique to estimate mean spill volume for each size class and combined this with a Monte Carlo simulation to generate confidence intervals for the estimate of the number of spills of each class size. Bootstrapping is a commonly used statistical tool for establishing estimates of parameters along with the parameter's expected distribution. This approach was used to estimate both the proportion and median size of spills which would be expected to be Class B, C, or D. There were no Class A spills (> 1,000 bbl) in Cook Inlet during the 1996–2019 period of interest, so statistical forecasting of this size spill is not possible using data from this time interval.

In a bootstrap model, the spills in the database are assumed to be random events with equal probability. The software then samples the dataset with replacement repeatedly for a sample of the same size as that actually observed. For each sample drawn, the proportion of spills of each spill size class is computed, as well as the median[7] spill volume from the Class. The distribution of these sample statistics over a large number of trials represents the distribution that is expected to occur naturally. The results of the bootstrap estimate of the distribution of proportions for each spill class are shown in Figure 16.

A Monte Carlo simulation is used to estimate spill volume. A large number of trials was run in which randomly drawn records from the database were used to develop a model for number of spills. The prediction function generated an expected value for each trial. These spill numbers estimates are then combined with the estimated statistics for proportion and median size to come up with estimates of the number of spills expected from each size group and finally the total annual spill volume estimation. The procedure is outlined below:

1. The total number of spills expected is computed using a linear regression model. Multiple realizations from a Monte Carlo simulation yield a distribution of the expected number at a given production level. This allows for the estimation of a confidence interval.
2. The proportion by spill size class is estimated using the bootstrapped procedure.
3. The median size of a spill in each size class as determined by the bootstrap procedure is then applied.

The formula to estimate the total annual spilled volume is:

$$Vol\_tot_y = Pred\_N\_tot_y \times Prop\_B \times Med\_B + Pred\_N\_tot_y \times Prop\_C \times Med\_C + Pred\_N\_tot_y \times Prop\_D \times Med\_D$$

Where: $Pred\_N\_tot_y$ = total number of spills predicted for annual oil production level Y using the regression model with multiple realizations created via a Monte Carlo simulation

[7] Because the distribution of spill volume is highly skewed, the median is a better estimate of the expected value than the mean.

Prop_X = Proportion of spills from Class X estimated using the bootstrapped procedure

Med_X=Median spill size of Class X estimated using the bootstrapped procedure

This method was used for five levels of oil production: 5, 7.5, 10, 12.5, and 15 million bbl per year. Table 14 presents the predicted number of spills from each of these production levels taken from the linear regression model presented in Section 5.2. Table 15 presents the median spill size by class and corresponding 95% confidence intervals. Table 16 presents the estimated number of spills of each size class and the total annual volume of spills predicted for each level of oil production.

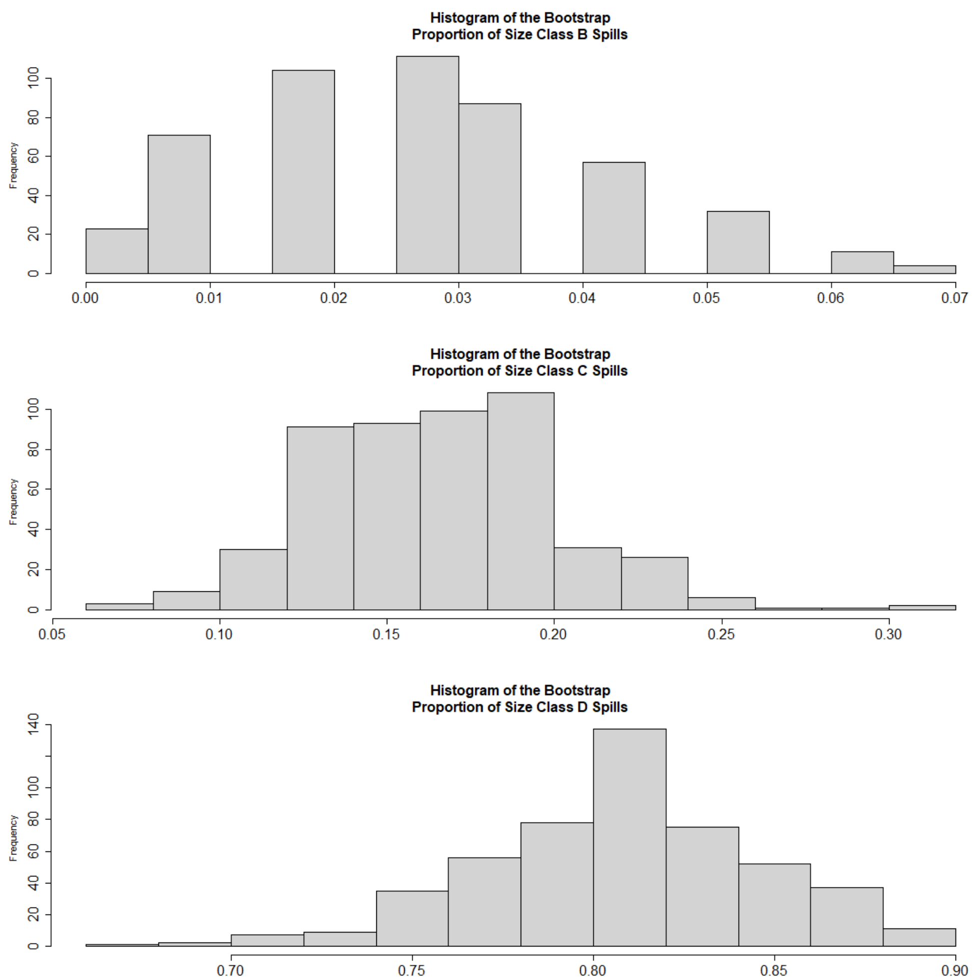

Figure 16. Bootstrap estimate of the distribution of proportions for each spill class

Table 14. Expected annual number of Cook Inlet spills for all size classes and corresponding 95% confidence interval for five levels of oil production

Oil Production (million bbl)	Expected Total Number of Spills	95% Confidence Interval
5	4	2.8 - 5.1
7.5	4.8	3.9 - 5.8
10	5.7	4.5 - 6.9
12.5	6.6	4.9 - 8.4
15	7.5	5.1 - 9.9

Table 15. Median Cook Inlet spill size by class and corresponding 95% confidence interval for Cook Inlet recorded spill 1996–2019

Class	Median Spill Size (bbl)
B > 200 - ≤ 1,000 bbl	490
C >10 - ≤200 bbl	15
D >1 - ≤10 bbl	2.4

Table 16. Expected annual number of Cook Inlet spills and corresponding 95% confidence interval four size classes and five levels of oil production; and estimated total annual volume of spills predicted from the bootstrap/Monte Carlo model

Oil Production (million bbl)	Class B >200 - ≤1,000 bbl		Class C >10 - ≤200 bbl		Class D >1 - ≤10 bbl		All Classes	
	Expected Number of Spills	95% Confidence Interval	Expected Number of Spills	95% Confidence Interval	Expected Number of Spills	95% Confidence Interval	Total Annual Volume (bbl)	95% Confidence Interval
5	0.1	0 - 0.3	0.7	0 - 1.5	3.3	0 - 7.3	72	0 - 202.5
7.5	0.1	0 - 0.4	0.8	0.1 - 0.6	4	0.5 - 8	87	5.8 - 226.2
10	0.2	0 - 0.4	1	0.2 - 1.8	4.7	1.1 - 8.8	102	14.2 - 253.3
12.5	0.2	0 - 0.5	1.1	0.4 - 2	5.4	1.7 - 9.7	118	21.3 - 282.3
15	0.2	0 - 0.5	1.3	0.5 - 2.3	6.2	2.2 - 10.7	134	26.5 - 312.6

Figure 17 shows the predicted total annual volume of oil spilled for the five levels of annual oil production and associated 95% confidence intervals.

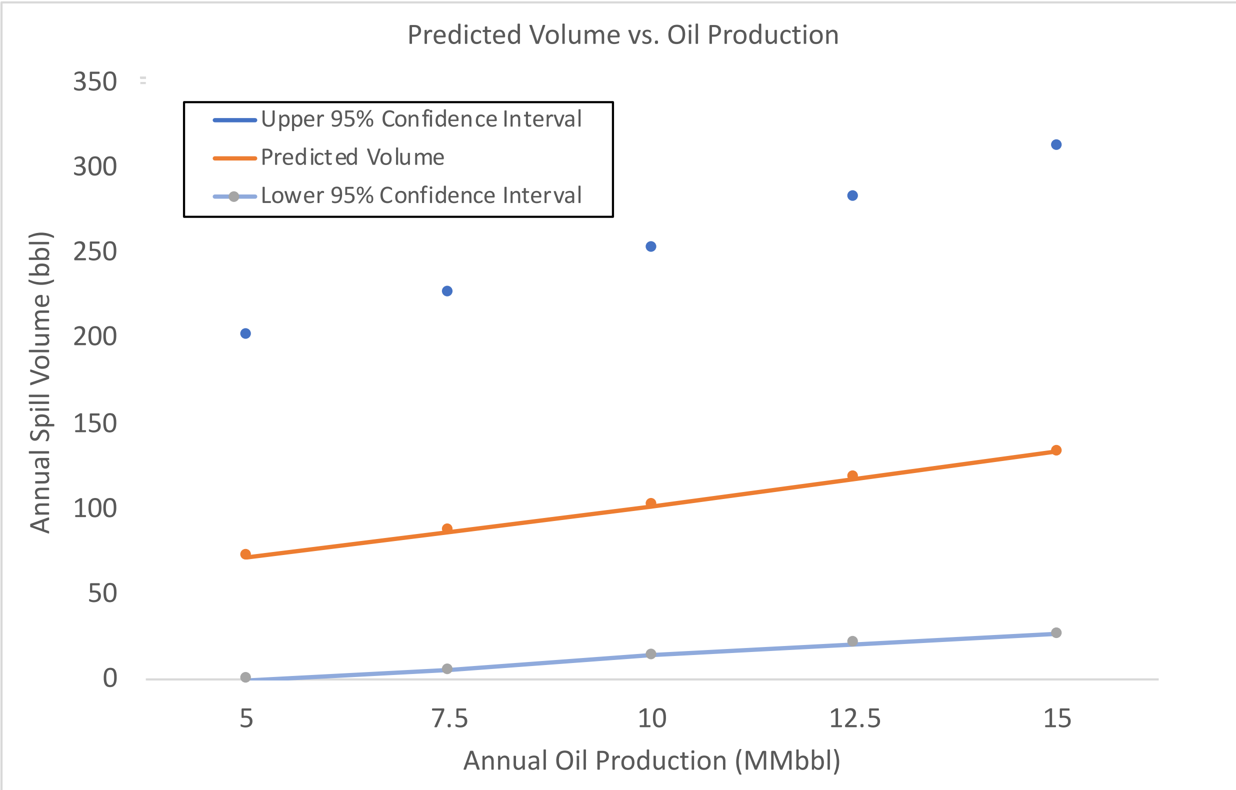

Figure 17. Bootstrap/Monte Carlo estimate of the predicted annual volume of Cook Inlet oil spilled vs annual crude oil production

5.4 Estimating Occurrence Rates by Oil Type

We now turn to estimating the occurrence rates for number and volume by oil type, either crude oil or refined oil.

5.4.1 Occurrence Rates for Number of Spills by Oil Type

Figure 11 depicts the number of recorded oil spills by substance type (crude and refined) versus the crude oil production by year. We attempted to develop models to predict the number of spills for each substance type.

Applying our modeling approach to the Cook Inlet annual crude oil spill data resulted in a regression model with Oil Production as the single independent variable.

The resulting linear regression model was: *N_crude_tot = -0.1432 + Oil Prod. x 0.3209*

Where: N_crude_tot = total annual number of crude oil spills

Oil_ Prod. = annual volume of crude oil produced from oil wells in million bbl

The relevant statistics for this model are shown in Table 17.

Table 17. Statistics for the linear regression model predicting annual number of crude oil spills from oil production

Coefficients	Estimate	Standard Error	t value	p-value	Significance
Intercept	-0.1432	0.9482	-0.151	0.8813	
Oil Prod.	0.3209	0.1167	2.750	0.0117	0.05
Residual Standard Error		1.844	Degrees Freedom		22
Multiple r-squared		0.2558	Adjusted *r*-squared		0.222
F-statistic		7.562	on 1 and 22 degrees of freedom		
p-value		0.01169			

The model indicates that for every increase of one MMbbl of oil production the number of annual spills is expected to increase 0.32 units. The model explains 26% of the variation observed in the annual number of spills. Figure 18 shows the model's predicted value, the 95% confidence interval, and the 95% prediction interval for the range of oil production values studied.

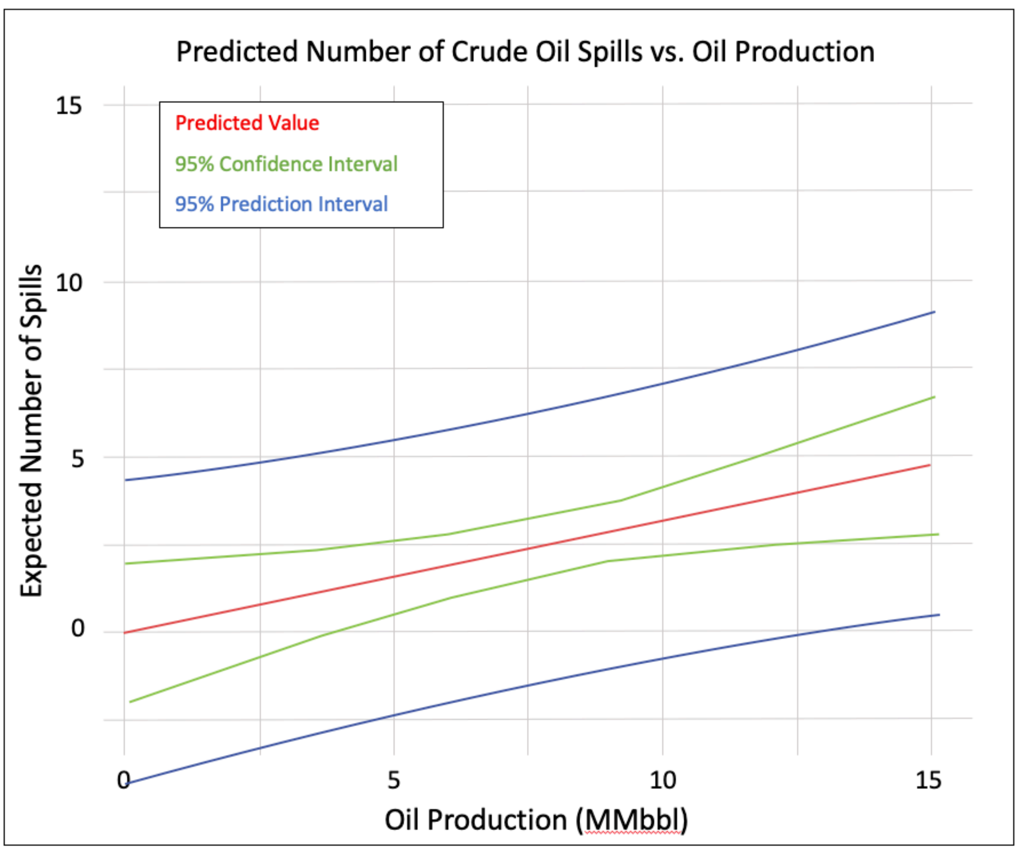

Figure 18. Predicted value, 95% confidence interval, and 95% prediction interval for the expected number of crude oil spills for the range of annual oil production values studied

The occurrence model to predict annual number of crude oil spills is very similar to the model developed to predict annual number of all types of oil spills.

Regression techniques were applied to develop a model to predict the annual number of refined product oil spills. A univariate model was developed with oil production as an independent variable, but with an R-square of 0.005, less than 1% of the variability in annual spill numbers for refined product was explained by the model. The p-value was 0.748 which is not significant at a 90% confidence level. For these reasons, the model was deemed unusable to predict annual numbers of refined spills. There was no significant linear relationship between annual number of refined oil spills and the oil production level.

The best method to predict the annual number of refined oil spills is the estimate of the mean number of refined oil spills which is 2.6 refined spills per year with a 95% confidence interval of 0.6 to 6.3. The skewness of the distribution is 1.06 and the kurtosis of the distribution is 0.96, so the distribution is close enough to normal to allow for a mean as an estimate. The reason that using the mean is the best method is that both the plot in Figure 11 and the regression against year indicate that the number of refined oil spills is relatively constant across time.

5.4.2 Occurrence Rates for Annual Volume of Spills by Oil Type

Figure 12 depicts the volume of recorded oil spill by substance type (crude and refined) versus the crude oil production by year. Neither the crude nor the refined spill data follows the trend in oil production, nor is the proportion of crude to refined spill volumes consistent over time or production level. We attempted to develop models to predict the number of spills for each substance type without success. There is no significant linear relationship between oil production and spill volume for either crude or refined oil. So, an estimate of annual spill volume across all years is the best estimate.

The distributions for crude and refined annual oil spill volumes are highly skewed[8], so the best estimate for annual spill volume by oil type is the median spill volume and the associated 95% percentile interval as presented in Table 18.

Table 18. Median annual spill volume and 95% percentile interval by oil type for Cook Inlet spills 1996–2019

Oil Type	Median Spill Volume (bbl)	Lower 5% Percentile Interval	Upper 95% Percentile Interval
Crude	6.3	0.0	63.2
Refined	13.0	1.3	453.1

[8] Crude: kurtosis = 5.4 skewness = 2.3, Refined: kurtosis = 6.0 skewness = 2.6

6 CONCLUSIONS

6.1 Limitations and Challenges of Occurrence Models

The models developed here do not address the causality of the relationships noted between the number of spills and independent variables explored, merely that they were unlikely to have occurred by chance. Therefore, caution should be used when applying statistical models for predictions in dissimilar circumstances. While these occurrence models performed adequately for predicting spill numbers in similar oil fields during a similar timeframe, using them to predict spills in other places or times could lead to predictions outside the confidence intervals due to differences in technology, industry practices, regulation and oversight, or other circumstances.

Factors besides oil production volume contribute to oil spill occurrence rates as well. For example, because some spills are caused by human error, the number of work hours by people employed in the industry could be related to spill occurrence. Spill volume is also a function of the time it takes to detect and stop a leak, which can depend on both technology and operator protocols or decisions. Therefore, advances in technology may have a big effect on volume spilled.

At the same time that using spill data from a specific location is important, it will always be challenging to model oil spill occurrences based on historical spills. Oil spills, especially large ones, are generally rare occurrences so datasets are prone to being small. This is further confounded, as was the case in this study, by changes in reporting requirements and record keeping. Industry practices also change, due to required or voluntary use of best practices, along with new technology. If we assume that the efforts of regulators and industry to reduce the number and size of spills will improve spill prevention over time, occurrence estimation models based on historic spills may over-predict future spills.

6.2 Occurrence Estimates for Spill Number

A variety of regression models was applied to explore the most accurate predictive approaches that could be used to estimate the number of spills based on various production variables. In some cases, strong predictive models were identified. In others, simpler estimating methods proved as accurate as regression modeling.

While several predictive models were developed for overall spill occurrence rates, there were challenges when similar approaches were applied to size category subsets. The best model for predicting the annual total number of spills was a linear regression based upon annual volume of oil produced in MMbbl. The model equation was:

$$N\_tot = 2.1557 + Oil\_Prod. \times 0.3591$$

The best model for predicting the annual total number of crude oil spills was a linear regression based upon volume of oil produced. The model equation was:

$$N\_crude\_tot = -0.1432 + Oil\ Prod. \times 0.3209$$

6.3 Occurrence Estimates for Spill Volume

We attempted to use regression to develop a model to predict total spill volume and spill volume by oil type without success. There is no significant linear relationship between any of the independent variables and the annual volume of oil spilled. So, an alternate approach was used to arrive at estimates of total spill volume using a bootstrap technique to estimate median spill volume for each size class and combined this with a Monte Carlo simulation to generate confidence intervals for the estimate of the number of spills of each class size. The resulting model was:

$$Vol\_tot_y = Pred\_N\_tot_y \times Prop\_B \times Med\_B + Pred\_N\_tot_y \times Prop\_C \times Med\_C + Pred\_N\_tot_y \times Prop\_D \times Med\_D$$

This model predicts an annual spill volume of 87 bbl with a 95% Confidence Interval of 6 to 226 bbl at a 7.5 MMbbl per year level of oil production.

6.4 Recommendations

Occurrence estimates could be improved by using more independent variables, though in order to be useful these need to be variables that can be estimated or planned on for the future. For example, the volume of refined product utilized to construct and operate the oil production infrastructure might be a better predictor of refined oil spill than total oil production itself.

Most crude oil spills are the result of the loss-of-integrity of some portion of the oil production infrastructure. Examining the spill record for an individual facility (e.g. pipeline, tank, or processing plant) and then comparing similar facilities to establish occurrence rates by facility type may provide additional insight into occurrence rates. Finally, as acknowledged, oil spill rate studies are limited by data quality. Reporting standards change over time and some data on potential independent variables are not recorded.

7 REFERENCES

ABS Consulting Inc. 2016. 2016 Update of Occurrence Rates for Offshore Oil Spills. Prepared by ABS Consulting Inc. for USDOI, BOEM/BSEE. Sterling, VA: USDOI, BOEM/BSEE. 95 pp.

ABSG Consulting Inc. 2018. US Outer Continental Shelf Oil Spill Statistics. Arlington (VA) :Prepared for US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-006.

Alaska Department of Environmental Conservation, Division of Spill Prevention and Response. 2003. Statewide Summary of Oil and Hazardous Substance Spill Data (Fiscal Years 1996–2002) Provisional Report.

Alaska Department of Environmental Conservation, Division of Spill Prevention and Response. 2007. Summary of Oil and Hazardous Substance Spills by Subarea (July 1, 1995–June 30, 2005).

Alaska Department of Natural Resources, Division of Oil and Gas. 2019. Cook Inlet Oil and Gas Units Map. https://dog.dnr.alaska.gov/Document/62118DF2DE684BDBA395A2A0F6D07207/12-4-2019__Cook_Inlet_Units_Region_Map

Anderson CM, Labelle RP. 1990. Estimated occurrence rates for analysis of accidental oil spills on the U.S. Outer Continental Shelf. *Oil & Chemical Pollution.* 6:21-35. http://www.boemre.gov/eppd/sciences/osmp/pdfs/AndersonAndLaBelle/AndersonAndLaBelle1990.pdf

Anderson CM, Labelle RP. 1994. Comparative occurrence rates for offshore oil spills. Spill Science and Technology Bulletin. 1(2):131-141. http://www.boemre.gov/eppd/sciences/osmp/pdfs/AndersonAndLaBelle/Anderson_LaBelle1944.pdf

Anderson CM, Labelle RP. 2000. Update of comparative occurrence rates for offshore oil spills. Spill Science and Technology Bulletin. 6(5/6):303-321. http://www.boemre.gov/eppd/

Anderson CM, Mayes M, Labelle RP. 2012. Update of Occurrence Rates for Offshore Oil Spills. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Report BOEM 2012-069.

Belmar Management Services. 1993. Oil Pipeline Risk Assessment, Cook Inlet, Alaska. Redondo Beach (CA).

Boettger B. 2018 Oct 25. Hilcorp replaces oil tankers with pipeline for Cook Inlet crude. Anchorage Daily News.

Energy Information Administration (EIA). Alaska North Slope First Purchase Price. 2020 Aug 3. U.S. Energy Information Administration; [accessed 2020 Aug 7]. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=F005071__3&f=M

Epstein LN. 2002. Lurking below: oil and gas pipeline problems in the Cook Inlet watershed. Cook Inlet Keeper. https://inletkeeper.org/wp-content/uploads/2017/10/Lurking-Below-Final-Report-2002.pdf

Fletcher S, Robertson T, Miller S. 2020. Cook Inlet pipeline infrastructure assessment: Final report. Anchorage (AK): Alaska Department of Environmental Conservation.

Hite DM, Stone DM. 2013. Oil and gas fields of the Cook Inlet Basin, Alaska. AAPG Memoir 104. Chapter 1, A History of oil and gas exploration, discovery, and future potential: Cook Inlet Basin, South-Central Alaska; p. 1-35.

Ji Z, Smith C, Johnson W. 2016. Oil-Spill Risk Analysis: Cook Inlet Planning Area, OCS Lease Sale 244. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Report BOEM 2016-068. 15 p.

Johnson W, Marshall C, Lear E. 2002. Oil-Spill Risk Analysis: Cook Inlet Planning Area, OCS Lease Sales 191 and 199. Sterling (VA): U.S. Department of the Interior, Minerals Management Service. OCS Report MMS 2002-074. 66 p.

Johnson W, Marshall C, Lear E. 2007. Oil-Spill Risk Analysis: Beaufort Sea Planning Area, OCS Lease Sale 202. Sterling (VA): U.S. Department of the Interior, Minerals Management Service. OCS Report MMS 2007-041. 19 p.

Johnson W, Marshall C, Lear E. 2007. Oil-Spill Risk Analysis: Sivulliq Exploration Project. Sterling (VA): U.S. Department of the Interior, Minerals Management Service. OCS Report MMS 2007-039. 54 p.

Roberts D. 1996. Cook Inlet spills 1966 through 1991. U.S. Department of the Interior, Minerals Management Service, Alaska OSC Region.

Robertson TL, DeCola E, Pearson L. 2010. Alaska North Slope spills analysis: Final report on North Slope Spills analysis and expert panel recommendations on mitigation measures. Report to Alaska Department of Environmental Conservation. http://www.dec.alaska.gov/spar/ipp/ara/documents/101123NSSAReportvSCREENwMAPS.pdf

Robertson TL, Campbell LK, Pearson L, Higman B. 2013. Oil spill occurrence rates for Alaska North Slope crude & refined oil Spills. Report to the Bureau of Ocean and Energy Management. https://www.boem.gov/sites/default/files/uploadedFiles/BOEM/BOEM_Newsroom/Library/Publications/2013-0205.pdf

Sienkiewicz M. 1992. Spill data base, report on Kenai District spills, September 14 1992. State of Alaska, Department of Environmental Conservation.

Stone D, Hite D. 2014. Oil and Gas Fields of the Cook Inlet Basin, Alaska. Tulsa (OK): American Association of Petroleum Geologists.

Whitney J. 2002. Cook Inlet, Alaska Oceanographic and Ice conditions and NOAA's 18-year oil spill response history for the years 1984-2001. Hazardous Material Response and Assessment Division, Office of Response and Restoration, National Ocean Services, Anchorage, Alaska. 111 p.

8 APPENDICES

Appendix A: Collated Oil Spill Dataset

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-1	03/05/66	1966	100.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-2	07/08/66	1966	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-3	07/10/66	1966	75.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Fire/ Explosion	Other
CI-4	09/23/66	1966	50.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-5	10/31/66	1966	60.00	C	Crude Oil	Crude Oil	Oil Exploration	Oil Exploration	Offshore	Exploration	Unknown	Human Error	Human Error: Unknown
CI-6	12/13/66	1966	1400.00	A	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-7		1966	50.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Other	Other
CI-8	05/02/67	1967	7.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-9	08/11/67	1967	1400.00	A	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-10	10/26/67	1967	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-11	11/26/67	1967	30.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Unknown	Other	Other
CI-12	02/29/68	1968	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-13	03/28/68	1968	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-14	03/31/68	1968	2.60	D	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Unknown	Unknown	Unknown
CI-15	04/11/68	1968	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-16	04/17/68	1968	315.00	B	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-17	04/17/68	1968	15.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Unknown	Unknown	Unknown
CI-18	05/18/68	1968	23.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-20	05/19/68	1968	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-21	05/26/68	1968	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-22	06/06/68	1968	380.00	B	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-23	07/17/68	1968	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-24	08/13/68	1968	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-25	09/12/68	1968	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-26	10/20/68	1968	35.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Tank	Human Error, Overfill	Human Error: Overfill
CI-27	10/23/68	1968	1000.00	B	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-28	10/30/68	1968	2.00	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-29	11/06/68	1968	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-30	11/07/68	1968	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Tank	Human Error, Overfill	Human Error: Overfill
CI-31	12/17/68	1968	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-32	02/20/69	1969	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-33	04/18/69	1969	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-34	04/22/69	1969	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-35	06/04/69	1969	124.00	C	Refined: Lube/Gear Oil	Refined: Other	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
CI-36	07/06/69	1969	40.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-37	03/03/70	1970	10.00	D	Refined: Bunker oil	Refined: Other	Support Dock	Support Facility/Services	Onshore	Support Services	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-38	04/01/70	1970	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-39	04/09/70	1970	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Dumping	Human Error: Other
CI-40	07/20/70	1970	5.00	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Granite Point	Unknown	Unknown	Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-41	09/23/70	1970	1.30	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Other	Other
CI-42	10/27/70	1970	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Flare	Other	Other
CI-43	01/07/71	1971	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-44	03/07/71	1971	8.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-45	04/12/71	1971	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Unknown	Unknown	Unknown
CI-46	04/17/71	1971	10.00	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Equipment Failure, Tank Failure	Human Error: Other
CI-47		1971	50.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-48	02/14/72	1972	10.00	D	Crude Oil	Crude Oil	Vessel	Support Facility/Services	Offshore	Support Services	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-49	08/09/72	1972	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-50	10/16/72	1972	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Human Error	Human Error: Unknown
CI-51		1972	3.90	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-52	02/22/74	1974	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-53	02/22/74	1974	119.00	C	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Vessel	Collision/Allision/Grounding	Human Error: Other
CI-54	03/10/74	1974	10.00	D	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Unknown	Other	Other
CI-55	10/05/74	1974	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Tank	Human Error, Overfill	Human Error: Overfill

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-56	05/05/75	1975	5.00	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-57	07/14/75	1975	2.00	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-58	08/03/75	1975	3.00	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-59		1976	2.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Unknown	Unknown	Unknown
CI-60		1977	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Tank	Human Error, Overfill	Human Error: Overfill
CI-61		1978	3.60	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-62		1978	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-63		1979	2.00	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Unknown	Unknown
CI-64	05/29/86	1986	10.00	D	Refined: Bunker oil	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-292	01/19/87	1987	151.00	C	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error	Human Error: Other
CI-65		1987	50.00	C	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-66		1988	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-67		1988	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-68		1988	114.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-69	11/14/88	1988	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-70		1988	50.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Unknown	Human Error, Overfill	Human Error: Overfill
CI-71		1988	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Unknown	Unknown
CI-72		1988	261.90	B	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Unknown	Unknown	Unknown	Unknown
CI-73		1988	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Unknown	Unknown	Unknown
CI-74		1988	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-75		1988	5.00	D	Crude Oil	Crude Oil	Oil Exploration	Oil Exploration	Onshore	Exploration	Unknown	Unknown	Unknown
CI-76		1988	1.20	D	Refined: Unknown	Refined: Other	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
CI-77	12/08/88	1988	2000.00	A	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Tank	Equipment Failure, Other	Mechanical Failure: Other
CI-78		1988	1.20	D	Refined: Diesel	Refined: Diesel	Vehicle	Support Facility/Services	Onshore	Support Services	Vehicle	Human Error	Human Error: Unknown
CI-79		1988	141.00	C	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Vessel	Unknown	Unknown
CI-293	01/31/89	1989	110.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Tank	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-80		1989	1.20	D	Refined: Hydraulic Oil	Refined: Other	Vehicle	Support Facility/Services	Unknown	Support Services	Hydraulic System	Unknown	Unknown
CI-81		1989	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-82		1989	1.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-83		1989	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-84		1989	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-85		1989	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-86		1989	5.00	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-87		1989	58.00	C	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-88		1989	60.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Equipment Failure, Tank Failure	Human Error: Other
CI-89		1989	1.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-90		1989	2.40	D	Refined: Turbine oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Human Error	Human Error: Unknown
CI-91		1989	12.40	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Unknown	Unknown	Unknown
CI-92		1989	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Unknown	Unknown	Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-93		1989	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Unknown	Unknown	Unknown
CI-94		1989	8.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Unknown	Unknown	Unknown
CI-95	12/17/90	1990	15.00	C	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Offshore	Cook Inlet Pipeline	Loading Arm	Collision/Allision/Grounding	Human Error: Other
CI-96		1990	5.00	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-97		1990	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-98		1990	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-99		1990	2.40	D	Refined: Unknown and water	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-100	03/10/90	1990	2300.00	A	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-101		1990	200.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-102		1990	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-103		1990	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-104		1990	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Equipment Failure, Gauge/Site Glass Failure	Mechanical Failure: Other
CI-105		1990	28.60	C	Refined: Jet	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-106		1990	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Kenai Pipeline	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-107		1990	1.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Tank Failure	Human Error: Other
CI-108		1990	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-109		1990	1.20	D	Refined: Lube/Gear Oil	Refined: Other	Unknown	Unknown	Onshore	Support Services	Unknown	Other	Other
CI-110		1990	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Unknown	Unknown
CI-111		1990	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Unknown	Unknown
CI-112	08/29/91	1991	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Tank	Unknown	Unknown
CI-113	08/13/91	1991	95.20	C	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Other	Collision/Allision/Grounding	Human Error: Other
CI-114		1991	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-115		1991	18.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-116		1991	3.00	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Beluga River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-117		1991	4.80	D	Refined: Gasoline	Refined: Other	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Equipment Failure, Gauge/Site Glass Failure	Mechanical Failure: Other
CI-118		1991	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Tank	Human Error, Overfill	Human Error: Overfill
CI-119		1991	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-120		1991	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Middle Ground Shoals	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-121		1991	2.70	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-122		1991	1.30	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Unknown	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-123		1991	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Unknown	Unknown
CI-124		1991	4.80	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Beluga River	Unknown	Unknown	Unknown
CI-125		1991	2.40	D	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Onshore	Support Services	Unknown	Unknown	Unknown
CI-126		1991	15.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Unknown	Unknown
CI-127		1991	7.10	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Weld Failure	Mechanical Failure: Other
CI-128	01/04/92	1992	400.00	B	Crude Oil	Crude Oil	Pipeline	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Freezing	Mechanical Failure: Other
CI-129	10/01/92	1992	95.20	C	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-294	04/27/92	1992	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-130		1992	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Flare	Other	Other
CI-131		1992	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-132		1992	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-133		1992	220.00	B	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Freezing	Mechanical Failure: Other
CI-134		1992	1.20	D	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Tank	Human Error, Overfill	Human Error: Overfill
CI-135		1992	1.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-136		1992	4.50	D	Crude Oil	Crude Oil	Unknown	Unknown	Unknown	Middle Ground Shoals	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-137		1992	10.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-138		1992	2.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-139		1992	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-140		1992	1.20	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-141		1992	4.00	D	Crude Oil	Crude Oil	Oil Exploration	Oil Exploration	Offshore	Exploration	Unknown	Human Error	Human Error: Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-142		1992	39.70	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Human Error	Human Error: Unknown
CI-143		1992	6.00	D	Crude Oil	Crude Oil	Unknown	Unknown	Onshore	Support Services	Unknown	Unknown	Unknown
CI-144		1992	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Unknown	Unknown	Unknown	Unknown
CI-145	04/20/93	1993	47.60	C	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Unknown	Unknown	Human Error	Human Error: Unknown
CI-146	05/17/93	1993	50.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Flare	Other	Other
CI-147	05/25/93	1993	2.40	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-148	11/08/93	1993	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Unknown	Unknown
CI-149	12/28/93	1993	370.00	B	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-150		1993	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-151		1993	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Kenai Pipeline	Pipe or Line	Freezing	Mechanical Failure: Other
CI-152		1993	378.00	B	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Pipe or Line	Other	Other
CI-153		1993	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Unknown	Equipment Failure, Other	Mechanical Failure: Other
CI-154	04/21/93	1993	45.70	C	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Granite Point	Unknown	Human Error	Human Error: Unknown
CI-155		1993	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Other	Other
CI-156		1993	126.10	C	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Vessel	Collision/Allision/Grounding	Human Error: Other
CI-157	02/23/94	1994	20.00	C	Crude Oil	Crude Oil	Pipeline	Oil Production	Onshore	Unknown	Pipe or Line	Freezing	Mechanical Failure: Other

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-158	02/25/94	1994	1.20	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Unknown	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-159	04/06/94	1994	100.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Tank	Human Error	Human Error: Other
CI-161	05/13/94	1994	1.20	D	Refined: Diesel	Refined: Diesel	Vessel	Support Facility/Services	Offshore	Support Services	Vessel Transfer	Unknown	Unknown
CI-162	08/01/94	1994	25.00	C	Crude Oil and Produced Water	Crude Oil and Produced Water	Oil Production	Oil Production	Offshore	Unknown	Tank	Equipment Failure, Tank Failure	Human Error: Other
CI-163	08/05/94	1994	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Cook Inlet Pipeline	Tank	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-164	08/09/94	1994	2.00	D	Crude Oil and Produced Water	Crude Oil and Produced Water	Oil Production	Oil Production	Unknown	Unknown	Well	Equipment Failure, Other	Mechanical Failure: Other
CI-165	08/20/94	1994	2.40	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Unknown	Unknown	Tank	Equipment Failure, Other	Mechanical Failure: Other
CI-166	10/09/94	1994	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Pipe or Line	Erosion	Mechanical Failure: Other
CI-167	11/18/94	1994	15.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Tank	Human Error, Overfill	Human Error: Overfill
CI-168	12/26/94	1994	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Unknown	Unknown	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-169	01/21/95	1995	1.40	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Onshore	Unknown	Pipe or Line	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-170	03/03/95	1995	4.00	D	Crude Oil and Produced Water	Crude Oil and Produced Water	Oil Production	Oil Production	Onshore	Granite Point	Unknown	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-171	04/10/95	1995	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Tank	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-172	04/22/95	1995	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Well	Equipment Failure, Other	Mechanical Failure: Other
CI-173	07/24/95	1995	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-174	07/28/95	1995	20.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-175	12/05/95	1995	135.70	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Unknown	Tank	Human Error, Overfill	Human Error: Overfill
CI-176	01/10/96	1996	2.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-177	04/20/96	1996	2.00	D	Crude Oil	Crude Oil	Transmission Pipeline	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-178	08/09/96	1996	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error, Overfill	Human Error: Overfill
CI-179	10/05/96	1996	11.90	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-180	12/20/96	1996	1.30	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-181	02/16/97	1997	7.10	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-182	03/06/97	1997	214.30	B	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Trading Bay	Unknown	Unknown	Unknown
CI-183	03/30/97	1997	27.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-184	04/17/97	1997	1.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Vehicle	Human Error	Human Error: Unknown
CI-185	06/22/97	1997	2.40	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Onshore	West McArthur River	Unknown	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-186	08/18/97	1997	5.00	D	Refined: Ballast water w oil	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-187	08/26/97	1997	1.20	D	Refined: Diesel	Refined: Diesel	Oil Exploration	Oil Exploration	Onshore	Exploration	Unknown	Unknown	Unknown
CI-188	09/16/97	1997	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Granite Point	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-189	09/19/97	1997	2.00	D	Refined: Unknown	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-190	10/20/97	1997	2.00	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Unknown	Unknown
CI-191	11/06/97	1997	1.50	D	Refined: Diesel	Refined: Diesel	Support Dock	Support Facility/Services	Onshore	Support Services	Vehicle	Human Error	Human Error: Unknown
CI-192	02/06/98	1998	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Unknown	J TUBE	Unknown	Unknown
CI-193	02/10/98	1998	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Vehicle	Human Error	Human Error: Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-194	02/28/98	1998	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Tank	Human Error, Overfill	Human Error: Overfill
CI-195	05/17/98	1998	20.00	C	Crude Oil	Crude Oil	Transmission Pipeline	Oil Production	Onshore	Middle Ground Shoals	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-196	05/17/98	1998	10.00	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Tank	Human Error, Overfill	Human Error: Overfill
CI-197	07/11/98	1998	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Unknown	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-198	10/07/98	1998	1.30	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Unknown	Unknown	Unknown
CI-199	11/19/98	1998	1.10	D	Crude Oil	Crude Oil	Transmission Pipeline	Oil Production	Onshore	Kenai Pipeline	Unknown	Human Error	Human Error: Unknown
CI-200	01/06/99	1999	60.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-201	02/13/99	1999	8.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-202	03/14/99	1999	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-203	06/18/99	1999	1.30	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-204	07/09/99	1999	2.60	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Unknown	Corrosion	Mechanical Failure: Corrosion
CI-205	10/23/99	1999	12.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-206	05/31/00	2000	5.80	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Unknown	Human Error	Human Error: Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-207	07/26/00	2000	1.20	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Unknown	Unknown	Unknown
CI-208	08/18/00	2000	1.20	D	Refined: Unknown	Refined: Other	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Unknown	Other	Other
CI-209	11/17/00	2000	4.80	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Unknown	Human Error	Human Error: Unknown
CI-210	11/28/00	2000	12.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-211	12/12/00	2000	2.40	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Onshore	Granite Point	Unknown	Unknown	Unknown
CI-212	01/27/01	2001	4.80	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-213	07/31/01	2001	123.80	C	Refined: Diesel	Refined: Diesel	Transmissi on Pipeline	Oil Production	Onshore	Kenai Gas	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-214	11/14/01	2001	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Other	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-215	11/27/01	2001	4.80	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Middle Ground Shoals	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-216	12/04/01	2001	4.80	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Redoubt	Other	Unknown	Unknown
CI-217	12/13/01	2001	10.20	C	Refined: Unknown	Refined: Other	Oil Exploration	Oil Exploration	Offshore	Exploratio n	Unknown	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-218	01/29/02	2002	1.60	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Well	Unknown	Unknown
CI-219	03/04/02	2002	4.00	D	Refined: Unknown	Refined: Other	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Tank	Unknown	Unknown

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-220	06/17/02	2002	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Human Error	Human Error: Unknown
CI-221	09/05/02	2002	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-222	12/12/02	2002	1.10	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Tank	Human Error, Overfill	Human Error: Overfill
CI-223	02/04/03	2003	2.00	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Onshore	Kenai Pipeline	Other	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-224	02/25/03	2003	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Other	Unknown	Unknown
CI-225	07/05/03	2003	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Unknown	Unknown	Unknown
CI-226	08/17/03	2003	15.00	C	Refined: Gasoline	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-227	10/28/04	2004	2.40	D	Crude Oil	Crude Oil	Unknown	Unknown	Offshore	Unknown	Unknown	Unknown	Unknown
CI-228	11/30/04	2004	500.00	B	Refined: Natural Gas Liquids	Refined: Natural Gas Liquids	Oil Production	Oil Production	Onshore	Beaver Creek	Tank	Human Error	Human Error: Unknown
CI-229	12/07/04	2004	1.20	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Onshore	Swanson River	Tank	Equipment Failure, Gauge/Site Glass Failure	Mechanical Failure: Other
CI-230	02/18/05	2005	70.00	C	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-231	05/02/05	2005	4.80	D	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Pipe or Line	Human Error	Human Error: Unknown
CI-232	07/12/05	2005	2.40	D	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Unknown	Unknown	Pipe or Line	Crack	Mechanical Failure: Other

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-233	07/28/05	2005	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Granite Point	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-234	12/15/05	2005	1.00	D	Refined: Asphalt	Refined: Other	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-235	01/10/06	2006	3.60	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Human Error	Human Error: Unknown
CI-236	02/08/06	2006	2.40	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-237	08/27/06	2006	2.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Human Error	Human Error: Unknown
CI-238	07/06/07	2007	5.00	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-239	07/23/07	2007	17.00	C	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Human Error	Human Error: Unknown
CI-240	09/11/07	2007	24.20	C	Refined: Diesel	Refined: Diesel	Oil Exploration	Oil Exploration	Onshore	Exploration	Well	Other	Other
CI-241	10/02/07	2007	1.30	D	Refined: Hydraulic Oil	Refined: Other	Oil Exploration	Oil Exploration	Onshore	Exploration	Hydraulic System	Unknown	Unknown
CI-242	04/16/08	2008	10.00	D	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-243	11/13/08	2008	2.00	D	Refined: Hydraulic Oil	Refined: Other	Natural Gas Production	Oil Production	Offshore	North Cook Inlet	Vehicle	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-244	05/04/09	2009	1.30	D	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Kenai Pipeline	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-245	12/19/09	2009	1.40	D	Refined: Hydraulic Oil	Refined: Other	Oil Exploration	Oil Exploration	Onshore	Exploration	Hydraulic System	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-246	03/07/10	2010	1.70	D	Refined: Natural Gas Liquids	Refined: Natural Gas Liquids	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Unknown	Unknown	Unknown
CI-247	07/20/10	2010	15.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-248	04/25/11	2011	8.30	D	Refined: Gasoline	Refined: Other	Oil Production	Oil Production	Onshore	Trading Bay	Tank	Human Error	Human Error: Unknown
CI-249	05/18/11	2011	5.20	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-250	05/18/11	2011	5.20	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-251	07/19/11	2011	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-252	01/31/12	2012	11.40	C	Refined: Diesel	Refined: Diesel	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Tank	External Factors	Other
CI-253	04/28/12	2012	1.30	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Redoubt	Drum(s)	Human Error	Human Error: Unknown
CI-254	07/11/12	2012	3.30	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Other	Other
CI-255	09/22/12	2012	4.60	D	Refined: Hydraulic Oil	Refined: Other	Natural Gas Production	Oil Production	Offshore	North Cook Inlet	Drum(s)	Human Error	Human Error: Unknown
CI-256	05/12/13	2013	1.20	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Tank	Human Error	Human Error: Unknown

CI-257	07/30/13	2013	2.60	D	Refined: Hydraulic Oil	Refined: Other	Natural Gas Production	Oil Production	Onshore	Unknown	Hydraulic System	Equipment Failure, Gauge/Site Glass Failure	Mechanical Failure: Other
CI-258	08/04/13	2013	1.80	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	West McArthur River	Tank	Equipment Failure, Gauge/Site Glass Failure	Mechanical Failure: Other
CI-259	08/11/13	2013	5.00	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Drum(s)	Human Error	Human Error: Unknown
CI-260	10/25/13	2013	2.20	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Ninilchik	Tank	Human Error	Human Error: Unknown
CI-261	04/17/14	2014	25.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Other	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
CI-262	04/27/14	2014	4.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Other	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-263	06/14/14	2014	1.70	D	Refined: Lube/Gear Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Human Error	Human Error: Unknown
CI-264	06/20/14	2014	40.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Human Error	Human Error: Unknown
CI-265	07/15/14	2014	2.40	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Human Error	Human Error: Unknown
CI-266	02/13/15	2015	9.50	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-267	03/06/15	2015	1.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Pipe or Line	Equipment Failure, Valve Failure	Mechanical Failure: Valve/Seal
ID	**Date**	**Year**	**Size (bbl)**	**Size Class**	**Sub-stance**	**Consolidated Substance**	**Facility Type**	**Consolidated Facility Type**	**Location**	**Oil Field / Infra-structure**	**Source**	**Cause**	**Consolidated Cause**

ID	Date	Year	Size (bbl)	Size Class	Sub-stance	Consolidated Substance	Facility Type	Consolidated Facility Type	Location	Oil Field / Infra-structure	Source	Cause	Consolidated Cause
CI-268	03/06/15	2015	1.40	D	Refined: Natural Gas Liquids	Refined: Natural Gas Liquids	Oil Production	Oil Production	Onshore	West McArthur River	Pipe or Line	Human Error	Human Error: Unknown
CI-269	03/15/15	2015	11.90	C	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Kenai Gas	Tank	Human Error	Human Error: Unknown
CI-270	08/23/15	2015	4.80	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-271	09/12/15	2015	15.00	C	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-272	06/06/16	2016	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	West McArthur River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-273	11/19/16	2016	490.00	B	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	North Cook Inlet	Pipe or Line	Unknown	Unknown
CI-274	12/19/16	2016	1.50	D	Crude Oil	Crude Oil	Natural Gas Production	Oil Production	Onshore	North Cook Inlet	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-275	12/26/16	2016	1.50	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Equipment Failure, Unknown	Mechanical Failure: Unknown
CI-276	01/04/17	2017	4.00	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Cosmopoli tan	Pipe or Line	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-277	01/25/17	2017	1.50	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Equipment Failure, Seal Failure	Mechanical Failure: Valve/Seal
CI-278	01/29/17	2017	1.30	D	Refined: Hydraulic Oil	Refined: Other	Oil Production	Oil Production	Offshore	Trading Bay	Hydraulic System	Equipment Failure, Unknown	Mechanical Failure: Unknown

CI-279	03/03/17	2017	1.20	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Offshore	Trading Bay	Pipe or Line	Corrosion	Mechanical Failure: Corrosion
CI-280	01/24/18	2018	10.50	C	Refined: Diesel	Refined: Diesel	Oil Production	Oil Production	Offshore	Granite Point	Tank	Human Error	Human Error: Unknown
CI-281	03/04/19	2019	2.70	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Cosmopoli tan	Tank	Human Error, Overfill	Human Error: Overfill
CI-282	04/15/19	2019	5.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Middle Ground Shoals	Pipe or Line	Unknown	Unknown
CI-283	05/23/19	2019	1.20	D	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Unknown	Unknown	Unknown
CI-284	05/28/19	2019	2.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Unknown	Well	Unknown	Unknown
CI-285	07/17/19	2019	2.40	D	Refined: Diesel	Refined: Diesel	Natural Gas Production	Oil Production	Onshore	Beluga River	Vehicle	Human Error	Human Error: Unknown
CI-286	08/03/19	2019	7.20	D	Crude Oil	Crude Oil	Crude Oil Terminal	Oil Production	Onshore	Cook Inlet Pipeline	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other
CI-287	08/08/19	2019	1.20	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Well	Unknown	Unknown
CI-288	08/13/19	2019	2.40	D	Refined: Unknown	Refined: Other	Oil Production	Oil Production	Onshore	Swanson River	Well	Unknown	Unknown
CI-289	10/01/19	2019	7.10	D	Refined: Diesel	Refined: Diesel	Support Dock	Support Facility/ Services	Onshore	Support Services	Unknown	Other	Other
CI-290	10/20/19	2019	3.00	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Trading Bay	Pipe or Line	Human Error	Human Error: Unknown
CI-291	12/27/19	2019	1.40	D	Crude Oil	Crude Oil	Oil Production	Oil Production	Onshore	Swanson River	Pipe or Line	Equipment Failure, Line Failure	Mechanical Failure: Other

Appendix B: Exposure Variable Datasets

Table B-1. Cook Inlet in-scope pipeline miles, 1960-2019

Years	Pipeline Miles	Years	Pipeline Miles	Years	Pipeline Miles
1960	18.8	**1980**	286.3	**2001**	315.1
1961	18.8	**1981**	286.3	**2002**	327.9
1962	18.8	**1982**	286.3	**2003**	327.9
1963	18.8	**1983**	286.3	**2004**	327.9
1964	18.8	**1984**	286.3	**2005**	327.9
1965	41.5	**1985**	286.3	**2006**	332.7
1966	162.3	**1986**	305.7	**2007**	332.7
1967	214.9	**1987**	305.7	**2008**	332.7
1968	249.3	**1988**	305.7	**2009**	332.7
1969	249.3	**1989**	305.7	**2010**	332.7
1970	249.3	**1990**	305.7	**2011**	332.7
1971	271.0	**1991**	305.7	**2012**	332.7
1972	275.7	**1992**	305.7	**2013**	332.7
1973	275.7	**1993**	305.7	**2014**	332.7
1974	286.3	**1994**	305.7	**2015**	348.7
1975	286.3	**1995**	305.7	**2016**	348.7
1976	286.3	**1996**	305.7	**2017**	348.7
1977	286.3	**1997**	305.7	**2018**	352.2
1978	286.3	**1998**	305.7	**2019**	352.2
1979	286.3	**1999**	313.5		
1960	18.8	**2000**	315.1		

Table B-2. Adjusted Alaska North Slope crude oil pricing, 1996-2019

Years	Price (millions of dollars)	Adjusted Price (millions of dollars)
1996	15.3341667	25.2046933
1997	14.7825	23.7598552
1998	8.45	13.3809404
1999	12.6283333	19.5068096
2000	23.6733333	35.4538201
2001	18.1841667	26.5014464
2002	19.3733333	27.764764
2003	23.77	33.341524
2004	33.1366667	45.2175597
2005	47.3116667	62.4392979
2006	56.9691667	72.8873095
2007	63.7991667	79.232205
2008	91.235	108.957409
2009	54.8366667	65.8183551
2010	72.1683333	85.3736891
2011	98.4725	112.942437
2012	98.345	110.527222
2013	95.8433333	106.124652
2014	86.4525	94.1685876
2015	41.3433333	44.9985385
2016	33.2575	35.710172
2017	44.9358333	42.7021524
2018	62.575	60.9194094
2019	57.27	56.7592687

Table B-3. Cook Inlet gas production per year, 1958-2019

Years	Oil (bbl)	Gas (mcf)	Water (bbl)	Years	Oil (bbl)	Gas (mcf)	Water (bbl)
1958				**1989**	-	194,090,185	143,159
1959				**1990**	-	203,987,009	309,117
1960	-	37,739	-	**1991**	-	197,336,158	242,486
1961	-	214,718	-	**1992**	-	198,799,256	224,546
1962	-	1,642,495	-	**1993**	-	189,891,574	99,059
1963	-	8,002,308	-	**1994**	321	180,287,182	162,780
1964	-	8,631,569	-	**1995**	162	179,190,365	140,882
1965	-	8,312,234	-	**1996**	15	183,440,890	54,262
1966	-	34,396,154	-	**1997**	-	179,233,348	59,061
1967	-	40,005,807	-	**1998**	-	182,656,508	98,506
1968	-	48,641,633	-	**1999**	-	177,223,490	119,999
1969	2,497	76,054,167	-	**2000**	-	181,124,159	180,590
1970	2,229	130,474,114	-	**2001**	-	193,920,605	177,204
1971	1,119	125,267,279	-	**2002**	-	192,827,922	243,356
1972	1,799	126,212,038	3,014	**2003**	-	195,636,474	506,737
1973	1,036	123,954,869	2,800	**2004**	-	202,128,978	504,379
1974	331	125,242,246	2,960	**2005**	-	205,829,839	829,280
1975	877	138,109,178	2,903	**2006**	-	191,166,300	1,051,776
1976	547	142,903,238	2,664	**2007**	1	162,804,610	711,470
1977	430	150,351,112	3,208	**2008**	-	146,119,376	970,955
1978	625	166,275,131	5,508	**2009**	-	133,896,300	886,289
1979	383	172,308,231	3,826	**2010**	-	120,989,397	834,278
1980	-	165,698,798	320,914	**2011**	-	111,335,111	1,006,790
1981	-	180,472,551	14,479	**2012**	-	106,928,394	1,018,633
1982	-	189,586,171	51,652	**2013**	431	90,612,468	1,367,908
1983	-	196,212,558	47,204	**2014**	338	103,259,917	1,769,975
1984	-	197,290,321	44,914	**2015**	638	96,321,416	1,964,557
1985	-	204,257,471	67,252	**2016**	919	83,966,916	1,524,551
1986	-	180,707,429	92,728	**2017**	1,017	81,938,839	1,262,904
1987	-	184,662,427	229,360	**2018**	311	70,891,456	1,358,333
1988	-	185,554,958	202,303	**2019**	297	64,177,324	1,269,635

Table B-4. Cook Inlet oil production per year, 1958-2019

Years	Oil (bbl)	Gas (mcf)	Water (bbl)	Years	Oil (bbl)	Gas (mcf)	Water (bbl)
1958	35,754	5,643	283	1989	15,366,389	112,082,370	38,712,597
1959	186,590	27,296	33,422	1990	11,147,416	107,531,650	30,576,153
1960	557,999	99,176	11,508	1991	15,339,764	110,643,489	50,367,108
1961	6,326,501	1,293,259	158,415	1992	15,179,279	110,273,127	50,439,615
1962	10,259,110	1,914,055	294,133	1993	13,853,287	103,666,218	47,117,253
1963	10,739,964	2,808,007	458,781	1994	15,561,658	130,892,139	50,615,808
1964	11,053,872	3,233,232	1,253,159	1995	15,514,208	108,387,133	52,898,991
1965	11,131,271	3,842,367	1,683,426	1996	14,586,281	82,372,508	51,820,943
1966	14,364,432	6,822,597	2,114,821	1997	12,143,488	58,638,705	50,874,675
1967	28,913,488	22,587,317	2,467,556	1998	11,801,635	43,381,126	49,768,194
1968	66,145,673	51,210,051	3,246,604	1999	10,917,841	43,122,262	50,427,705
1969	74,037,841	71,489,063	4,099,504	2000	10,718,184	37,860,296	51,639,919
1970	82,414,675	87,889,247	6,370,585	2001	11,497,190	35,916,321	48,615,772
1971	77,628,053	104,298,296	9,341,630	2002	11,283,636	18,030,781	49,449,635
1972	72,639,686	98,434,976	11,248,886	2003	10,078,643	11,688,052	48,892,890
1973	72,195,717	101,280,794	14,929,151	2004	8,207,600	6,355,064	44,633,568
1974	70,073,989	104,574,885	17,065,332	2005	7,074,882	4,553,700	42,039,178
1975	69,110,608	114,444,540	19,210,229	2006	6,228,885	3,436,591	40,260,914
1976	62,404,340	123,747,811	20,981,345	2007	5,486,978	3,140,799	37,882,256
1977	56,095,147	129,603,409	24,511,389	2008	4,769,533	2,893,736	37,451,687
1978	50,131,629	127,525,293	25,402,876	2009	2,740,653	1,874,874	22,121,676
1979	43,044,992	132,754,714	28,241,973	2010	3,739,107	2,404,347	32,982,194
1980	36,246,519	134,230,280	32,258,740	2011	3,885,271	2,444,354	33,427,551
1981	31,075,237	118,565,482	30,910,087	2012	4,023,894	2,749,154	32,012,876
1982	27,411,153	119,534,948	29,861,736	2013	5,333,534	5,008,934	37,103,404
1983	24,762,908	109,838,396	28,101,256	2014	6,245,120	6,358,641	48,404,657
1984	21,983,532	108,130,486	30,402,206	2015	6,527,364	6,680,749	52,491,029
1985	16,944,201	101,661,216	26,845,812	2016	5,628,097	7,023,563	49,746,162
1986	17,580,258	104,166,508	32,861,957	2017	5,239,268	9,213,871	47,768,469
1987	16,190,722	91,651,657	32,887,027	2018	5,606,516	12,218,500	50,143,706
1988	15,715,951	110,729,879	34,254,187	2019	5,210,591	15,339,901	47,131,088

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).