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Update of Occurrence Rates for Offshore Oil Spills

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Abstract

Estimates of occurrence rates for offshore oil spills are useful for analyzing potential oil-spill impacts and for oil-spill response contingency planning. With the implementation of the Oil Pollution Act of 1990 (U.S. Public Law 101-380, August 18, 1990), estimates of oil-spill occurrence became even more important to natural resource trustees and to responsible parties involved in oil and gas activities.

Oil-spill occurrence rate estimates have been updated based on U.S. Outer Continental Shelf (OCS) Platform and Pipeline Spill Data (1964 through 2010), Worldwide Tanker Spill Data (1974 through 2008), and Barge Spill Data for U.S. waters (1974 through 2008). These oil-spill occurrence rates ("spill rates") are expressed and normalized in terms of the number of spills per volume of crude oil handled. All estimates of spill rates were restricted to spills ≥1,000 barrels (159 m^3, 159 kiloliters, 136 metric tonnes, 42,000 U.S. gallons). Spill rates for spills ≥ 1,000 include spill rates for spills of ≥ 10,000 barrels and ≥ 100,000 barrels.

Updated spill rates for spills ≥ 1,000 barrels (bbl) and ≥ 10,000 bbl, compared to the previously published rates calculated through 1999 (Anderson and LaBelle, 2000), indicate:

- *Spill rates for OCS platforms were unchanged for spills ≥1,000 bbl at 0.32 spills per billion barrels (Bbbl), but improved from 0.12 to 0.06 spills per Bbbl for spills ≥10,000 bbl when examined over the entire record (1964 through 2010) and adjusted for a trend.*

- *When comparing the most recent 15-years data (1996 through 2010 data) to the last 15-years data in the previous analysis (Anderson and LaBelle 2000: 1985 through 1999 data) spill rates increased from 0.13 to 0.25 spills per Bbbl for spills ≥1,000 bbl; and increased from 0.05 to 0.13 spills per Bbbl for spills ≥10,000 bbl. These rates are still relatively low and include a spill from Hurricane Rita (2005) and the Macondo well spill in 2010. Prior to these two spills, the last OCS Platform spill ≥1,000 bbl occurred in 1980, and the last OCS Platform spill ≥10,000 bbl occurred in 1970. The most recent 15-year period spans the move of oil production into deepwater with deepwater Gulf of Mexico OCS oil production increasing from 20% of the total U.S, crude oil production in 1996 to 81% of the total in 2010.*

- *Spill rates for OCS pipelines declined from 1.33 to 0 .94 spills per Bbbl over the entire record (1964 through 2010) for spills ≥1,000 bbl when adjusted for a trend, and from 0.33 to 0.19 spills per Bbbl for spills ≥ 10,000 bbl. When examining the record over the last 15 years (1996 through 2010), the rates dropped from*

1.38 to 0.88 for spills ≥ 1,000 bbl and from 0.34 to 0.18 spills per Bbbl for spills ≥ 10,000 bbl.

- *All tanker spill rates continued the substantial declines noted in the last review (Anderson and LaBelle, 2000). Most likely, tanker spills have declined due to major regulatory changes in the early 1990's that substantially eliminated the use of single-hull tankers by requiring double hulls or their equivalent.*

- *Spill volumes for spills from OCS platforms were also updated to include the average and median spill sizes for (a) the entire record from 1964 through 2009 and 2010, (b) the period 1995 through 2009 and (c) the period from 1996 to 2010. Two ending dates are shown to demonstrate the influence of the extreme volume of the 2010 Macondo well spill.*

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ABBREVIATIONS AND ACRONYMS LIST

ANS	Alaska North Slope
bbl	Barrel or barrels; Barrel (42 U.S. gallons, 0.159 kiloliters, 0.159 m^3, or 0.136 metric tonnes)
Bbbl	Billion barrels, 10^9 bbl or 1,000,000,000 bbl.
Billion	10^9 as used in the U.S. and Canada; not 10^{12}, as used in Europe
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
COE	U.S. Army Corps of Engineers
DOC	Department of Commerce
DOI	Department of the Interior
EIS	Environmental Impact Statement
IMO	International Maritime Organization
MMbbl	Millions of barrels
MMS	Minerals Management Service
NEPA	National Environmental Policy Act
OCS	Outer Continental Shelf
ONRR	Office of Natural Resource Revenue
OPA 90	Oil Spill Pollution Act of 1990
OSRA	Oil Spill Risk Analysis
OSRP	Oil Spill Response Plans
TAPS	Trans-Alaska Pipeline System
USCG	U.S. Coast Guard
VPBS	volume (of oil) produced between spills

1.0 INTRODUCTION

The purpose of this report is to document the updated oil-spill occurrence rate estimates used in reports generated by the Bureau of Ocean Energy Management (BOEM). This report describes the data used, the methodology applied, and the results achieved to prepare these estimates.

1.1 Overview of Report

This report is organized as follows:

- Section 1. Introduction
- Section 2. Methods and Assumptions
- Section 3. Analysis of Spill Occurrence Data and Oil Handled
- Section 4. Spill Rate Trend Analysis
- Section 5. Results: Estimated Spill Rates
- Section 6. Historic, Average, and Median Spill Sizes
- Section 7. Discussion and Conclusions

Also included are Sections 8 (Acknowledgments), 9 (References) and three appendices. Appendix A covers statistical tests conducted on the data. Appendix B presents sample calculations on estimated spill occurrence probabilities as calculated from spill rates. Appendix C details historic spill sizes and spill numbers and discusses spills associated with hurricane damage. These have been included to provide the reader with background information for those seeking further detail.

1.2 Background

BOEM is charged with management of oil and gas development on the Outer Continental Shelf in an environmentally and economically sound manner. The U.S. Outer Continental Shelf (OCS) as defined by the Federal government consists of the submerged lands, subsoil, and seabed, lying between the seaward extent of the States' jurisdiction and the seaward extent of Federal jurisdiction. Federal jurisdiction is defined under accepted principles of international law. Generally, the OCS begins 3-9 nautical miles from shore (depending on the state) and extends 200 nautical miles outward or farther if the continental shelf extends beyond 200 nautical miles (http://www.bsee.gov/Priority-Pages/Outer-Continental-Shelf-(OCS)-Jurisdiction.aspx). As part of the responsibility to manage the OCS, BOEM conducts modeling of oil-spill trajectories to identify areas that may be impacted by a spill, should a spill occur in a given area. The oil-spill modeling outputs are used in preparation of National Environmental Policy Act (NEPA) documents such as Environmental Impact Statements (EISs) and Environmental Assessments (EAs). The data from this current report are used by BOEM in both the oil-spill modeling and in the EIS preparation. This section provides additional detail on each of these points.

1.2.1 Bureau of Ocean Energy Management Responsibilities

On October 1, 2011, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), was replaced by the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) as part of a major reorganization. BOEM is responsible for managing environmentally and economically responsible development of the nation's offshore resources. Its functions include offshore leasing, resource evaluation, review and administration of plans for oil and gas exploration, development, and production, renewable energy development, NEPA analysis, and environmental studies (http://www.boem.gov/). BSEE is responsible for safety and environmental oversight of offshore oil and gas operations, including permitting and inspections of offshore oil and gas operations. Its functions include the development and enforcement of safety and environmental regulations, permitting offshore exploration, development and production, inspections, offshore regulatory programs, oil spill response, and training and environmental compliance programs (http://www.bsee.gov/).

1.2.2 BOEM Oil-Spill Modeling Program

BOEM assesses oil-spill risks associated with offshore energy activities off the U.S. continental coast and Alaska by calculating oil-spill trajectories and contact probabilities through the BOEM Oil Spill Modeling Program http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill.aspx. The BOEM Oil-Spill Risk Analysis (OSRA) model combines the probability of spill occurrence with a statistical description of hypothetical oil-spill movement on the ocean surface. The OSRA model was initially developed in 1975 by the Department of the Interior (DOI) as a tool to evaluate offshore oil-spill risks (Smith *et al.*, 1982; LaBelle and Anderson, 1985; Ji *et al.,* 2011).

1.2.3 Applications of OSRA

The major use of OSRA estimates is in support of OCS Lease Sale NEPA documents. BOEM is committed to the continuous improvement of OSRA estimates and NEPA analysis, and BOEM uses the results of new ocean, ice, and meteorology field and modeling studies to fulfill that commitment. As offshore activity expands into deeper waters and new geographic areas, BOEM oil-spill modeling will be used in pertinent NEPA assessments and validated with environmental observations.

Modeling results are used by:

- BOEM staff for preparation of environmental documents in accordance with NEPA (http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/NEPA/Index.aspx)
- Other Federal and State agencies for review of EISs
- Environmental assessments
- Endangered species and essential fish habitat consultations

- Oil industry specialists for preparation of oil spill response plans (OSRP) http://www.bsee.gov/About-BSEE/index.aspx.
- BSEE in oil spill planning and preparedness

It should be recognized that the OSRA was developed to address a need for a long-term, stochastic approach to estimate risk over decades for programmatic analyses. It is not a real-time spill response tool, although features and inputs to the model may be applicable for those uses as well.

1.2.4 Need for Oil-Spill Occurrence Rate Estimation Methodology

A realistic, objective methodology for estimating oil-spill occurrence rates is required for the OSRA model's application. The estimated mean number of spills is used in conjunction with the Poisson distribution (as described in Section 2.4) to estimate the probability of spill occurrence. BSEE developed and maintains oil-spill databases on all Outer Continental Shelf (OCS) spills, tanker spills in U.S. and worldwide waters, and barge spills in U.S. waters which are used to support these estimations (Lanfear and Amstutz, 1983; Anderson and LaBelle, 1990, 1994, 2000). This report updates the work of Anderson and LaBelle (2000).

2.0 METHODS AND ASSUMPTIONS

Many factors can affect the likelihood of an oil spill occurring over the 15- to 40-year life typically associated with lease sale activities: timing of exploration, development, and production; volume of production; type and location of drilling rigs; mode of product transportation and loading; weather and other external factors. Such data limitations preclude using elaborate spill-prediction techniques.
http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill-Occurence-Rate-for-Oil-Spill-Risk-Analysis-(OSRA).aspx

This report presents a simple approach for estimating oil spill occurrence normalized as a function of the volume of oil handled, where "handled" is defined for OCS platforms and pipelines as petroleum produced from OCS platforms, and "handled" is defined for tankers and barges as petroleum transported. The method used in revising oil spill occurrence rates involved three basic steps:

1. Data on historical spill occurrences and on volume of oil handled were examined.
2. Volume was chosen as the exposure variable.
3. Spill occurrence rates were estimated and normalized based on number of spills per volume handled.

The estimated mean number of spill occurrence is used with the Poisson distribution to estimate the probability of spill occurrence. Oil spill occurrence rates (hereafter referred to simply as "spill rates") were calculated for: OCS platforms, OCS pipelines, Worldwide, U.S., and Alaska North Slope tankers, and U.S. barges.

2.1 Data on Historical Spill Occurrences

This section addresses the following aspects of the data on oil spill occurrence:

- Sources of oil spill occurrence data
- Availability of historic oil spill records
- Spill data details

2.1.1 Sources of Oil-Spill Occurrence Data

BSEE maintains oil-spill databases on all U.S. Outer Continental Shelf spills, tanker spills worldwide, and barge spills in U.S. waters. BSEE collects information from many sources to maintain this database. Information on worldwide tanker spills comes from a number of international and foreign sources. Information on tanker spills and barge spills in U.S. waters is collected by the United States Coast Guard (USCG). Data on spills from pipelines and platforms on the OCS is collected under BSEE regulatory authority from the lessees. In the U.S., spills of oil and hazardous substances are also reported to the National Response Center.

2.1.2 Historic Spill Records

BSEE requires that all OCS oil spills ≥ 1 bbl be reported to the Bureau. Oil spills of any size are required to be reported to the National Response Center. Preliminary information from ongoing OCS spill investigations can also be made available to BSEE for analyses. BSEE maintains a database on spills of all sizes of crude oil and "petroleum," which includes crude oil and petroleum products. Spill data from 1964 through 2010 were utilized for the OCS pipeline and platform spill data presented in this update.

Spill data from 1974 through 2008 was utilized for tanker spills, worldwide tankers, and barges in U.S. waters. Spills from tankers in U.S. waters are a subset of worldwide tanker spills, as are the Alaska North Slope (ANS) tanker fleet's spills. The record on the ANS fleet does not begin until 1977, when this fleet began transporting oil from Valdez, AK.

Prior to 1973, international oil spill occurrences were recorded on an irregular basis; more stringent reporting requirements were introduced in 1973 (Intergovernmental Maritime Consultative Organization International Convention for the Prevention of Pollution from Ships, 1973; Federal Water Pollution Control Act, U.S. Public Law 92-500, October 18, 1972; amended by U.S. Public Law 93-207, December 28, 1973).

For tanker and barge spill data, there is generally a time lag in their availability. For spills ≥1,000 bbl, spill investigations frequently take a year or more to complete, especially since spill volumes are generally used to calculate monetary penalties. Responsible parties worldwide are reluctant to share spill data; they generally report the minimum information required to the relevant governing authorities (which may share some or none of the information with the outside world). The USCG, the reporting authority for tanker and barge spills in US waters, typically withholds data on spills until their investigation is complete.

Although there are reporting regulations for spills in international waters, public availability of this spill information is delayed and of inconsistent quality. It generally requires significant manpower and other costs to collect comprehensive worldwide tanker spill data.

For the reasons cited above, data on barge and tanker spills analyzed in this report (through 2008) were the data available during the initial drafting of the report.

2.1.3 Spill Data Details

The types of data that are reported about spills vary by source, but the data generally include information on the spill substance, size, source, and location. In this report the data are reported in categories, as listed below:

- **Spilled substances:**
  1) The term petroleum is used for platform and pipeline spills and includes crude oil and condensate. For platform spills, the term petroleum also includes diesel fuel because in the past, a few spills of diesel fuel from platforms have occurred as a result of hurricane damage. These spills are counted in this study;
  2) Spills from tankers (worldwide, U.S. and those carrying Alaska North slope production) involve the spillage of crude oil, and so term 'crude oil' is used for tanker spills in this study;
  3) Barge spills (U.S. waters) involve spills of both crude oil and other petroleum products (gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, lubricating oils and greases, naphtha, petroleum solvents, asphalt, tar and pitches, and liquefied gases) and data on both types of spills are available. Therefore, both the terms crude oil and petroleum are used for barge spills in this study.

- **Spill sizes**: Three sizes of spills are analyzed: ≥1,000 bbl and ≥10,000 bbl (for all spill sources) and ≥100,000 bbl (for worldwide tankers). The focus of this report is on large spills that are ≥1,000 bbl, because spills smaller than that may not persist long enough to be simulated by trajectory modeling. Another consideration is that a large spill is more likely to be identified and reported; therefore, these historic large spill records are generally more comprehensive than those of smaller spills. Smaller spills are addressed in BOEM's environmental analyses without the use of trajectory modeling. Appendix C presents data on all OCS oil spills regardless of size. It should be noted that spills ≥ 10,000 bbl and ≥100,000 bbl are subsets of the spill rate for spills ≥ 1,000 bbl.

- **Spill Sources**: Six basic sources of spills are evaluated in this report
  - OCS platforms
  - OCS pipelines
  - Worldwide tankers, coastal and offshore waters

- Tankers in U.S. coastal and offshore waters
- Tankers and/or U.S. flagships carrying Alaska North Slope crude
- Barges in U.S. coastal, offshore, and inland waters

In this report, OCS platform spills include spills related to operations at both drilling rigs and production platforms.

2.2. Selection of the Exposure Variable

Two basic criteria were used in selecting the exposure variable: the exposure variable should be simple to define, and it should be a quantity that can be estimated. The volume of oil handled was chosen as the exposure variable primarily for the following reasons:

- ❖ Historic data on the volume of OCS oil handled, and associated oil spills, is recorded and maintained by DOI, Office of Natural Resource Revenue (ONRR). Using these volumes makes the calculation of the estimated oil-spill occurrence rate simple—the ratio of the number of historic spills to the volume of oil handled. Oil volume exposures for tanker rates were also based on comprehensively maintained data series from: COE (Waterborne Commerce) for tankers in U.S. waters; DOC (ANS loadings) for ANS tankers; and British Petroleum (Statistical Review of World Energy - world crude oil imports) for tankers worldwide.

- ❖ Estimates of future OCS oil production are scientifically estimated by the BOEM Resource Evaluation Program. The estimates of future oil production are multiplied by the oil-spill occurrence rates to estimate the mean number of spills likely to occur as the result of that volume of production.

For this report, volume is reported in bbl to assist policy and decision makers in government and industry. Based on average Arabian light crude oil (35.5° American Petroleum Institute (API) gravity), 1 bbl is equal to the following: 0.159 kiloliters, 0.159 m^3, 0.136 metric tonnes, and 42 U.S. gallons.

2.3 Spill Rate Definition

Estimated occurrence rates for oil spills (spill rates) are based on historic spill occurrences and the associated volume of oil produced and transported. Spill rates are expressed in terms of the estimated mean number of spills per billion barrels (Bbbl) of oil handled. Bbbl is defined as 10^9 bbl or 1,000,000,000 bbl. In other words, for this report, a 'billion' is 10^9, as commonly used in the United States and Canada (not 10^{12}, which the term 'billion' represents in Europe).

A spill rate is an estimate of the mean number of spills of a given size range that is likely to occur over a uniform volume of oil handled. Spill rates for spills ≥1,000 bbl include spills ≥10,000 bbl and ≥ 100,000 bbl.

For each spill source analyzed, spill occurrence rates are estimated for spills ≥1,000 bbl and spills ≥10,000 bbl; additionally, spill occurrence rates are estimated for worldwide tanker spills ≥100,000 bbl, because the average tanker spill size is 118,000 bbl.

2.4 Poisson Distribution Discussion

This section considers whether oil-spill occurrence is a Poisson process, and presents equations used in BOEM's estimation of spill rates.

2.4 .1 Requirements for Poisson Distribution for Estimating Oil-Spill Occurrence

Spill occurrence has been modeled previously as a Poisson process (Smith *et al.*, 1982; Lanfear and Amstutz, 1983; Anderson and LaBelle, 1990, 1994, 2000). These references can be found at http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill-Occurence-Rate-for-Oil-Spill-Risk-Analysis-(OSRA).aspx.

A stochastic process, $N(t)$, is a counting process, if $N(t)$ represents the total number of events that have occurred up to time t. To determine if the counting process of spill occurrence is a Poisson process, with t = the volume of oil handled as the exposure variable instead of time, and where λ is the true rate of spill occurrence per unit exposure, the occurrence of spills must meet the following three criteria (Ross, 1985):

(a) $N(0)$ must equal zero with a probability equal to 1.

(b) The process must have independent increments (i.e., the number of spill occurrences for any given interval does not depend on the previous or following intervals).

(c) The number of events in any interval of length t must be Poisson distributed with a mean of λt (i.e., this process must have stationary increments where the number of spills that occur in any interval depends only on the length of the interval).

These criteria have been met since:

(a) No spills can occur when no (0 bbl) oil is handled.

(b) Analysis of the record indicates that individual spill events are independent of previous spill events over time and are independent of volume of oil handled.

(c) In the situation where the data indicated that there was a decrease in the frequency of spill events over time and production, a sensitivity analysis was performed to identify where the increments became relatively stationary. The spill rate was then calculated from that point forward. For a more detailed discussion, see Appendix A.

2.4.2 Poisson Equation Used in Spill Rate Estimations

Because spill occurrences meet the criteria for a Poisson process, the following equations were used in our estimation of spill rates. The estimated volume of oil handled is the exposure variable. Smith *et al.* (1982), using Bayesian inference techniques, presented a derivation of this process, assuming the probability of *n* spills over some future exposure *t* (the volume of oil handled) is expected to occur at random with a frequency specified by equation (1):

$$P[n \text{ spills over future exposure } t] = \frac{(\lambda t)^n e^{-\lambda t}}{n!} \qquad (1)$$

where λ is the true rate of spill occurrence per unit exposure.

The predicted probability takes the form of a negative binomial distribution specified by equation (2):

$$P(n) = \frac{(n + v - 1)!\, t^n \tau^v}{n!(v - 1)!(t + \tau)^{n + v}} \qquad (2)$$

where τ is past exposure and *v* is the number of spills observed in the past. The negative binomial is then shown to converge over time to the Poisson, with λ estimated using equation (3) (Smith *et al.*, 1982):

$$\lambda = v/\tau \qquad (3)$$

where λ is the spill occurrence rate, *v* is the number of spills (crude oil or refined) that occurred over the volume of crude oil (τ) handled (in our case, in units of Bbbl).

Since spill occurrence probabilities are used in public policymaking, a sample calculation of spill occurrence probability is presented in Appendix B.

3.0 ANALYSIS OF SPILL OCCURRENCE DATA AND OIL HANDLED

Historic oil-spill occurrences ≥1,000 bbl and the volume in Bbbl (Bbbl = 10^9 bbl) of associated oil handled were analyzed for the following types of spills:

- Petroleum spills from OCS platforms
- Petroleum spills from OCS pipelines
- Crude oil spills from tankers worldwide in coastal and offshore waters
- Crude oil spills from tankers in US coastal and offshore waters
- Alaska North Slope crude oil spills from U.S. tankers
- Crude oil and petroleum spills from barges in US coastal, inland, and offshore waters.

In this report, the term "handled" means produced from OCS platforms or OCS pipelines, or transported via tankers and barges.

3.1 Petroleum Spills from OCS Platforms and Pipelines

From1964 through 2009, 17.5 Bbbl of oil were produced and < 570,000 bbl spilled. The spill record improved over this time period. Barrels of oil spilled per Bbbl of crude oil produced declined from more than 255,000 bbl (1964 through 1970), to about 17,000 bbl (1971 through 1990), to approximately 6,400 (1991 through 2009) bbl spilled per Bbbl crude oil produced (Table 1). This improvement is also illustrated by the increase in the volume of production per bbl of oil spilled over the same time periods (Table 1).

These improvements were largely due to the decreasing size of larger spills. From1964 through 2009, the maximum size of OCS spills≥ 1,000 bbl declined. Early in this time period (from1964 through 1970) there were 10 spills ≥ 1,000 bbl, the two largest of which were: a 160,000 bbl pipeline spill in the Gulf of Mexico in 1967 and an 80,000 bbl platform spill off Santa Barbara, CA in 1969. The largest spill that occurred from 1971 through 1990 was a pipeline spill of almost 20,000 bbl in 1974. From1991 through 2005, the largest spills were an 8,200 pipeline spill caused by Hurricane Georges in 1998 and a platform spill of almost 5,100 bbl in 2005 caused by Hurricane Rita. From 2006 through 2009, the largest spill was a 1,500 bbl pipeline spill in 2009 (Table 2).

This pattern of the largest spills decreasing in size continued from 1964 through early 2010, a period of over 45 years. In 2010, the improvements seen in the spill record were broken by the Macondo well spill in the Gulf of Mexico, with an estimated volume of 4.9 million barrels.[1] The Macondo well spill was a complete loss of well control. This was the first uncontrolled deepwater blowout to occur on the OCS and it continued for 87 days.

From 1964 through 2010, there have been 33 spills ≥ 1,000 bbl from OCS platforms and pipelines. Thirteen of these spills were related to OCS platforms (Fig. 1; Table 3). Historically, most of the spills of this size have been crude oil or condensate but the two diesel spills ≥1,000 bbl associated with platforms are also included. Causes of the platform spills include: blowouts and other losses of well control; collisions; fuel transfer mishaps, damaged, lost or failed tanks including storage barges; and hurricane-related damage.

This report evaluates the number of production intervals between spill events. From 1964 through 2010, there were three platform spills ≥1,000 bbl during Hurricane Hilda in 1964, and three platform spills ≥ 1,000 bbl during Hurricane Rita in 2005. Since there is no production between spills during a hurricane, the sum of the three platform spill volumes was treated as a single spill event (Table 3). Hurricane-related spills are detailed in Appendix C.

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[1] This analysis assumes the volume of oil released from this incident was 4.9 million bbl, the volume utilized in: "Oil Budget Calculator: Deepwater Horizon Technical Documentation", November 2010, Report by The Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team http://www.noaanews.noaa.gov/stories2010/PDFs/OilBudgetCalc_Full_HQ-Print_111110.pdf This spill volume may be revised in the future based on additional studies.

Table 1. OCS Petroleum Spills ≥ 1 Barrel and OCS Production, 1964 through 2009

Year	Barrels Spilled per Bbbl Produced	Barrels Produced per Barrel Spilled	Production (Billion barrels) Barrels	Barrels Spilled by Spill Size			Number of Spills by Spill Size		
				Total	1 - 999 bbl	≥ 1,000 bbl	Total	1 - 999 bbl	≥ 1,000 bbl
1964-1970[1]	255,280	3,917	1.54	394,285	3,499	390,786	33	23	10
1971-1990[1]	16,682	59,945	6.79	113,307	21,415	91,892	1,921	1,909	12
1991-2009[1]	6,427	155,601	9.20	59,142	28,144	30,998	853	843	10
Total[2]	32,329	30,932	17.53	566,734	53,058	513,676	2,807	2,775	32

[1] Spill data for 1964-1970 is for spills ≥ 50 bbl. Spill data for spills ≥ 1 bbl begins in 1970 but is more robust starting in 1971.

[2] Barrels of production or spillage may not add due to rounding of decimals not shown

Sources: U.S. DOI/BOEMRE OCS Spill Database, May 2011; U.S. DOI/ONRR OCS Production Data, May 2011 (http://www.boemre.gov/stats/OCSproduction.htm)

Table 2. Number of OCS Petroleum Spills ≥ 1,000 Barrels, 1964 through 2010

Year	Barrels[1] Spilled	Number Spills	Number of Spills by Spill Size in Barrels[1]							
			1,000-1,999	2,000-4,999	5,000-9,999	10,000-19,999	20,000-49,999	50,000-149,999	150,000-199,000	200,000 or more
1964-1970	390,786	10	1	2	2	1	0	3	1	0
1971-1990	91,892	12	2	3	4	3	0	0	0	0
1991-2005	28,182	8	2	4	2	0	0	0	0	0
2006-2009	2,816	2	2	0	0	0	0	0	0	0
2010	4,900,000	1	0	0	0	0	0	0	0	1
Total	5,413,676	33	7	9	8	4	0	3	1	1

[1] Barrel = 42 U.S. Gallons

Source: U.S. DOI/BOEMRE OCS Spill Database, May 2011

Twenty of the 33 spills ≥1,000 bbl that occurred from 1964 through 2010 were related to leaking or damaged OCS pipelines (Fig. 1, Table 4). Causes of these pipeline spills include impact from external forces such as anchors, trawls, construction operations, or mudslides; loss of separation between pipelines; failures due to corrosion; and hurricane-related damage.

Total OCS production from 1964 through 2010 was 18.1 Bbbl of crude oil and condensate. Historically, 95 percent or more of the total OCS production (on an annual basis) has been transported by pipeline. Of the remaining 5 percent or less, there have been no spills ≥ 1,000 bbl resulting from the transport of OCS petroleum by barge.

Table 3. Petroleum Spills ≥ 1,000 Barrels from OCS Platforms, 1964 through 2010

Date	Planning Area[1] Block Number	Water Depth feet	Distance to Shore miles	Volume Spilled bbl[2]	Operator	Facility or Structure Cause of Spill Consequences of Spill
4/8/1964	EI 208	94	48	2,559	Continental Oil	Freighter struck Platform A, fire, platform and freighter damaged
10/3/1964	Hurricane:			11,869 [3]	Event Total	5 platforms destroyed during Hurricane Hilda:
	EI 208	94	48	5,180	Continental Oil	Platforms A, C & D destroyed, blowouts (several days)
	SS 149	55	33	5,100	Signal O & G	Platform B destroyed, blowout (17 days)
	SS 199	102	44	1,589	Tenneco Oil	Platform A destroyed, lost storage tank
7/19/1965	SS 29	15	7	1,688 [4]	PanAmerican	Well #7 drilling, blowout (8 days), minimal damage
1/28/1969	Santa Barbara Channel,	190	6	80,000	Union Oil	Well A-21drilling, blowout (10 days), 50,000 bbl during blowout phase, subsequent seepage 30,000 bbl (over decades), 4,000 birds killed, considerable oil on beaches.
3/16/1969	SS 72	30	6	2,500	Mobil Oil	Submersible rig Rimtide drilling in heavy seas bumped by supply vessel, rig shifted and sheared wellhead, blowout (3 to 4 days).
2/10/1970	MP 41	39	14	65,000[5]	Chevron Oil	Platform C, fire of unknown origin, blowout 12 wells (49 days) lost platform, minor amounts of oil on beaches.
12/1/1970	ST 26	60	8	53,000	Shell Oil	Platform B, wireline work, gas explosion, fire, blowout (138 days), lost platform and 2 drilling rigs, 4 fatalities, 36 injuries, minor amounts of oil on beaches.
1/9/1973	WD 79	110	17	9,935	Signal O & G	Platform A oil storage tank structural failure
1/26/1973	PL 23	61	15	7,000	Chevron Oil	Platform CA storage barge sank in heavy seas
11/23/1979	MP 151	280	10	1,500 [6]	Texoma Production	Moblie Offshore Drilling Unit (MODU) Pacesetter III's diesel tank holed, workboat contact in heavy seas
11/14/1980	HI 206	60	27	1456	Texaco Oil	Platform A storage tank overflow during Hurricane Jeanne evacuation
9/24/2005	Hurricane:			5,066 [7]	Event Total	One platform and two rigs destroyed by Hurricane Rita:
	EI 314	230	78	2,000 [4]	Forest Oil	Platform J destroyed, lost oil on board and in riser
	SM 146	238	78	1,494 [7]	Hunt Petroleum	Jack-up Rig Rowan Fort Worth swept away, never found
	SS 250	182	69	1,572 [8]	Remington O & G	Jack-up Rig Rowan Odessa legs collapsed
4/20/2010	MC 252	4,992	53	4.9 million [9]	BP E & P	Deepwater Horizon rig, gas explosion, blowout (87 days to cap well), fire. Drilling rig sank, 11 fatalities, multiple injuries, beaches, wildlife affected, temporary closure of area fisheries.considerable oil on beaches.

NOTES: Spills are crude oil releases unless otherwise noted; no spill contacts to land unless otherwise noted; Outer Continental Shelf (OCS) is submergered lands, subsoil, and seabed administered by U.S. Federal Government, http://www.boemre.gov/aboutmms/ocsdef.htm

[1] Planning Area in Gulf of Mexico (GOM) unless otherwise noted. GOM Planning Areas: EI Eugene Island, HI High Island, MP Main Pass, PL South Pelto, SS Ship Shoal, SM South Marsh Island, ST GOM Planning Area Maps http://www.gomr.boemre.gov/homepg/lsesale/map_arc.html.

[2] bbl= Barrel = 42 gallons

[3] Hurricane Hilda, 10/3/1964, platform spills ≥ 1,000 bbl at three facilities totaled to 11,869 bbl - treated as one spill event.

[4] Condensate, a liquid product of natural gas production. From 1964 through 2009, over 17.5 billion bbl oil and 176.1 mcf natural gas produced

[5] Spill volume estimate between 30,000 bbl to 65,000 bbl, previously reported as 30,000 bbl

[6] Diesel fuel

[7] Hurricane Rita, 9/24/2005, one platform and 2 rig losses ≥ 1,000 bbl at three locations totaled to 5,066 bbl - treated as one spill event. The 5,066 bbl spill was a "passive" spill, based on unrecovered pre-storm inventories from the platform and two rigs - no spill observed, no response required.

[8] Diesel fuel and other refined petroleum products stored on rig

[9] "Oil Budget Calculator Deepwater Horizon Technical Documentation", Nov. 2010, www.noaanews.noaa.gov/stories2010/PDFs/OilBudgetCalc_Full_HQ-Print_111110.pdf

Source: U.S. DOI/BOEMRE OCS Spill Database, May 2011

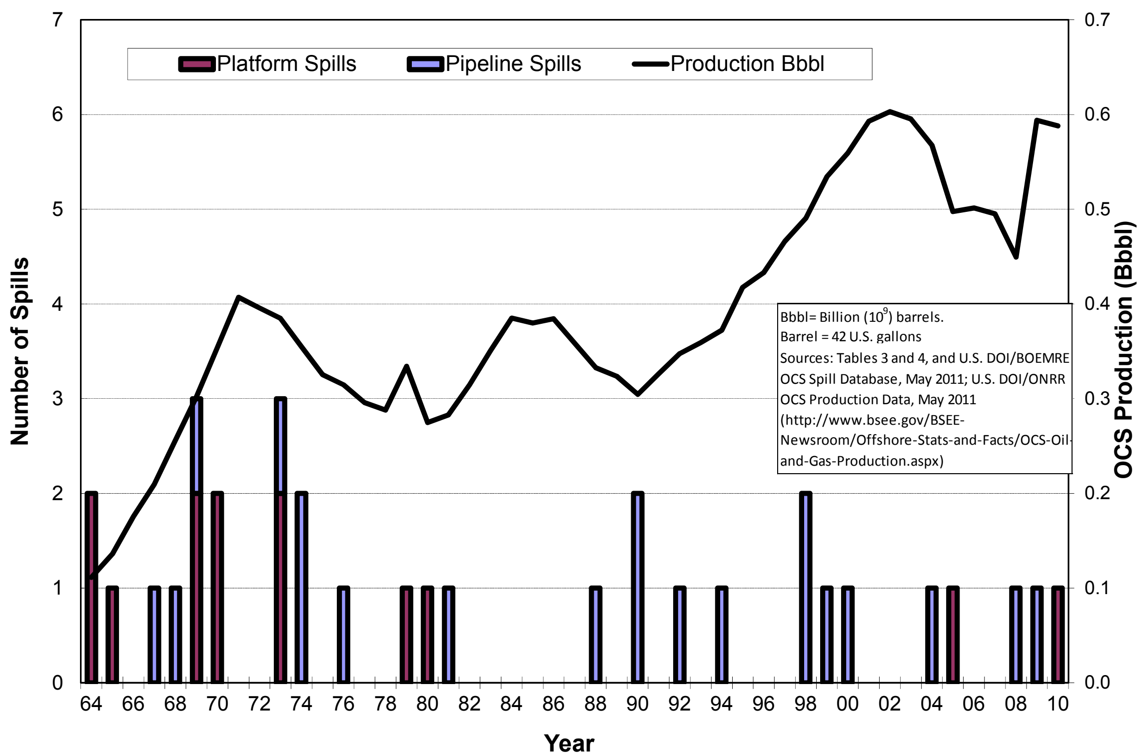


Figure 1. OCS Oil Production vs. Petroleum Spills ≥ 1,000 Barrels from OCS Oil and Gas Operations, 1964 through 2010

The advantages of limiting the analysis to spills from OCS platforms and pipelines are that spill rates will better reflect the magnitude of spill occurrence under U.S. regulatory and operational controls, and the individual spill and production records are readily accessible. A disadvantage is that there are a small number of observations, which limits statistical analysis of spill rate variations that may exist between the northern Pacific, Atlantic, or Alaska waters versus the southern California and the Gulf of Mexico waters (where most of the OCS experience in the United States has occurred). OCS engineering and operational regulations include requirements tailored to each area's environment, which may offset or even reduce the spill frequency relative to historic experience.

However, alternative oil spill rates for the Arctic portion of the OCS have been developed. Because sufficient historical data on offshore oil spills for this region or for Arctic conditions do not exist, an oil spill occurrence model based on fault tree methodology was developed. The base data from the Gulf of Mexico OCS, including the variability of the data, were augmented and modified to represent expected Arctic offshore OCS oil spill rates. (Bercha Group, 2006, 2008, 2011). In a separate study, Eschenbach and Harper (2006) developed alternate offshore oil-spill rates by applying statistical methods to oil-spill base data from the Gulf of Mexico for the estimation of spill rates in the Arctic OCS (See References for links to publications including these alternate rates).

Table 4. Petroleum Spills ≥ 1,000 Barrels from OCS Pipelines, 1964 through 2010

Date	Planning Area[1] Block Number	Water Depth (feet)	Distance to Shore (miles)	Volume Spilled (bbl[2])	Operator	Pipeline Segment (Pipeline Authority[3]) Cause/Consequences of Spill
10/15/1967	WD 73	168	22	160,638	Humble Pipe Line	12" oil pipeline Seg #7791 (DOT), anchor kinked, corrosion, leak
3/12/1968	ST 131	160	28	6,000	Gulf Oil	18" oil pipeline Seg #3573 (DOT), barge anchor damage
2/11/1969	MP 299	210	17	7,532	Chevron Oil	4" gas pipeline Seg #3469 (DOT), anchor damage
5/12/1973	WD 73	168	22	5,000	Exxon Pipeline	corrosion, leak
4/17/1974	EI 317	240	75	19,833	Pennzoil	14" oil Bonita pipeline Seg #1128 (DOI), anchor damage
9/11/1974	MP 73	141	9	3,500	Shell Oil	8" oil pipeline Seg #36 (DOI), Hurricane Carmen broke tie-in to 12" pipeline, minor contacts to shoreline, brief cleanup response in Chandeleur Area.
12/18/1976	EI 297	210	17	4,000	Placid Oil	10" oil pipeline Seg #1184 (DOI), trawl damage to tie-in to 14" pipeline
12/11/1981	SP 60	190	4	5,100	Atlantic Richfield	8" oil pipeline Seg #4715 (DOT), workboat anchor damage
2/7/1988	GA A002	75	34	15,576	Amoco Pipeline	14" oil pipeline Seg #4879 (DOT), damage from illegally anchored vessel
1/24/1990	SS 281	197	60	14,423[4]	Shell Offshore	4" condensate pipeline Seg #8324 (DOI), anchor damage to subsea tie-in
5/6/1990	EI 314	230	78	4,569	Exxon	8" oil pipeline Seg #4030 (DOI), trawl damage
8/31/1992	PL 8	30	6	2,000	Texaco	20" oil pipeline Seg #4006 (DOT), Hurricane Andrew, loose rig Treasure 75 anchor damage, minor contacts to shoreline, brief cleanup response.
11/16/1994	SS 281	197	60	4,533[4]	Shell Offshore	4" condensate pipeline Seg #8324 (DOI), trawl damage to subsea tie-in
1/26/1998	EC 334	264	105	1,211[4]	Pennzoil E & P	16" gas & condensate pipeline Seg #11007 (DOT), anchor damage to tie-in to 30" pipeline, anchor dragged by vessel in man overboard response.
9/29/1998	SP 38	108	6	8,212	Chevron Pipe Line	10" gas & oil pipelne Seg #5625 (DOT), Hurricane Georges, mudslide damage, small amount of oil contacted shoreline.
7/23/1999	SS 241	133	50	3,200	Seashell Pipeline	12" oil pipeline Seg #6462 & Seg #6463 (DOT), "Loop Davis" jack-up rig barge crushed pipeline when sat down on it.
1/21/2000	SS 332	435	75	2,240	Equilon Pipeline	24" oil pipeline Seg #10903 (DOT), anchor damage from MODU under tow
9/15/2004	MC 20	479	19	1,720[5]	Taylor Energy	6" oil pipeline Seg #7296 (DOI), Hurricane Ivan, mudslide damage
9/13/2008	HI A264	150	73	1,316[6]	HI Offshore System	42" gas pipeline Seg #7364 (DOT), Hurricane Ike, anchor damage parted pipeline
7/25/2009	SS 142	60	30	1,500	Shell Pipe Line	20" oil pipeline Seg #4006 (DOT), micro-fractures from chronic contacts at pipeline crossing caused failure (separators between pipelines missing).

NOTES: Crude oil release unless otherwise noted; no spill contacts to land unless otherwise noted. Outer Continental Shelf (OCS) - submergered lands, subsoil, and seabed administered by U.S. Federal Government, http://www.boemre.gov/aboutmms/ocsdef.htm

[1] Planning Area in Gulf of Mexico (GOM) unless otherwise noted. GOM Planning Areas: EC East Cameron, EI Eugene Island, GA Galveston, HI High Island, MC Mississippi Canyon, MP Main Pass, PL South Pelto, SS Ship Shoal, SP South Pass, ST South Timbalier, WD West Delta. GOM Planning Area Maps http://www.gomr.boemre.gov/homepg/lsesale/map_arc.html.

[2] bbl= Barrel= 42 U. S. Gallons

[3] Pipeline Authority: (DOI) Department of Interior, BOEMRE; (DOT) Departmant of Transportation, PHMSA

[4] Condensate, a liquid product of natural gas production. Between 1964 - 2009, over 17.5 billion bbl oil and 176.1 mcf natural gas produced on OCS.

[5] The 1,720 bbl spill was a 'passive' spill, based on unrecovered pre-storm inventory trapped in the segment by a mudslide - no spill observed, no response required.

[6] The 1,316 bbl spill was a 'passive' spill, based on unrecovered pre-storm inventory in the segment parted by storm - no spill observed, no response required.

Source: U.S. DOI/BOEMRE OCS Spill Database, May 2011

3.2. Crude Oil Spills from Tankers in Worldwide Coastal and Offshore Waters

Tanker and barge spills can occur due to mishaps during loading, unloading, and taking on fuel oil, and from groundings, hull failures, and explosions. Spill data for tankers in worldwide coastal and offshore waters identify whether the spill occurred "At Sea" or "In Port". From 1974 through 2008, there were 303 crude oil spills ≥1,000 bbl from self-propelled crude oil carriers (Fig. 2; Table 5). Prior to this time, international spill occurrences were recorded on an irregular basis; more stringent reporting requirements were introduced in 1973 (Intergovernmental Maritime Consultative Organization International Convention for the Prevention of Pollution from Ships, 1973; Federal Water Pollution Control Act, U.S. Public Law 92-500, October 18, 1972; amended by U.S. Public Law 93-207, December 28, 1973).

Inland spills (those in rivers, canals, etc.) and spills from barges were specifically excluded from the calculations under the assumption that international transportation of crude oil is performed by tanker to and from coastal ports. Worldwide transport of crude oil from 1974 through 2008 was estimated to total 359.9 Bbbl, based on world crude oil imports and exports (British Petroleum Company, 2009).

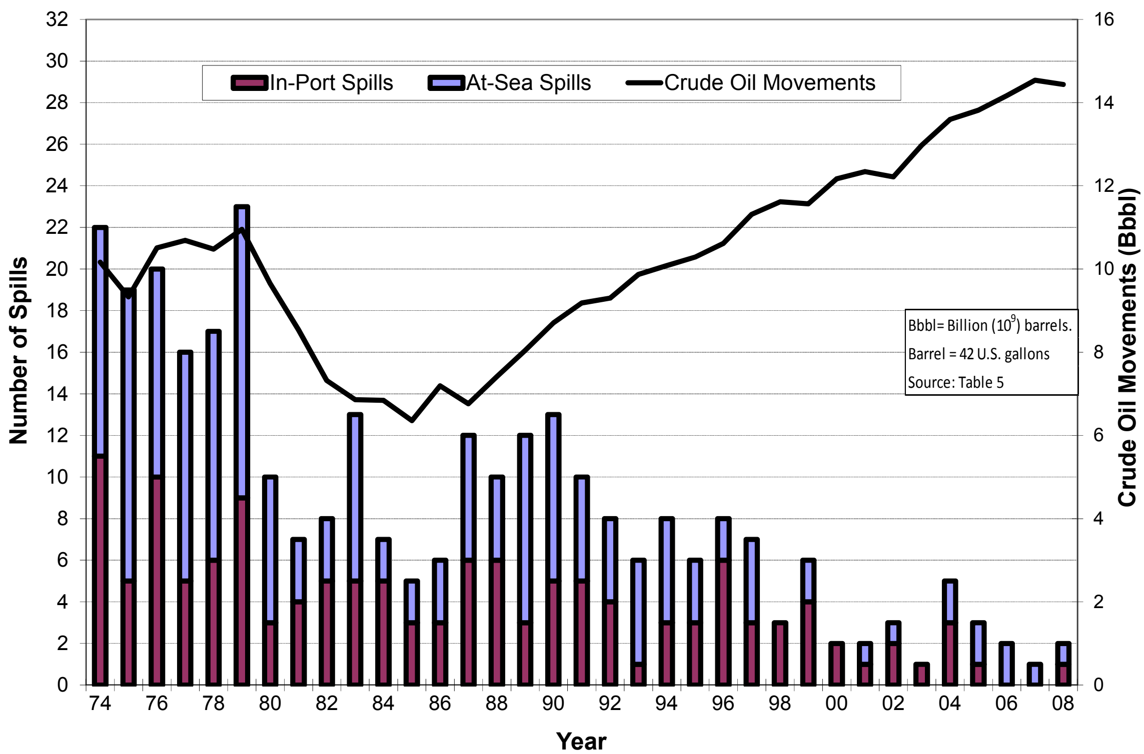


Figure 2. Crude Oil Spills ≥ 1,000 Barrels from Tankers Worldwide vs. Crude Oil Transported Worldwide, 1974 through 2008

Table 5. Crude Oil Spills ≥ 1,000 Barrels from Tankers Worldwide At Sea, and In Port, Worldwide Crude Oil Transported and Annual Spill Rates, 1974 through 2008

Year	All Spills	Spills In Port			Spills At Sea			Crude Oil Handled[3] Bbbl[4]	Spills Per Bbbl[4]
		1,000 to 9,999 bbl[1]	10,000 to 99,999 bbl[1]	≥ 100,000 bbl[1]	1,000 to 9,999 bbl[1]	10,000 to 99,999 bbl[1]	≥ 100,000 bbl[1, 2]		
1974	22	8	2	1	7	2	2	10.165	2.164
1975	19	1	1	3	7	4	3	9.330	2.036
1976	20	6	3	1	2	2	6	10.510	1.903
1977	16	2	2	1	3	3	5	10.692	1.496
1978	17	3	1	2	3	4	4	10.480	1.622
1979	23	4	2	3	4	5	5	10.956	2.099
1980	10	1	1	1	3	2	2	9.657	1.036
1981	7	3	1	0	3	0	0	8.535	0.820
1982	8	3	1	1	3	0	0	7.318	1.093
1983	13	4	1	0	1	4	3	6.860	1.895
1984	7	2	3	0	1	1	0	6.845	1.023
1985	5	1	2	0	0	1	1	6.353	0.787
1986	6	3	0	0	0	3	0	7.191	0.834
1987	12	5	1	0	3	3	0	6.762	1.775
1988	10	3	3	0	2	1	1	7.412	1.349
1989	12	2	1	0	1	5	3	8.041	1.492
1990	13	5	0	0	2	5	1	8.707	1.493
1991	10	3	0	2	2	1	2	9.183	1.089
1992	8	2	1	1	3	1	0	9.301	0.860
1993	6	0	1	0	2	1	2	9.873	0.608
1994	8	1	1	1	1	2	2	10.083	0.793
1995	6	3	0	0	2	1	0	10.287	0.583
1996	8	5	0	1	2	0	0	10.618	0.753
1997	7	2	0	1	2	2	0	11.316	0.619
1998	3	3	0	0	0	0	0	11.617	0.258
1999	6	4	0	0	1	1	0	11.567	0.519
2000	2	0	2	0	0	0	0	12.173	0.164
2001	2	1	0	0	1	0	0	12.344	0.162
2002	3	2	0	0	1	0	0	12.217	0.246
2003	1	0	0	1	0	0	0	12.974	0.077
2004	5	3	0	0	1	1	0	13.596	0.368
2005	3	1	0	0	2	0	0	13.819	0.217
2006	2	0	0	0	0	2	0	14.166	0.141
2007	1	0	0	0	0	1	0	14.540	0.069
2008	2	1	0	0	0	1	0	14.439	0.139
TOTAL	303[5]	86	30	20	65	59	42	359.927	0.839

[1] Barrel (bbl) = 42 gallons

[2] Largest tanker spill was 1.9 million bbl, ABT Summer, May 1991, Atlantic Ocean off Angola

[3] BP Annual Statistical Review of World Energy, World Import and Export table in Oil Section, world crude oil import/export figure

[4] Bbbl= Billion barrels; Billion = 10^9

[5] 303 spills totaling 28.85 million bbl crude oil spilled; excludes inland spills

Sources: U.S. DOI/BOEMRE Worldwide Tanker Spill Database, January 2011; BP Statistical Review of World Energy (1975-2009)

There have been changes in the BSEE tanker database since Anderson and LaBelle, 2000, because new information became available. i.e., the spill count for 1987 has been reduced from 15 to 13: one spill was dropped because it resulted from an act of war; the second spill was dropped because it was due to an intentional discharge (neither of these two spills was accidental); and the third spill was dropped because it was a duplicate spill.

3.3 Crude Oil Spills from Tankers in U.S. Coastal and Offshore Waters

Fifty-three crude oil tanker spills ≥1,000 bbl occurred in U.S. coastal and offshore waters (including U.S. territorial waters) from 1974 through 2008 (Table 6; Fig. 3). These spills are a subset of the spills included in the worldwide tanker spill, and as such, are identified as occurring either "At Sea" or "In Port." Estimations of crude oil transport by tankers in U.S. waters were based on foreign transport (imports + exports = 84.2 Bbbl) and domestic transport (coastal + interterritorial = 20.3 Bbbl) of crude oil for the years 1974 through 2008 (U.S. Army Corps of Engineers [COE], 2009).

Comprehensive data on locations of all individual vessel routes, the volumes moved over each route, and the oil spills associated with each specific route are unavailable. Therefore, a simple assumption regarding spills associated with foreign transport (U.S. crude oil imports and exports) was made that half of the spills related to foreign movements occurred in U.S. waters, and the other half occurred in international or foreign waters at the other end of the trip. In the spill rate calculation, the volume of foreign transport was adjusted by 50 percent to account for these assumptions, which resulted in an estimated 62.4 Bbbl of transport associated with tanker spills in U.S. waters (50% foreign + 100% domestic transport).

3.4 Crude Oil Spills from Alaska North Slope (ANS) Tankers

The Trans-Alaska Pipeline System (TAPS) is the main transportation artery carrying crude oil and some natural gas liquids from Alaska's Arctic to Valdez, an ice-free port on the southern coast of Alaska. The TAPS startup was in August 1977. Spill data for tankers carrying ANS crude oil from Valdez identify whether the spill occurred "At Sea" or "In Port."

From 1977 through 2008, approximately15.3 Bbbl of ANS crude oil were loaded onto tankers at Valdez, Alaska (U.S. Department of Commerce (DOC), 2009). Loadings peaked at 0.73 Bbbl in 1988 and have steadily declined since to 0.50 Bbbl in 1996 and 0.23 Bbbl in 2008. The bulk of these loadings (87-97%) have had destinations to either the U.S. west coast (Puget Sound, WA; San Francisco, CA; or Los Angeles, CA) or Panama. Panama destinations peaked at 43 percent of loadings in 1982, and have since tapered to zero in 1996. The destinations of the balance of the loadings were generally the Virgin Islands, Hawaii or Alaska.

Table 6. Crude Oil Spills ≥ 1,000 Barrels form Tankers in U.S. Waters At Sea and In Port, Crude Oil Transported via Tanker in U.S. Waters, and Annual Tanker Spill Rates, 1974 through 2008

Year	All Spills	Spills In Port: 1,000 to 9,999 bbl[1]	Spills In Port: 10,000 to 99,999 bbl[1]	Spills In Port: ≥ 100,000 bbl[1]	Spills At Sea: 1,000 to 9,999 bbl[1]	Spills At Sea: 10,000 to 99,999 bbl[1]	Spills At Sea: ≥ 100,000 bbl[1, 2]	Imports & Exports Bbbl[3]	Domestic Transport[4] Bbbl[3]	Adjusted Transport[5] Bbbl[3]	Spills Per Bbbl
1974	5	3	1	0	1	0	0	1.437	0.221	0.940	5.322
1975	6	1	0	1	2	1	1	1.702	0.173	1.024	5.859
1976	3	3	0	0	0	0	0	2.245	0.149	1.272	2.359
1977	3	1	1	0	0	0	1	2.686	0.204	1.547	1.939
1978	1	0	0	0	1	0	0	2.576	0.594	1.882	0.531
1979	5	3	1	0	0	0	1	2.521	0.639	1.900	2.632
1980	2	0	1	0	1	0	0	2.035	0.842	1.860	1.076
1981	2	1	1	0	0	0	0	1.737	0.875	1.744	1.147
1982	1	0	1	0	0	0	0	1.501	0.937	1.688	0.593
1983	1	1	0	0	0	0	0	1.208	0.990	1.594	0.627
1984	1	0	0	0	0	1	0	1.142	0.922	1.493	0.670
1985	2	1	1	0	0	0	0	1.084	1.002	1.544	1.295
1986	3	3	0	0	0	0	0	1.441	0.994	1.715	1.750
1987	3	0	0	0	1	2	0	1.582	1.061	1.852	1.620
1988	2	1	1	0	0	0	0	1.680	1.004	1.844	1.085
1989	2	1	0	0	0	0	1	1.988	0.879	1.873	1.068
1990	3	1	0	0	0	2	0	2.058	0.816	1.845	1.626
1991	2	2	0	0	0	0	0	1.949	0.817	1.792	1.116
1992	1	1	0	0	0	0	0	2.145	0.760	1.833	0.546
1993	0	0	0	0	0	0	0	2.382	0.663	1.854	-.-[7]
1994	0	0	0	0	0	0	0	2.576	0.649	1.937	-.-[7]
1995	1	1	0	0	0	0	0	2.470	0.595	1.830	0.546
1996	1	1	0	0	0	0	0	2.684	0.558	1.900	0.526
1997	1	1	0	0	0	0	0	2.879	0.513	1.953	0.512
1998	0	0	0	0	0	0	0	2.903	0.424	1.876	-.-[7]
1999	0	0	0	0	0	0	0	2.963	0.344	1.826	-.-[7]
2000	1	0	1	0	0	0	0	3.489	0.317	2.062	0.485
2001	0	0	0	0	0	0	0	3.242	0.348	1.969	-.-[7]
2002	0	0	0	0	0	0	0	3.195	0.341	1.939	-.-[7]
2003	0	0	0	0	0	0	0	3.438	0.339	2.058	-.-[7]
2004	1	1	0	0	0	0	0	3.536	0.319	2.087	0.479
2005	0	0	0	0	0	0	0	3.480	0.298	2.038	-.-[7]
2006	0	0	0	0	0	0	0	3.489	0.245	1.990	-.-[7]
2007	0	0	0	0	0	0	0	3.472	0.254	1.990	-.-[7]
2008	0	0	0	0	0	0	0	3.278	0.242	1.881	-.-[7]
TOTAL	53[6]	27	9	1	6	6	4	84.193	20.328	62.425	0.849

[1] bbl= Barrel = 42 gallons

[2] Largest tanker spills: 427,500 bbl, Epic Colocotronis, 1975; 266,000 bbl, Corinthos, 1975; 262,000 bbl, Exxon Valdez, 1989.

[3] Bbbl= Billion barrels; Billion = 10^9

[4] Coastal and intraterritorial domestic transport of crude oil (excludes inland transport)

[5] Assumes half of exposure from U.S. imports/exports occurs outside U.S. waters = 100% Domestic Transports + 50% Imports & Exports

[6] 53 spills totaling 1.97 million bbl crude oil spilled; includes spills in U.S. territorial waters; excludes inland spills

[7] Dash (-.-) indicates zero spills observed; rate not calculated

Sources: U.S. DOI/BOEMRE Worldwide Tanker Spill Database, January 2011;

U.S. Army Corps of Engineers, Waterborne Commerce of the United States, Part 5, National Summaries, 1975 - 2009,

Table 2-1 Summary of Foreign and Domestic Waterborne Commerce by Type of Traffic and Commodity.

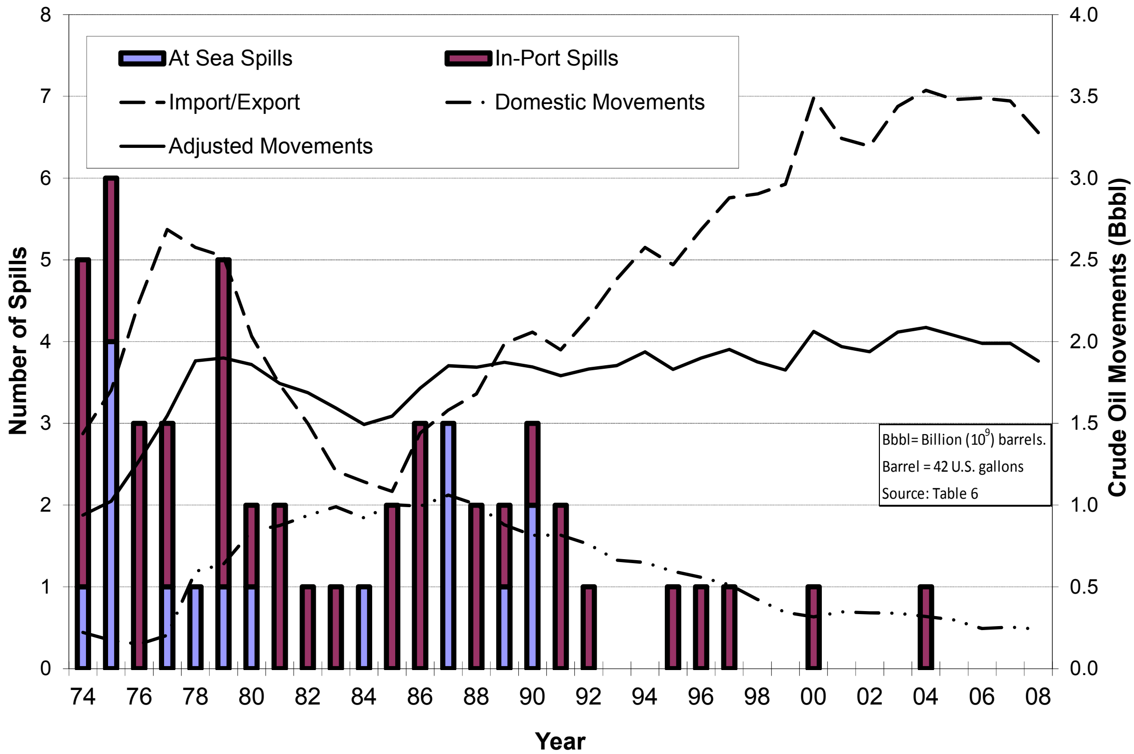


Figure 3. Crude Oil Spills ≥ 1,000 Barrels from Tankers in U.S. Waters vs. Crude Oil Transported in U.S. Waters, 1974 through 2008

The earliest three spills of ANS crude oil transported via tanker occurred in 1978, 1980, and 1981 outside of U.S. waters. All subsequent spills occurred in U.S. waters. Eleven tanker spills ≥1,000 bbl associated with the transportation of ANS crude oil occurred in U.S. waters from1977 through 2008 (Fig. 4).

These 11 spills were:

- The Exxon Valdez spill (1989 – 262,000 bbl) which was the largest
- Three Stuyvesant spills:
  - 1981 - 3,600 bbl
  - 1987 - 15,000 bbl
  - 1987 - 14,300 bbl
- Seven other spills, less than 9,500 bbl each.
  - Exxon San Francisco (1991) was the last of the ANS spills

3.5 Petroleum and Crude Oil Spills from Barges in U.S. Coastal, Offshore, and Inland Waters

From 1974 through 2008, 197 petroleum spills ≥1,000 bbl (28 of which were crude oil spills) occurred from barges in U.S. coastal, offshore, and inland waters (including U.S.

territorial waters) (Table 7, Fig. 5). Because the data available on barge transport in U.S. waters do not differentiate between inland and coastal/offshore transport, inland transport was included. Petroleum included crude oil and petroleum products such as gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, lubricating oils and greases, naphtha, petroleum solvents, asphalt, tar and pitches, and liquefied gases. Petroleum transported from 1974 through 2008 were estimated to be 58.5 Bbbl (9.1 Bbbl of which were crude oil), based on the portion of U.S. domestic petroleum transported by barge (COE, 2009).

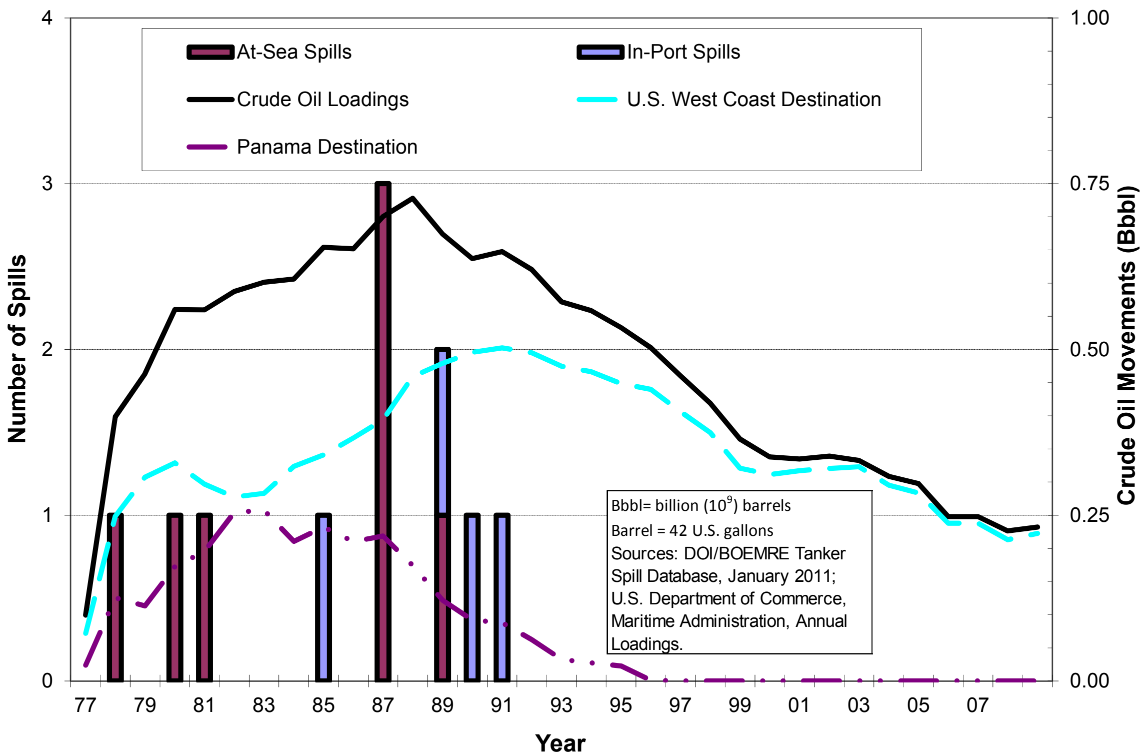


Figure 4. Alaska North Slope Crude Oil Tanker Spills ≥ 1,000 Barrels vs. Total Crude Oil Loadings at Valdez, Alaska, and Crude Oil Shipment Destinations, 1974 through 2008

4.0 SPILL RATE TREND ANALYSES

Trend analysis was performed for the entire record (1964 through 2010) for spills ≥1,000 bbl from OCS platforms and pipelines. This was performed to determine if the observed decline in spill occurrence in the spill record represented a trend.
In a situation where the data indicated that there was a trend, a sensitivity analysis was conducted to determine at what point the increments became relatively stationary. The spill rates were then calculated from that point forward. Appendix A provides the reader with further details of the trend analysis methodology.

Table 7. Petroleum Spills ≥1,000 Barrels from Barges in U.S. Waters including Inland Waters, Petroleum Transported via Barges, and Annual Barge Spill Rates, 1974 through 2008

		All Petroleum Spills (including Crude Oil)					Crude Oil Spills Only					
Year	All Spills	1,000 to 9,999 bbl[2]	10,000 to 24,999 bbl	≥ 25,000 bbl[2]	Petroleum Transported[1] Bbbl[3]	Spills Per Bbbl[3]	All Spills	1,000 to 9,999 bbl[2]	10,000 to 24,999 bbl[2]	≥ 25,000 bbl[2]	Crude Oil Transported [1] Bbbl[3]	Spills Per Bbbl[3]
1974	14	10	2	2	1.616	8.663	6	4	2	0	0.321	18.692
1975	12	8	4	0	1.607	7.467	4	3	1	0	0.331	12.085
1976	9	9	0	0	1.746	5.155	3	3	0	0	0.339	8.850
1977	13	12	1	0	1.785	7.283	0	0	0	0	0.327	[4]-.-
1978	15	12	3	0	1.850	8.108	2	2	0	0	0.359	5.571
1979	10	10	0	0	1.707	5.858	1	1	0	0	0.319	3.135
1980	10	10	0	0	1.716	5.828	2	2	0	0	0.270	7.407
1981	6	4	0	2	1.675	3.582	0	0	0	0	0.219	[4]-.-
1982	5	4	0	1	1.569	3.187	0	0	0	0	0.227	[4]-.-
1983	6	2	3	1	1.537	3.904	1	0	1	0	0.251	3.984
1984	8	5	2	1	1.640	4.878	1	0	1	0	0.275	3.636
1985	12	9	2	1	1.580	7.595	2	2	0	0	0.300	6.667
1986	6	5	1	0	1.642	3.654	1	1	0	0	0.296	3.378
1987	5	5	0	0	1.666	3.001	0	0	0	0	0.270	[4]-.-
1988	9	8	0	1	1.738	5.178	1	1	0	0	0.305	3.279
1989	7	7	0	0	1.715	4.082	0	0	0	0	0.283	[4]-.-
1990	12	10	2	0	1.744	6.881	2	2	0	0	0.311	6.431
1991	3	3	0	0	1.649	1.819	0	0	0	0	0.282	[4]-.-
1992	3	3	0	0	1.601	1.874	0	0	0	0	0.279	[4]-.-
1993	2	2	0	0	1.638	1.221	0	0	0	0	0.284	[4]-.-
1994	1	0	1	0	1.637	0.611	0	0	0	0	0.269	[4]-.-
1995	5	4	1	0	1.600	3.125	0	0	0	0	0.257	[4]-.-
1996	4	3	1	0	1.613	2.480	0	0	0	0	0.262	[4]-.-
1997	3	3	0	0	1.734	1.730	0	0	0	0	0.262	[4]-.-
1998	1	1	0	0	1.702	0.588	1	1	0	0	0.215	4.651
1999	3	3	0	0	1.649	1.819	0	0	0	0	0.202	[4]-.-
2000	2	2	0	0	1.670	1.198	0	0	0	0	0.195	[4]-.-
2001	2	2	0	0	1.684	1.188	0	0	0	0	0.183	[4]-.-
2002	1	1	0	0	1.600	0.625	0	0	0	0	0.191	[4]-.-
2003	1	1	0	0	1.634	0.612	0	0	0	0	0.209	[4]-.-
2004	2	2	0	0	1.688	1.185	0	0	0	0	0.210	[4]-.-
2005	2	1	0	1	1.709	1.170	1	1	0	0	0.205	4.878
2006	2	2	0	0	1.753	1.141	0	0	0	0	0.191	[4]-.-
2007	0	0	0	0	1.795	[4]-.-	0	0	0	0	0.187	[4]-.-
2008	1	1	0	0	1.636	0.611	0	0	0	0	0.169	[4]-.-
Total	197[5]	164	23	10	58.525	3.366	28[6]	23	5	0	9.055	3.092

[1] Petroleum includes crude oil, gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, lubricating oils and greases, asphalt, and liquified gases.

[2] Barrel (bbl) = 42 gallons

[3] Billion = 10^9, Billion barrels = Bbbl

[4] Dash (-.-) indicates zero spills observed, rate not calculated.

[5] 197 spills totaling 1.21 million bbl crude oil spilled; includes 28 crude oil spills totalling 0.18 million bbl.

[6] 28 crude oil spills totalling 0.18 million bbl

Note: Largest barge spill was 48,600 bbl, UMTB 183, December 1988, south of Semedi Islands, AK

Sources: U.S. DOI/BOEMRE Worldwide Tanker Spill Database, January 2011;

U.S. Army Corps of Engineers, Waterborne Commerce of the United States, Part 5, National Summaries, 1975 - 2009,

Table 2-3 Domestic Barge Traffic by type of Traffic and Commodity.

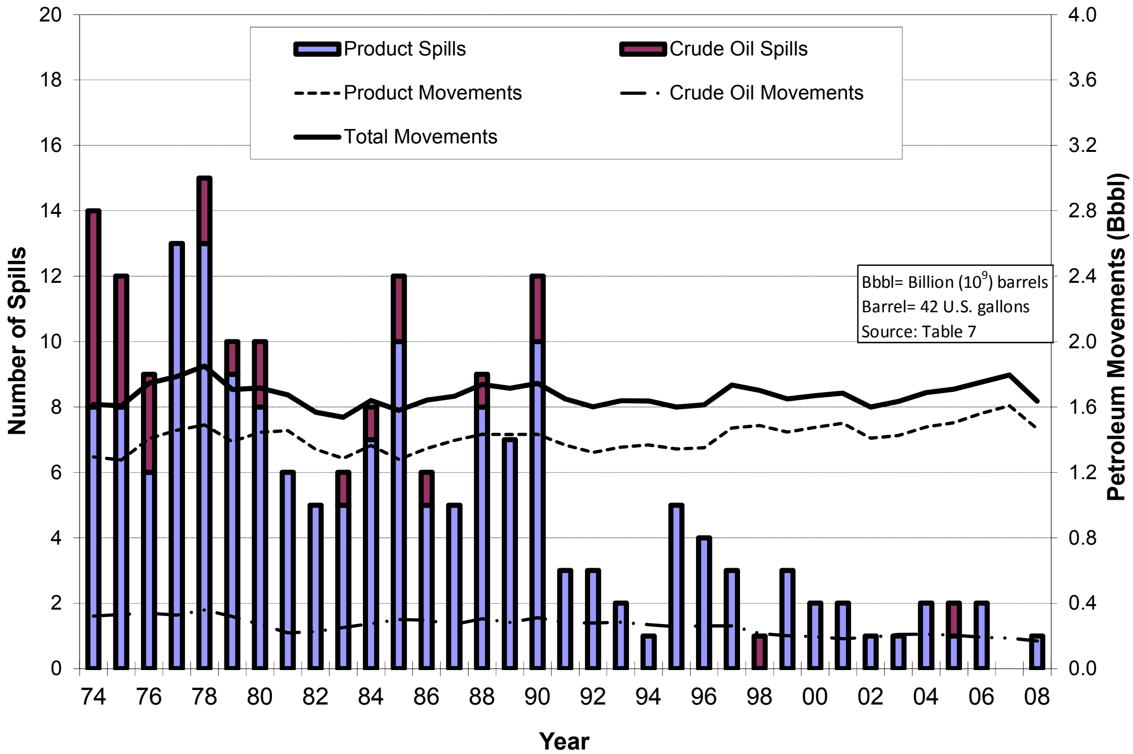


Figure 5. Crude Oil and Petroleum Spills ≥ 1,000 Barrels from Barges in U.S. Waters vs. Petroleum Transported in U.S. Waters, 1974 through 2008

For OCS platforms, a decline in the spill rate, based on oil produced, was identified early in the record through trend analysis (Nakassis, 1982; Anderson and LaBelle, 1990) and this trend was also evident in the two subsequent analyses (Anderson and LaBelle, 1994 and 2000). Trend analysis, conducted for this report, identified the continuation of this trend. The rates for spills ≥1,000 bbl were calculated by excluding the earliest portion of the historic record (where the earlier spill rate differed from the current trend; Appendix A, Table A-1).

For OCS pipelines, a decrease in the spill rate, based on volume produced, was also identified in Anderson and LaBelle 1990), but this trend was not evident in the previous two analyses (Anderson and LaBelle, 1994 and 2000). In this report, although the nonparametric tests did not clearly show evidence of a trend, a decrease was identified in the frequency of pipeline spills over the second half of the total volume produced. Pipeline spill rates were calculated by excluding the first half of the historic production volume record (where the spill rate differed from the current trend.) (See Appendix A, Table A-2.)

4.1 Tests to Determine if OCS Spill Observations are Random and Independent

To determine whether the spill observations were random and independent, nonparametric tests that had been applied in previous analyses (Nakassis, 1982; Anderson and LaBelle, 1990) were again used in this study. These are detailed in Appendix A. A variable that was independent of the spill rate distribution was constructed – the amount of crude and condensate production observed between spills. A hypothesis that this new variable was random and independent was tested using Hotelling and Pabst's Test (Bradley, 1968, Table I); Kendall's Test for Correlation (Bradley, 1968, Table XI), and Runs Up, Runs Down Test (Bradley, 1968, Table X). If the variable (production observed between spills) is independent and random, then the observed decline in the spill rate represents a trend. The first two tests indicate the volume of oil produced between OCS platform spills still appears to be nonrandom and to increase over time. This trend was identified in previous analyses (Nakassis, 1982; Anderson and LaBelle, 1994, and 2000) and indicates that the spill rates, based on oil produced, have declined over time.

Only the Hotelling and Pabst's test hinted that volume of oil produced between OCS pipeline spills is nonrandom.

4.2 Production Interval Analysis

Spill rate trends were identified using an analysis of the number of spills per production interval. OCS platform and pipeline spills were examined over uniform intervals of production, 1.0 Bbbl intervals for platforms (Fig. 6) and 0.5 Bbbl intervals for pipelines (Fig.7).   Interval lengths were selected to maximize single spill occurrences per interval for the most recent spills; intervals with no spills are considered to be non-spill observations. (Note: an extra 0.1 Bbbl of production falls in the last interval, which is production interval 18 for platforms and interval 36 for pipelines)

OCS Platform Data—The previously identified trend in OCS platform spills (Nakassis, 1982; Anderson and LaBelle, 1990, 1994, 2000) continued with 9 of the 13 spills occurring in production intervals 1 through 3, and 12 of the last 15 production intervals being non-spill observations (Fig. 6). This increase in the number of non-spill production intervals indicates an improvement trend in the spill rates from OCS platforms. The sensitivity analysis indicated that the same starting point for the trend utilized in the previous studies (Nakassis, 1982, Anderson and LaBelle, 1990, 1994, and 2000) was also appropriate for this report. Starting the trend at this point captures 87% of the most recent production record, yet it includes 38.5% (5 of 13) of the OCS platform spills.

OCS Pipeline Data—Although the non-parametric testing of the pipeline data does not clearly identify the existence of a trend, an OCS pipeline spill trend can be identified in the second half of the record, with 11 of the 20 spills (and 9 non-spill intervals) occurring before the middle (18^{th}) production interval and 9 spills (and 11 non-spill intervals) occurring between the 18^{th} and 36^{th} intervals (Fig. 7). The two spills in the last two half-Bbl production intervals (interval numbers 34 and 35) negate most findings of a trend in

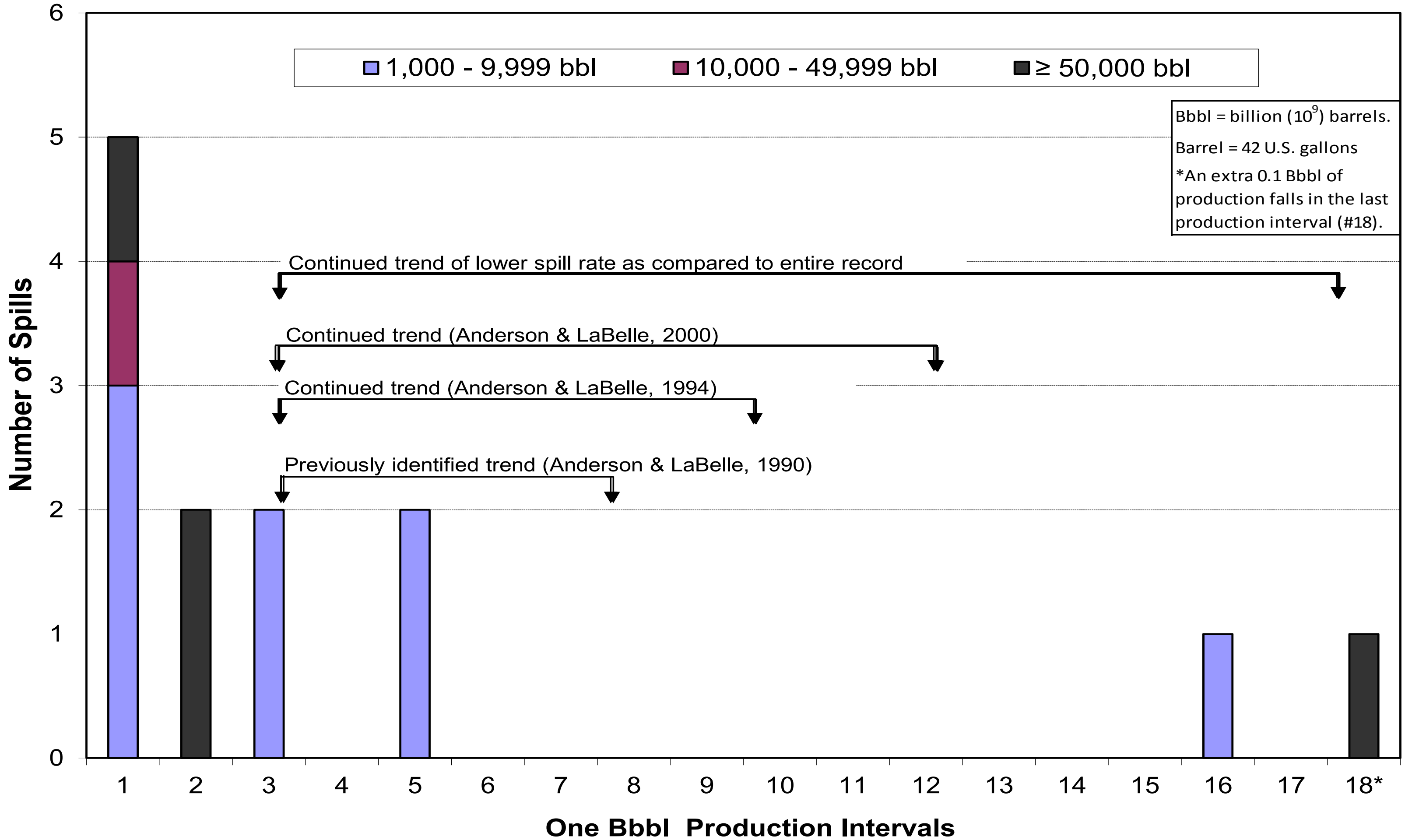
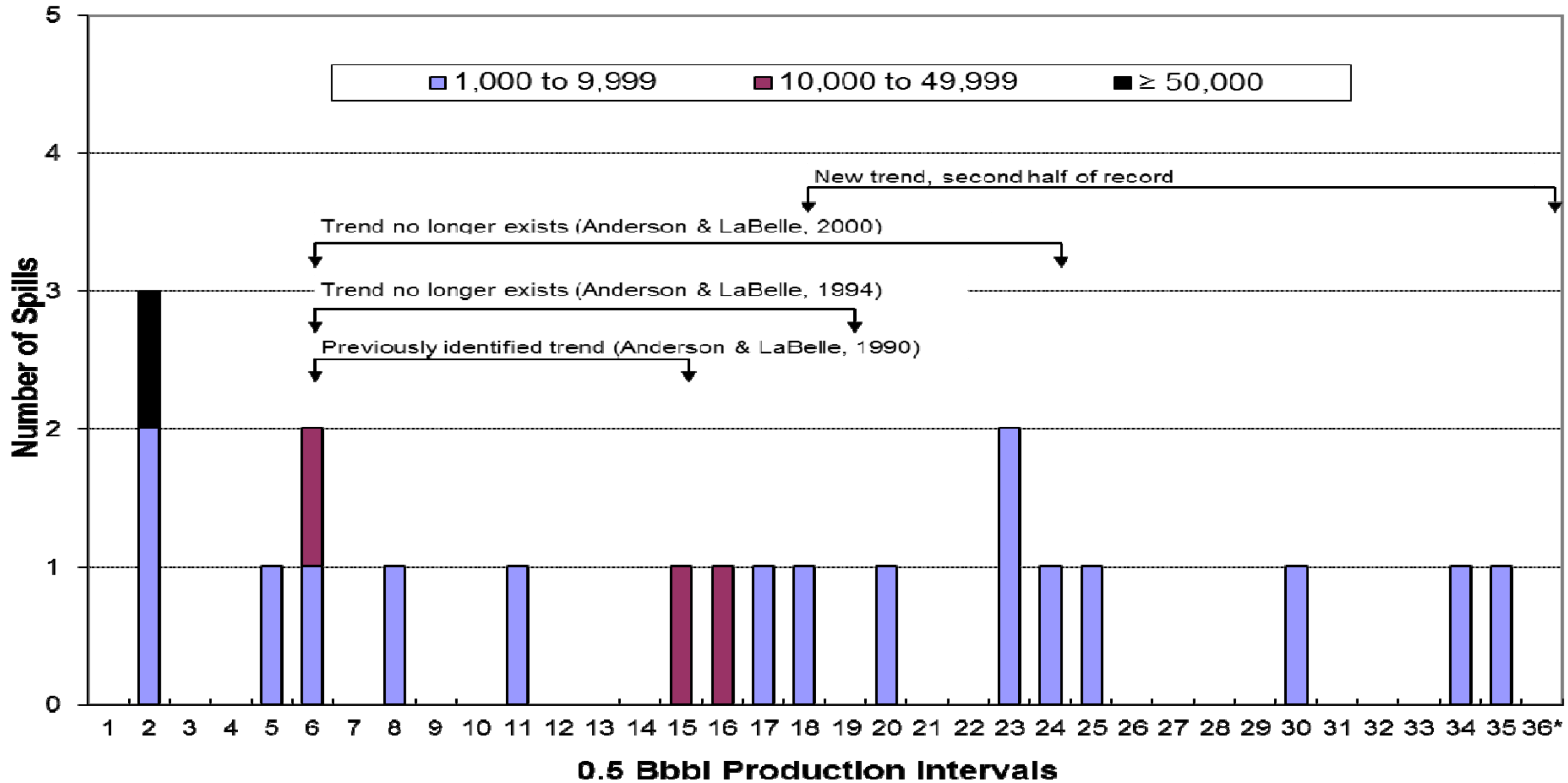


Figure 6. Petroleum Spills ≥ 1,000 Barrels from OCS Activities from Platforms, by Size Category within One Billion Barrel Production Intervals, 1964 through 2010



Bbbl= billion (10^9) barrels. Barrel= 42 U.S. gallons.
* An extra 0.1 Bbbl of production falls in the last production interval (#36).

Figure 7. Crude Oil Spills ≥ 1,000 Barrels from OCS Pipelines by Size Category within 0.5 Billion Barrel Production Intervals, 1964 through 2010

the nonparametric testing, but clearly there is a lower frequency of spills and an increase in the number of non-spill production intervals between spills in the second half of the record, which does indicate a positive trend. Although the sensitivity analysis did not clearly identify a point in the record where the cumulative percent of production becomes significantly greater than the cumulative percentage of the number of spills, the production interval analysis does identify the middle of the record as an appropriate starting point for the trend.

4.3 Fifteen –Year and Twenty-Year Analysis

Anderson and LaBelle (2000) calculated spill rates for the entire record and the last 15 years in order to compare the data sets. If spill occurrence rates have increased or decreased over time, eliminating the oldest records should make the rates more representative of current spill occurrence behavior.

To identify and evaluate more recent trends, spill rates were calculated for the last 10, 15 and 20 years to compare the data sets. The 15-year record was selected by Anderson and LaBelle (2000) because it represented how the spill rates have changed while still maintaining a significant portion of the production and spill record. In this report, to compare spill rates among the data sets, the 15-year period was again selected.

Thus, spill occurrence rates for OCS platform and pipeline spills, worldwide tanker spills, and barge spills in U.S. waters were calculated using the most recent 15 years of data. The 15-year records utilized were 1996 through 2010 for OCS platform and pipeline spills; and 1994-2008 for worldwide tanker spills and spills from barges in U.S. waters.

However, in the case of tanker crude oil spills in U.S. waters and ANS crude oil spills, the 15-year interval was extended to 20 years (1989 through 2008) in order to capture at least one spill in the rate computations of "At Sea" and "In Port" spills of ≥ 1,000 bbl.

4.4 Date Ranges for which Spill Rates were Calculated

Spill rates were calculated for the entire data record and the most recent 15 (or 20) years of available from each spill source as shown in Table 8 which lists the datasets used for each spill source category to calculate spill rates.

5.0 RESULTS: ESTIMATED SPILL RATES

Spill rates expressed in terms of spills per Bbbl of oil handled, were calculated for each spill source examined for spills ≥1,000 bbl and for spills ≥10,000 bbl. Spill rates for spills ≥100,000 bbl were also calculated for crude oil spills from tankers in worldwide coastal and offshore waters, where the average spill size for spills at sea was over 100,000 bbl (118,100 bbl). Tanker and barge rates were calculated using the entire record of observed spills and oil transported.

Table 8. Date Ranges of Spill Occurrence Records Utilized in this Report

Spill Source/Location	Date Range of Record Used	Data Availability for Spill Occurrence Rate Calculations
Worldwide Tanker Spills	1974-2008*	1974 earliest reliable data 2008 most recent data available
Worldwide Tanker Spills	1994-2008*	Last 15 years of data available
U.S. Coastal and Offshore Waters Tanker Spills	1974-2008*	1974 earliest reliable data 2008 most recent data available
U.S. Coastal and Offshore Waters Tanker	1989-2008*	Last 20 years of data used instead of 15 years in order to capture at least one spill in the rate computations of "At Sea" and "In Port" spills of ≥ 1,000 bbl.
Alaska North Slope Tanker Spills	1977-2008*	ANS tanker fleet began transport from Valdez in August 1977 2008 most recent data available
Alaska North Slope Tanker Spills	1989-2008*	Last 20 years of data used instead of 15 years in order to capture at least one spill in the rate computations of "At Sea" and "In Port" spills of ≥ 1,000 bbl.
U.S. Offshore, Coastal and Inland Waters Barge Spills	1974-2008*	1974 earliest reliable data 2008 most recent data available
U.S. Offshore, Coastal and Inland Waters Barge Spills	1994-2008*	Last 15 years of data available
OCS Pipeline and Platform Spills	1964-2010, adjusted for a trend	1964 earliest recorded spill ≥ 1,000 bbl; 2010 data are the most recent OCS pipeline and platform data available during the initial drafting of the report
OCS Pipeline and Platform Spills	1996-2010	Last 15 years of data available during the initial drafting of the report
*Data on barge and tanker spills analyzed in this report are current through 2008 because that was the latest data available during the initial drafting of the report.		

5.1 Petroleum Spill Rates from OCS Platforms

This section discusses estimates of OCS platform spill rates for both the entire record, adjusted for a trend, and the last 15-years. There have been two additional OCS platform spills (Table 3, Fig. 1) since the spill rates were last calculated (Anderson and LaBelle, 2000).

5.1.1 OCS Platforms: Entire Record (1964 through 2010)

Based on the last five spills that occurred over the most recent 15.6 Bbbl of production (i.e., based on production intervals 3 through 18, Fig 6), the updated spill rate was 0.32 spills per Bbbl handled for OCS platform spills ≥ to 1,000 bbl (Table 9). This 0.32 updated spill rate is identical to the previous rate (Anderson and LaBelle, 2000) which was calculated on the last 3 spills over the most recent 9.5 Bbbl of production at the time (through 1999). This calculation was based on the same trend from the same starting point of the data (as did previous OCS spill rates calculations (Anderson and LaBelle, 1990, 1994, 2000). The updated OCS platform spill rate estimate of 0.06 spills per Bbbl handled for spills ≥10,000 bbl (Table 9) was calculated based on the last spill ≥10,000 bbl that occurred over the most recent 15.6 Bbbl of production (i.e., based on production intervals 3-18, Fig. 6). This is a decline compared to the previous 0.12 spill rate (Anderson and LaBelle, 2000) which was based on a conservative approach for estimating a rate for OCS platform spills ≥10,000 bbl over an interval where no spills that large occurred.

5.1.2 OCS Platforms: Last 15 Years (1996 through 2010)

Spill rates for OCS platform spills of ≥ 1,000 bbl increased from 0.13 from1985 through 1999 (Anderson and LaBelle, 2000) to 0.25 from1996 through 2010. This increase is due to two new spills (Hurricane Rita and Macondo) that occurred in the most recent 15 year period (1996 through 2010), prior to which the next most recent OCS platform spill (≥ 1,000 bbl) occurred in 1980. Spill rates for OCS platform spills ≥ 10,000 bbl increased from 0.05 from1985 through 1999 (Anderson and LaBelle, 2000) to 0.13 from1996 through 2010. This increase is due to the Macondo well spill, prior to which the next most recent OCS Platform_spill ≥10,000 bbl was in 1970.

5.2 Petroleum Spill Rates from OCS Pipelines

This section discusses OCS Pipeline spill rates for both the entire record and the last 15 years. There have been four additional OCS pipeline spills (Table 4; Fig. 1) since the spill rates were last calculated (Anderson and LaBelle, 2000).

5.2.1 OCS Pipelines: Entire Record (1964 through 2010)

The updated spill rate of 0.94 spills per Bbbl handled for OCS pipeline spills ≥ 1,000 bbl (Table 9) was calculated based on the last nine spills that occurred over the most recent 9.6 Bbbl of production (i.e., based on production intervals 18-36, Fig 7). This calculation was based on the new trend of fewer spills per Bbbl in the second half of the production record. This 0.94 rate is lower than the 1.33 previous spill rate (Anderson and LaBelle, 2000) which was based on the entire record of 16 spills over 12.0 Bbbl of production at the time (through 1999). Over the entire record (1964 through 2010), 4 of 20 OCS pipeline spills (≥1,000 bbl) were ≥ 10,000 bbl, none of which occurred during the trend period of the second half of the production record. The updated OCS Pipeline spill rate estimate of 0.19 spills per Bbbl produced for spills ≥10,000 bbl (Table 9) was calculated by applying the ratio four out of 20 (4/20, or 20%) to the new 0.94 rate for spills ≥ 1,000 bbl. This is a decline compared to the previous 0.33 spill rate (Anderson and LaBelle, 2000) which was based on the entire record of 4 spills ≥ 10,000 bbl over 12.0 Bbbl of production.

Table 9. Spill Rates for Petroleum Spills ≥ 1,000 Barrels from OCS Platforms and Pipelines, 1964 through 2010

Spill Size and Source	Previous Rate, 1964 - 1999[1]			Updated Rate, 1964 - 2010			1996 - 2010		
	Volume Handled (Bbbl)[2]	Number of Spills	Spill Rate[3]	Volume Handled (Bbbl)[2]	Number of Spills	Spill Rate[3]	Volume Handled (Bbbl)[2]	Number of Spills	Spill Rate[3]
≥ 1,000 bbl[4]									
Platforms	9.5 of 12.0[5]	3 of 11[5]	0.32[5]	15.8 of 18.1[6]	5 of 13[6]	0.32	8.0	2	0.25
Pipelines	12.0	16	1.33	9.6 of 18.1[7]	9 of 20[7]	0.94	8.0	7	0.88
≥ 10,000 bbl[4]									
Platforms	12.0[8]	4[8]	0.12	15.8 of 18.1[9]	1 of 5[9]	0.06	8.0	1	0.13
Pipelines	12.0	4	0.33	9.6 of 18.1[10]	-[10]	0.19	8.0[11]	-[11]	0.18

Note: Petroleum includes crude oil, condensate, and diesel.

1 Anderson and LaBelle (2000)

2 Billion = 10^9 . Billion barrels = Bbbl = 10^9 bbl

3 Spill rate = number spills ≥ 1,000 bbl (or 10,000 bbl or 100,000 bbl) in size per Bbbl produced.

4 Barrel (bbl) = 42 gallons

5 Based on continued trend initially identified in Anderson and LaBelle (1990). Most recent 9.5 Bbbl production over which 3 spills ≥ 1,000 bbl occurred, 1964-1999.

6 Based on continued trend initially identified in Anderson and LaBelle (1990). Most recent 15.6 Bbbl production over which 5 spills ≥ 1,000 bbl occurred, 1964-2010.

7 New trend, 9 spills ≥ 1,000 bbl over most recent 9.6 Bbbl production 1964-2010; compare to 20 spills over entire 18.1 Bbbl production record (1.10 spills/Bbbl entire record).

8 Four of 11 platform spills were ≥10,000 bbl, none of which were in trend period. Based on ratio of 4/11 of the rate for platform spills ≥1,000 bbl in trend period, 1964-1999.

9 Based on continued trend initially identified in Anderson and LaBelle (1990). Most recent 15.6 Bbbl production over which one spill ≥ 10,000 bbl occurred, 1964-2010.

10 Four of 20 pipeline spills were ≥ 10,000 bbl, none of which were in the last 9.6 Bbbl production. Based ratio of on 4/20 of the pipeline rate for spills ≥ 1,000 bbl, in the last 9.6 Bbbl.

11 Four of 20 pipeline spills were ≥ 10,000 bbl, none of which were in last 15 years. Based on ratio of 4/20 of the pipeline rate for spills ≥ 1,000 bbl, 1996-2010.

Sources: U.S. DOI/BOEMRE OCS Spill Database, May 2011; U.S. DOI/ONRR OCS Production Data, May 2011 (http://www.boemre.gov/stats/OCSproduction.htm)

5.2.2 OCS Pipelines: Last 15 Years (1996 through 2010)

Spill rates for OCS pipelines ≥ 1,000 bbl declined from 1.38 from1985 through 1999 (Anderson and LaBelle, 2000) to 0.88 from1996 through 2010. Spill rates for OCS pipeline spills ≥ 10,000 bbl declined from 0.34 from1985 through1999 (Anderson and LaBelle, 2000) to 0.18 from1996 through 2010 (Table 9). Since there were no spills ≥ 10,000 bbl in the last 15 years, the revised rate of 0.18 spills per Bbbl produced was estimated by pro-rating the 0.88 rate for spills ≥ 1,000 bbl by the relative weight of spills ≥ 10,000 in the entire data set (4 out of 20 spills ≥ 1,000 or 4/20th).

It is worth noting that this most recent 15-year period (from 1996 through 2010) spans the move of OCS oil production into deepwater (> 1,000 ft. water depth). In 1996, deepwater oil production in the Gulf of Mexico was just under 20% of the total oil production in the region. In 2010, that percentage had increased to 81% (http://www.data.bsee.gov/homepg/data_center/production/production/summary.asp).

5.3 Crude Oil Spill Rates from Tankers in Worldwide Coastal and Offshore Waters

5.3.1 Worldwide Tankers: Entire Record, 1974 through 2008

Data on crude oil tanker spills ≥1,000 bbl occurring in worldwide waters from 1974 through 2008 (Fig. 2) provide a robust number of spill observations over time. The annual spill rate did not increase or decrease strictly monotonically over time. However, it clearly has declined over the decades (Table 10; Fig. 8). The annual rates varied between: 1.50 – 2.16 spills per Bbbl handled in the 1970's; 0.78 – 1.90 spills per Bbbl handled in the 1980's; 0.26 – 1.49 spills per Bbbl handled in the 1990's; and 0.07 – 0.37 spills per Bbbl handled from 2000 through 2008.

In the 1980's and early 1990's, the Nova (1985, Iran), the Khark 5 (1989, Morocco) and the Aegean Sea (1992, Spain) each spilled about half a million bbl; the Odyssey (1988, Canada) and the Haven (1991, Italy) each spilled about a million bbl; and the ABT Summer spilled almost 2 million bbl (1991, Angola); all were crude oil spills.

Following the March 1989 Exxon Valdez spill of about a quarter million bbl in Prince William Sound, the U.S. Congress passed the Oil Pollution Act of 1990 (OPA 90) which included establishing the double-hull standard for U.S. flagged oil tankers; all single-hull oil U.S. flagged oil tankers have since been sold, scrapped, or converted to other uses.

In 1992, changes in the international regulatory regime in the form of additions to MARPOL 73/78 (the International Convention for the Prevention of Pollution by Ships) mandated a phased worldwide transition to double-hull vessels or their equivalent. Although the double-hull requirement was adopted in 1992, following the Erika incident off the coast of France in December 1999 [about 150,000 bbl heavy fuel oil oiling 300 km shoreline, impacting oyster beds and killing over 60,000 birds], International Maritime Organization (IMO) Member States made further changes accelerating the phase-out of single-hull tankers (IMO website, June 2011). Consequently, the final phasing-out date for the last group of single-hull tankers was 2010. It is likely that these regulatory changes have greatly contributed to reductions in the frequency of large tanker spills identified in the tanker data in the last analysis (Anderson and LaBelle, 2000) with further reductions shown in this report.

Table 10. Spill Rates for Crude Oil Spills ≥ 1,000 Barrels from Worldwide Tankers, 1974 through 2008

Spill Size and Location	Previous[1] Rate[2] 1974 - 1999[1]			Updated Rate[2] 1974 - 2008			Last 15-Year Rate[2] 1994 - 2008		
	Volume Transported (Bbbl)[3]	Number of Spills	Spill Rate[2]	Volume Transported (Bbbl)[3]	Number of Spills	Spill Rate[2]	Volume Transported (Bbbl)[3]	Number of Spills	Spill Rate[2]
≥ 1,000 bbl[4]									
All Spills	239.7	278	1.16	359.9	303	0.84	185.8	59	0.32
In Port		117	0.49		137	0.38		33	0.18
At Sea		161	0.67		166	0.46		26	0.14
≥10,000 bbl[4]									
All Spills	239.7	143	0.59	359.9	151	0.42	185.8	20	0.11
In Port		44	0.18		50	0.14		7	0.04
At Sea		99	0.41		101	0.28		13	0.07
≥ 100,000 bbl[4]									
All Spills	239.7	58	0.24	359.9	62	0.17	185.8	6	0.03
In Port		16	0.07		20	0.05		4	0.02
At Sea		42	0.17		42	0.12		2	0.01

[1] Anderson and LaBelle (2000)

[2] Spill rate = number spills ≥ 1,000 bbl (or 10,000 bbl or 100,000 bbl) per Bbbl handled

[3] Billion barrels = Bbbl = 10^9 bbl;

[4] Barrel = bbl = 42 U.S. gallons;

Sources: DOI/BOEMRE Worldwide Tanker Spill Database, January 2011; BP Statistical Review of World Energy, 1975-2009

The spill rates calculated on the entire record for "At Sea" and "In Port" spills combined (Table 10) show a decline from 1.16 to 0.84 spills per Bbbl ≥1,000 bbl from Tankers Worldwide (compared to Anderson and LaBelle, 2000). Rates for larger spill sizes also declined, from 0.59 to 0.42 spills per Bbbl (spills ≥10,000 bbl) and from 0.24 to 0.17 spills per Bbbl (spills ≥ 100,000 bbl) (compared to Anderson and LaBelle, 2000).

Rates for spills that occurred offshore ("At Sea") were analyzed separately from those occurring in harbors or at piers ("In Port"). Inland tanker spills were excluded from this analysis because they are beyond BOEM purview. Both the "At Sea" and the "In Port" rates declined for all three spill sizes calculated for 1974 through 2008 as compared to the last calculations for 1974 through1999 (Anderson and LaBelle, 2000).

5.3.2 Tankers Worldwide: Last 15 Years (1994 through 2008)

The updated spill rates for crude oil spills from tankers worldwide in the last 15 years are significantly lower than rates based on the entire record for all three spill sizes, i.e. 0.32, 0.11 and 0.03 spills per Bbbl from1994 through 2008 versus 0.84, 0.42 and 0.17 spills per Bbbl from1974 through 2008 for spills ≥ 1,000 bbl, ≥ 10,000 bbl, and ≥ 100,000 bbl respectively.

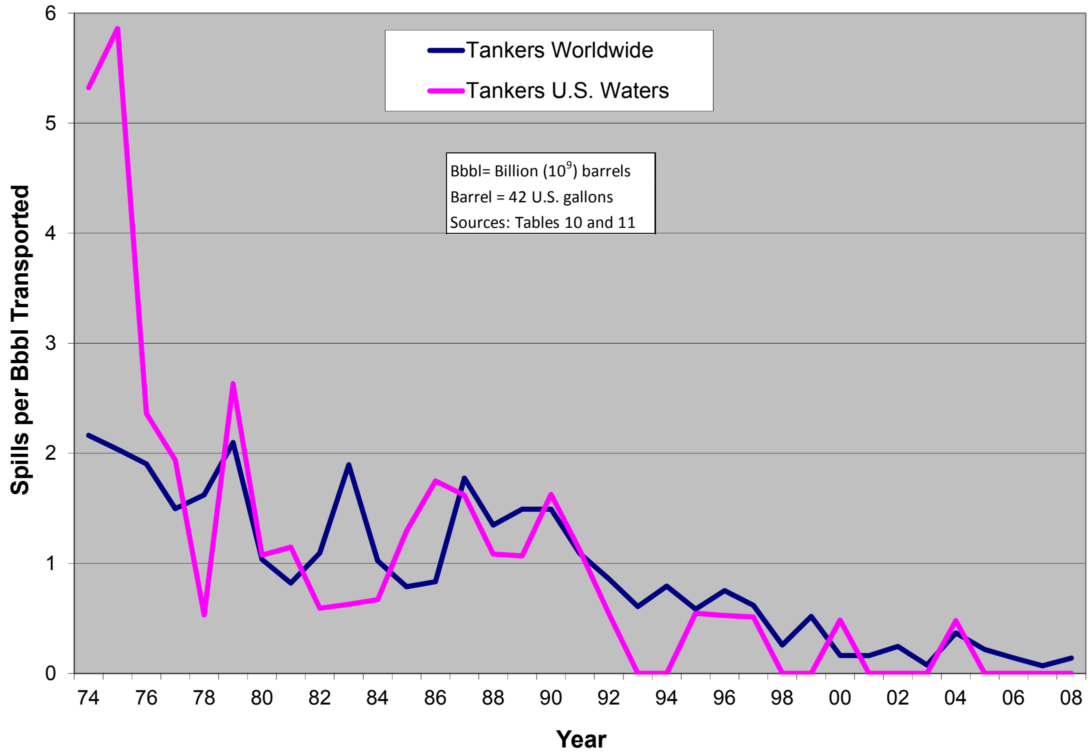


Figure 8. Spill Rates by Year for Crude Oil Spills ≥1,000 bbl from Worldwide Tankers and Tankers in U.S. Waters

The 15-year rates for 1994 through 2008 are also significantly lower than the 15-year rates for 1985 through1999 calculated in Anderson and LaBelle (2000) for all three spill sizes, i.e., 0.32, 0.11 and 0.03 spills per Bbbl from1994 through 2008 versus 0.82, 0.37 and 0.12 spills per Bbbl from1974 through1999 for spills ≥ 1,000 bbl, ≥ 10,000 bbl, and ≥ 100,000 bbl, respectively. In addition, both the "At Sea" and the "In Port" rates declined for all three spill sizes calculated for 1994 through 2008, as compared to the previous calculations for 1985 through 1999 (Anderson and LaBelle, 2000).

5.4 Crude Oil Spill Rates from Tankers in U.S. Coastal and Offshore Waters

5.4.1 U.S. Tankers: Entire Record (1974 through 2008)

Tanker spills ≥1,000 bbl in U.S. coastal and offshore waters (Fig. 3) have one to six spill observations each year from1974 through1992, but then have five observations total in the 16 years from1993 through 2008. The annual spill rate did not strictly increase or decrease monotonically over time (Fig. 8, Table 6). The highest annual rate, 5.86 spills per Bbbl handled, was in 1975 near the beginning of the data series, and the rate exceeds 2.00 spills per Bbbl handled in 1974, 1975, 1976, and 1979. In general, however, the rates in the second half of the time period were lower than those in the first half. In Table 11, the spill rates calculated on the entire record showed a decline compared to when they were last calculated (Anderson and LaBelle, 2000). Rates for spills ≥1,000 bbl declined from 1.03 to 0.85 spills per Bbbl handled. Rates for spills ≥10,000 bbl declined from 0.43 to 0.32 spills per Bbbl handled. “At Sea” and “In Port” rates also declined for both spill sizes (Table 11).

Table 11. Spill Rates for Crude Oil Spills ≥ 1,000 Barrels from Tankers in U.S. Coastal and Offshore Waters, 1974 through 2008

Spill Source	Previous[1] Rate[2] 1974 - 1999			Updated Rate[2] 1974 - 2008			Last 20-Year Rate[2] 1989 - 2008[3]		
	Volume Transported (Bbbl)[4]	Number of Spills	Spill Rate[2]	Volume Transported (Bbbl)[4]	Number of Spills	Spill Rate[2]	Volume Transported (Bbbl)[4]	Number of Spills	Spill Rate[2]
≥ 1,000 bbl[5]									
All Spills	44.5	46	1.03	62.4	53	0.85	38.5	13	0.34
In Port		30	0.67		37	0.59		10[6]	0.26
At Sea		16	0.36		16	0.26		3	0.08
≥ 10,000 bbl[5]									
All Spills	44.5	19	0.43	62.4	20	0.32	38.5	4	0.11
In Port		9	0.20		10	0.16		1[6]	0.03
At Sea		10	0.23		10	0.16		3	0.08

[1] Anderson and LaBelle (2000)

[2] Spill rate = number spills ≥ 1,000 bbl (or 10,000 bbl or 100,000 bbl) in size per Bbbl handled

[3] Zero spills ≥ 1,000 bbl from tankers in U.S. Waters "At Sea" occurred in the last 15 years (1994-2008). To capture the most recent "At Sea" spills, the 20-year distribution used instead of 15 year distribution.

[4] Billion barrels = Bbbl = 10^9 bbl

[5] Barrel = bbl = 42 U.S. gallons

[6] Note that, in last 15 years (1994-2008), there were 10 spills ≥ 1,000 bbl from tankers in U.S. Waters "In Port". One spill was ≥ 10,000 bbl; the total volume was 12,800 bbl.

Sources: DOI/BOEMRE Worldwide Tanker Spill Database, January 2011; U.S. Army Corps of Engineers, Waterborne Commerce of the United States, 1975-2009.

5.4.2 U.S. Tankers: Last 20 Years: (1989-2008)

In the last 15 years of data, there were no “At Sea” spills ≥1,000 bbl from crude oil Spills from tankers in U.S. coastal or offshore waters. For this reason, the last 20 years were examined instead. The spill rates for crude oil spills from tankers in U.S. coastal and offshore waters in the last 20 years dropped significantly when compared to the entire record (Table 11). Spill rates for spills ≥1,000 bbl dropped from 0.85 to 0.34 spills per Bbbl handled, and spills ≥10,000 bbl dropped from 0.32 to 0.11 spills per Bbbl handled. In both size categories, both the “At Sea” and “In Port” rates also decreased in the last 20 years as compared to the entire 1974 through 2008 record (Table 11). The 20-year rates for 1989 through 2008 are also significantly lower than the 15-year rates for 1985 through 1999 calculated previously (Anderson and LaBelle, 2000) for both spill sizes, i.e. 0.34, 0.26 and 0.08 spills per Bbbl for “All”, “In Port” and “At Sea” spills from1989 through 2008 vs. 0.73, 0.44 and 0.29 spills per Bbbl previous 15-year rates (1985 through 1999) for spills ≥ 1,000 bbl, and 0.11, 0.03 and 0.08 spills per Bbbl vs. 0.25, 0.07 and 0.18 spills per Bbbl for spills ≥ 10,000 bbl.

5.5 Crude Oil Spill Rates from ANS Tankers "In Port" and "At Sea"

5.5.1 ANS Tankers: Entire Record (1977 through 2008)

U.S. law requires that marine transportation of goods between U.S. ports be performed by U.S. flagships. These U.S. flagships must be owned by U.S. companies, built in the United States, and manned by U.S. crews. Table 12 presents the calculated spill rates for ANS crude oil transported by tanker from Valdez, Alaska to U.S. West Coast Destinations and to Panama. The table is based on the 11 spill observations that occurred from 1978 through1991, with no further observations from1992 through 2008 (Fig 4). The volume of ANS crude oil and associated tanker spill occurrences peaked from 1987 through1989, and has generally decreased in volume annually since then. No spill occurrences have been observed since 1991. The spill rates calculated on the entire record showed a decline compared to when they were last calculated (Anderson and LaBelle, 2000). Rates for spills ≥1,000 bbl declined from 0.88 to 0.72 spills per Bbbl handled. The decline occurred in both the "In Port" and the "At Sea" components. Rates for spills ≥10,000 bbl declined from 0.23 to 0.20. Due to the lack of any "In Port" spills ≥10,000 bbl, only an "At Sea" rate for spills ≥10,000 bbl was estimated (Table 12).

5.5.2 ANS Crude Oil from Tankers: Last 20 Years (1989 through 2008)

There were no spills ≥1,000 bbl from ANS Crude Tankers in the last 15 years of data, so the last 20 years were examined instead (Table 12). The spill rate for "In Port" crude oil spills ≥1,000 bbl from ANS Crude Tankers increased from 0.26 to 0.35 spills per Bbbl from the entire record to the last 20 years record, while the "At Sea" rate declined from 0.46 to 0.11 spills per Bbbl handled, for a net decline for the "All Spills" rate from 0.72 to 0.46 spills per Bbbl over the last 20 year period as compared to the entire 1977 through 2008 record. The "At Sea" spill rate for spills ≥10,000 bbl in the last 20 years declined compared to the entire record decreased from 0.20 to 0.12 spills per Bbbl handled. Due to the lack of any "In Port" spills ≥10,000 bbl, only an "At Sea" rate for spills ≥10,000 bbl was estimated. The last 20-year rates for 1989 through 2008 declined as compared to the previously calculated 15-year rates (Anderson and LaBelle, 2000) for both spill size categories; spill rates of 0.92, 0.46 and 0.46 spills per Bbbl for "All", "In Port" and "At Sea" spills of 1,000 bbl or greater (1985 through 1999) declined to 0.46, 0.35 and 0.11 spills per Bbbl (1989 through 2008). There was one "At Sea" spill of 10,000 bbl or greater in the last 20 years for an "At Sea" rate of 0.12 spills per Bbbl compared to 0.34 spills per Bbbl for the previously calculated (Anderson and LaBelle, 2000) 15-year (1985 through 1999) "At Sea" spill rate.

Table 12. Spill Rates for Alaska North Slope Crude Oil Spills ≥ 1,000 Barrels from Tankers, U.S. Flag Ships, 1977 through 2008

Spill Source: U.S. Flag Ships[1]	Previous[2] Rate[3] 1977 - 1999[4]			Updated Rate[3] 1977 - 2008			Last 20-Year Rate[3] 1989 - 2008[4]		
	Volume[5] Transported (Bbbl)[6]	Number of Spills	Spill Rate[3]	Volume[5] Transported (Bbbl)[6]	Number of Spills	Spill Rate[3]	Volume[5] Transported (Bbbl)[6]	Number of Spills	Spill Rate[3]
≥ 1,000 bbl[7]									
All Spills[8]	12.6	11	0.88	15.3	11	0.72	8.7	4	0.46
In Port		4	0.32		4	0.26		3	0.35
At Sea		7	0.56		7	0.46		1	0.11
≥10,000 bbl[7]									
All Spills	12.6	3	0.23	15.3	3	0.20	8.7	1	0.12
In Port[9]		0	-.-[10]		0	-.-[10]		0	-.-[10]
At Sea		3	0.23		3	0.20		1	0.12

[1] The Jones Act, part of the Merchant Marine Act of 1920, requires that goods transported by water between U.S. ports, such as North Slope Crude Oil from Valdez, AK to to U.S. coastal ports in Alaska, Hawaii, California and the Gulf of of Mexico be carried by U.S. Flag Ships. U.S. Flag Ships must be: constructed (or rebuilt) in the U.S., owned by U.S. citizens, crewed by U.S. citizens, and registered in the U.S..

[2] Anderson and LaBelle (2000)

[3] Spill rate = number of spills ≥ 1,000 bbl (or ≥ 10,000 bbl or ≥ 100,000 bbl) in size per Bbbl handled

[4] Zero spills ≥ 1,000 bbl for ANS crude oil tankers in last 15 years (1994-2008). Most recent 20-year distribution was used instead of 15-year data to capture at least one 'At Sea' and 'In Port' spill.

[5] Annual Alaskan North Slope Crude from Trans Alaska Pipeline System (TAPS) (http://www.alyeska-pipe.com/Default.asp) Loadings at Valdez Terminal in Alaska.

[6] Bbbl =Billion barrels = 10^9 bbl

[7] bbl= Barrel = 42 U.S. gallons

[8] Over the entire record, there were 11 spills totaling 0.32 million bbl from TAPS tanker fleet (all U.S. Flag Ships). Eight were in U.S. waters, two were in the Panama Canal Zone Zone (1978 and 1980), one was in Mexican waters (1981). The largest spill was the Exxon Valdez, 262,000 bbl, in March 1989.

[9] Zero 'In Port' spills of 10,000 bbl and greater observed over entire record; spill rate not calculated.

[10] Dash (-.-) indicates zero spills observed, rate not calculated.

Sources: DOI/BOEMRE Tanker Spill Database, January 2011; U.S. Department of Commerce, Maritime Administration, Annual Loadings.

5.6 Petroleum Spill Rates from Barges in U.S. Coastal, Offshore, and Inland Waters

5.6.1 U.S. Barges: Entire Record (1974 through 2008)

Data on petroleum spills ≥1,000 bbl from petroleum barges in U.S. coastal, offshore, and inland waters provide a robust number of spill observations since 1974 (Fig. 5, Table 7). The annual spill rate did not increase or decrease monotonically over time (Fig. 9; Table 7). The annual rate exceeded 7 spills per Bbbl handled in 1974, 1975, 1977, 1978, and 1985. These rates have declined over the years**.** In the 18 years from 1991 through 2008, the spill rates were generally 50 percent or less than the rates in the first 17 years from 1974 through 1990. The *lowest* rate (3.00 spills per Bbbl handled) in the earlier period, is nearly the same as the *highest* spill rate in the later part of the record (3.13 spills per Bbbl handled).

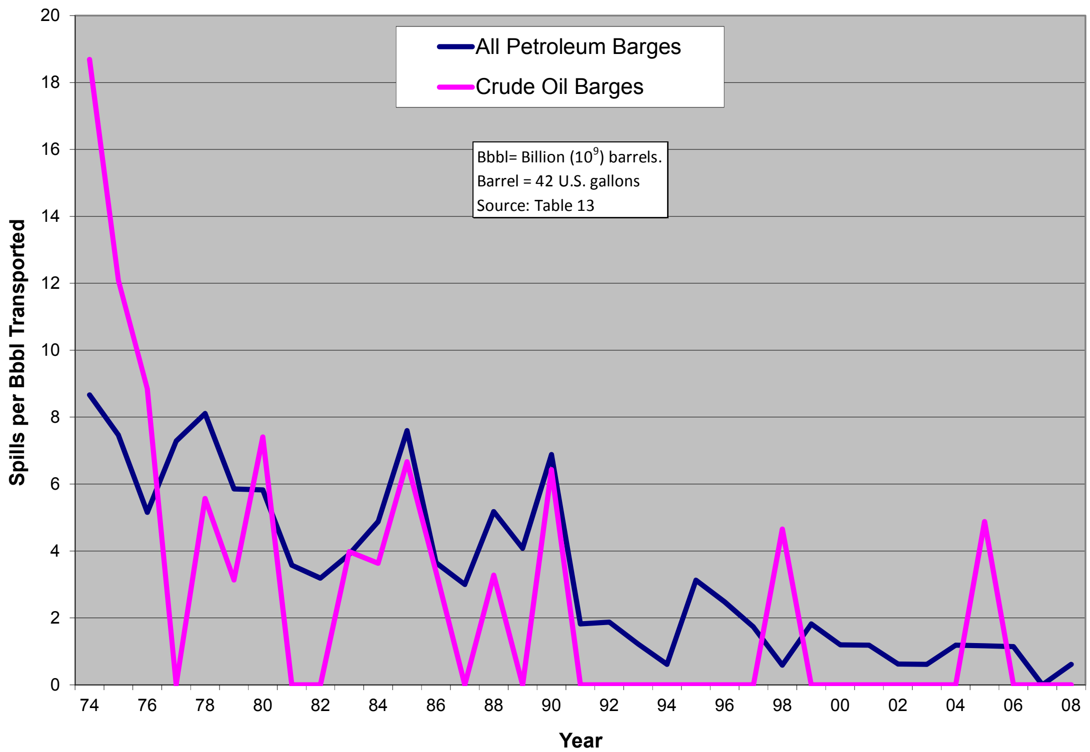


Figure 9. Spill Rates by Year for Petroleum and Crude Oil Spills ≥ 10,000 Barrels from Barges in U.S. Waters, Spills

Spill rates calculated on the entire record 1974 through 2008 showed a decline from 4.30 to 3.37 spills per Bbbl handled, compared to the previously calculated 1974 through 1999 record (Anderson and LaBelle, 2000) for spills of "all petroleum products" ≥1,000 bbl. Rates for all petroleum spills from barges spills ≥10,000 bbl declined from 0.81 to 0.56 spills per Bbbl handled (Table 13, Fig. 9).

Crude oil barge spills are a subset of the "all petroleum products" barge spills. Rates for crude oil spills from barges for spills ≥1,000 bbl or ≥10,000 bbl declined from 3.55 to 3.09 spills per Bbbl handled and from 0.68 to 0.55 spills per Bbbl handled, respectively for the entire 1977 through 2008 record compared to the previously calculated 1974 through 1999 record (Anderson and LaBelle, 2000).

5.6.2 U.S. Barges: Last 15 Years (1994 through 2008)

Barge spill rates for the last 15 years (1994 through 2008) declined dramatically as compared to the entire 1974 through 2008 record, especially for crude oil barges and for both spill sizes. The "all petroleum products" barge rates for spills ≥1,000 bbl declined

Table 13. Spill Rates for Petroleum and Crude Oil Spills from Barges in U.S. Coastal, Offshore and Inland Waters, 1974 through 2008

Spill Source	Previous Rate 1974 - 1999[2]			Updated Rate 1974 - 2008			Last 15-Year Rate 1994 - 2008		
	Volume Handled (Bbbl)[3]	Number of Spills	Spill Rate[4]	Volume Handled (Bbbl)[3]	Number of Spills	Spill Rate[4]	Volume Handled (Bbbl)[3]	Number of Spills	Spill Rate[4]
≥1,000 bbl[5]									
All Petroleum[1] Products	43.48	187	4.30	58.53	197	3.37	25.10	30	1.20
Crude Oil Only	7.32	26	3.55	9.06	28	3.09	3.21	2	0.62
≥ 10,000 bbl[5]									
All Petroleum[1] Products	43.48	35	0.81	58.53	33	0.56	25.10	4	0.16
Crude Oil Only	7.32	5	0.68	9.06	5	0.55	----[6]	----[6]	0.12[6]

[1] Petroleum includes crude oil, gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, lubricating oils and greases, asphalt, and liquified gases.

[2] Anderson and LaBelle (2000)

[3] Billion barrels = Bbbl = 10^9 bbl

[4] Spill rate = number spills ≥ 1,000 bbl or 10, 000 bbl per Bbbl handled

[5] Barrel = bbl = 42 U.S. gallons

[6] Five of 26 crude oil spills from barges were ≥ 10,000 bbl, none of which were in last 15 years. The rate is based on 5/26 of the the ≥ 1,000 bbl 'Crude Oil Only' rate for 1994-2008.

Sources: DOI/BOEMRE Worldwide Tanker Spill Database, January 2011; U.S. Army Corps of Engineers (USACOE), Waterborne Commerce of the United States, 1975-2009.

from 3.37 to 1.20 spills per Bbbl handled, and crude oil spill rates from barges declined from 3.09 to 0.62 spills per Bbbl handled. The "all petroleum products" barge rates for spills ≥10,000 bbl declined from 0.56 to 0.16 spills per Bbbl handled, with the "crude oil only" rates declining from 0.55 spills per Bbbl handled to less than 0.12 spills per Bbbl handled. The updated 15-year rates of 1.20 and 0.62 spills per Bbbl for "all petroleum product" spills and "crude oil only" spills of 1,000 bbl or greater were significant reductions compared to the 3.08 and 1.23 spills per Bbbl 15-year (1985 through1999) spill rates previously calculated (Anderson and LaBelle, 2000). The rates for spills of 10,000 bbl or greater also declined from 0.52 and 0.23 spills per Bbbl for "all petroleum product" spills and "crude oil only" spills in the last 15-years (1985 through 1999) calculation (Anderson and LaBelle, 2000) to 0.16 and 0.12 spills per Bbbl respectively for the most recent 15-year period (1994 through 2008) (Fig. 9, Table 13).

6.0 DISCUSSION OF SPILL SIZES

This section discusses the historic OCS spill sizes relative to spill numbers from all sources, the means and medians in spill sizes, and some trends in these data.

6.1 Summary of Historic OCS Spills ≥ One Barrel

The vast majority of spills are ≥ 1,000 barrels. If you include all spills ≥ one barrel, for the 46-year time period from1964 through 2009, you find that 98.9 percent of all spills were <1,000 barrels in volume and 1.1 percent of spills were ≥1,000 barrels in volume. However, the spills ≥ 1,000 barrels in volume accounted for 90.6 percent by volume of the almost 570,000 bbl petroleum spilled in that time period (Fig. 10) (and more than 99.9 percent by volume from 1964 through 2010 due to the Macondo well spill; see Appendix C).

6.2 Average and Median Spill Sizes for All Spill Sources

Averages and medians are statistical measures that are frequently used to characterize a *typical* event. The median ("middle number") spill size is the number where half of the historic spills are of higher volume and half of the spills are of lower volume.

The median is different from the average, which is just the sum of volume of all spills divided by the number of the spills. Both of these numbers help describe a set of values, such as spill volumes.

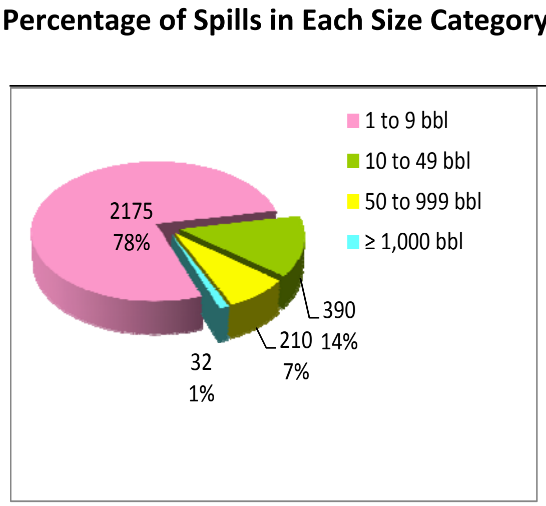
Average and median spill sizes were calculated for each spill source for spills ≥ 1,000 bbl and for spills ≥10,000 bbl for entire record and for the most recent 15 (or 20) years of data. Tables 14 and 15 provide average and median spill sizes by spill size category and source. In the case of OCS Platform spills, average and median spill sizes were calculated both through 2009 and 2010 to show the influence of the Macondo well spill.

The Macondo well spill size overwhelms the rest of the record in any calculation using spill volume. The Macondo well spill volume was more than 8.5 times the cumulative 570,000 bbl of petroleum than had been spilled in the previous 46 years (including all spills ≥ one bbl) on the OCS from1964 through 2009 from all OCS oil and gas activities).

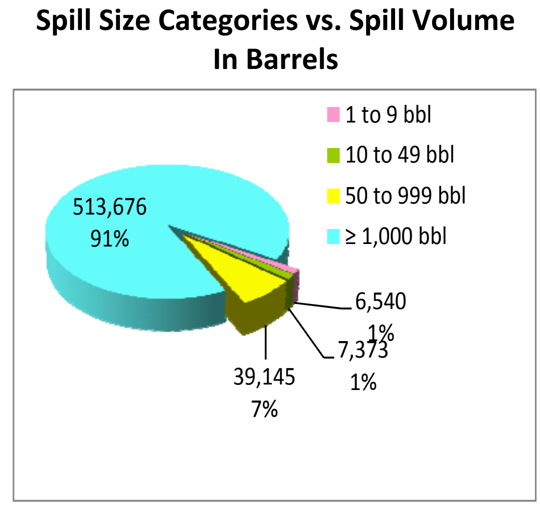
The Macondo well spill was a complete loss of well control. This was the first uncontrolled deepwater blowout to occur on the OCS and it continued for 87 days.

In the interest of characterizing the size of a more *typical* or *representativ*e OCS spill one could exclude the Macondo well spill volume in the calculation of average or median spill size because the BOEM EISs include an analysis of a very large oil spill event (such as the Macondo well spill). It is appropriate, however, to count the Macondo well spill in the spill rates for spills ≥1,000 and 10,000 bbl, which are used in the EISs as spill rate estimates.

Figures 11 and 12 compare the average and median spill sizes over the entire record for each data source and for the most recent 15 year period prior to Macondo well for OCS platforms and for the most recent 15 (or 20) years for pipelines, tankers, and barges for spills ≥ 1,000 and ≥10,000 bbl, respectively.



Number of Spills, All Spill Sizes
Total = 2807
1964 through 2009



Spill Volume, All Spill Sizes
Total = 566,734 Barrels
1964 through 2009

Petroleum Spills from OCS Oil & Gas Activities by Spill Size, 1964 to 2009					
Spill Size in Barrels	Number of Spills	Barrels Spilled	Average Spill Size	% Spills ≥1 bbl[1]	% Volume ≥ 1bbl[1]
1 to 9	2175	6,540	3	77.48%	1.15%
10 to 49	390	7,373	19	13.89%	1.30%
50 to 999	210	39,145	186	7.48%	6.91%
≥ 1,000	32	513,676	16,052	1.14%	90.64%
Total ≥ 1 bbl	2,807	566,734	202	100.00%	100.00%
[1]bbl = Barrel = 42 U.S. Gallons					

Figure 10. Petroleum Spills from OCS Oil and Gas Activities: Spill Numbers and Sizes by Size Category, 1964 through 2009

Excluding the Macondo well spill in the average and median spill sizes, the size of spills from platforms and pipelines tend to be smaller than those from tankers (Figs. 11 and 12).

Also, tanker spills in U.S. coastal and offshore waters tend to be smaller than tanker spills worldwide. Although the estimated rate for barge spills in U.S. waters is relatively high in comparison to the other estimated spill rates, the average and median spill sizes are comparatively small (Figs. 11 and 12).

Table 16 provides data for OCS pipeline and pipeline spill for all sizes for the time period from 1996 through 2010. Spill numbers, volumes, spill sizes (average and median) by spill source are listed. Spill rates for platforms and pipelines combined were also calculated and are listed by spill size category.

Table 14. Average and Median Spill Sizes ≥ 1,000 Barrels by Spill Source

Spill Source	Entire Record			Last 15 Years[1]		
	Number of Spills	Average Spill Size (bbl)[2]	Median Spill Size (bbl)[2]	Number of Spills	Average Spill Size (bbl)[2]	Median Spill Size (bbl)[2]
OCS Platforms (1964-2009 pre-Macondo)[4]	4/12[3]	3,755/20,131[3]	3,283/6,033[3]	1	5,066	5,066
OCS Platforms (1964-2010 includes Macondo)[4]	5/13[5]	983,000/395,500[5]	5,066/7,000[5]	2	2.5 million	2.5 million
OCS Pipelines (1964-2010)	9/20 [6]	2,881/13,605 [6]	2,000/4,551 [6]	7	2,771	1,720
Tankers Worldwide, Total (1974-2008)	303	95,224	9,762	59	34,932	5,657
In Port	137	67,505	6,310	33	39,674	2,831
At Sea	166	118,100	17,381	26	28,915	10,745
Tankers in U.S. Waters, Total (1974-2008)	53	37,249	6,310	13	31,925	3,100
In Port	37	14,854	4,000	10	4,250	2,375
At Sea	16	89,036	16,000	3	124,170	92,850
Tankers Alaska North Slope Crude, Total (1977-2008)[1]	11	29,495	4,950	4	68,765	5,729
In Port	4	4,712	3,845	3	4,386	2,000
At Sea	7	43,657	4,950	1	262,000	262,000
Barges in U.S. Waters Including Inland Waters (1974-2008)						
Petroleum Spills	197	6,123	2,750	30	5,385	2,185
Crude Oil Only	28	6,415	3,777	2	2,834	1,417

[1] "Last 15 Years" is actually "Last 20 Years", 1989-2008, for U.S. tankers and ANS tankers, so that Tankers in U.S. Waters would have at least one "At Sea" spill and so that Tankers Alaska North Slope Crude would have at least one spill in the calculation.

[2] bbl= Barrel = 42 U.S. gallons

[3] Four spills in previously identified trend on 1964-2009 OCS Platforms (pre-Macondo record). Average and median spill sizes: 4 spills in trend - 3,755 bbl and 3,283 bbl respectively; and over entire 12-spill record - 20,131 bbl and 6,033 bbl respectively.

[4] Two platform events were a combination of 3 spills each: Hurricane Hilda in 1964 and Hurricane Rita in 2005 (see Table 3). If these 2 spill events were calculated as 6 spills, then there were 16 OCS Platform spills over the entire 1964-2009 record, with average and median spill sizes 15,098 bbl and 2,530 bbl respectively; and there were 17 OCS Platform spills over the entire 1964-2010 record, with average and median spill sizes 302,450 bbl and 2,559 bbl respectively.

[5] Five spills in previously identified trend on 1964-2010 OCS Platforms record. Average and median spill sizes: 5 spills in the trend 983,000 bbl and 5,066 bbl respectively; and over entire 13 spill record - 395,500 bbl and 7,000 respectively.

[6] Nine spills in identified trend in 1964-2010 OCS Pipelines record. Average and median spill sizes: 9 spills in trend, 2,881 bbl and 2,000 bbl respectively; and over entire 20 spill record - 13,605 bbl and 4,551 respectively.

Sources: DOI/BOEMRE OCS Spill Database, May 2011; DOI/BOEMRE Worldwide Tanker Spill Database, January 2011.

Table 15. Average and Median Spill Sizes ≥ 10,000 Barrels by Spill Source

Spill Source	Entire Record[1]			Last 15 Years[2]		
	Number of Spills	Average Spill Size (bbl)[3]	Median Spill Size (bbl)[3]	Number of Spills	Average Spill Size (bbl)[3]	Median Spill Size (bbl)[3]
U.S. OCS Platforms (1964-2009 pre-Macondo)	none/ 4[3]	none/ 52,467[3]	none/ 59,000[3]	0	none	none
U.S. OCS Platforms (1964-2010 includes Macondo)[2]	1/5[4]	4.9 million/ 1 million[4]	4.9 million/ 65,000[4]	1	4.9 million	4.9 million
U..S. OCS Pipelines (1964-2010)	none/ 4[5]	none/ 52,618[5]	none/ 17,705[5]	0	none	none
Tankers Worldwide, Total	151	187,028	56,940	20	95,517	43,380
In Port	50	178,528	50,010	7	173,401	119,048
At Sea	101	191,236	62,899	13	53,580	35,000
Tankers in U.S. Waters, Total	20	92,391	22,905	4	96,328	55,306
In Port	10	45,232	21,000	1	12,800	12,800
At Sea	10	139,550	79,651	3	124,170	92,850
Tankers Alaska North Slope Crude, Total	3	97,062	15,000	1	262,000	262,000
In Port	0	none	none	0	none	none
At Sea	3	97,062	15,000	1	262,000	262,000
Barges in U.S. Waters Including Inland Waters						
Petroleum Spills	33	21,682	17,857	4	23,857	18,785
Crude Oil Only	5	19,344	18,238	0	none	none

[1] "Last 15 Years" actually "Last 20 Years", 1989-2008, for Tankers in U.S. Waters to have at least one "At Sea" spill and for Tankers Alaska North Slope Crude to have at least one spill in calculation.

[2] bbl = Barrel = 42 U.S. gallons

[3] Four spills in previously identified trend on 1964-2009 OCS Platforms pre-Macondo record of which none was ≥ 10,000 bbl. in entire record - 52,467 bbl and 59,000 bbl respectively. Average and median spill sizes for the 4 spills ≥ 10,000 bbl

[4] One of five spills in previously identified trend on 1964-2010 OCS Platforms record was ≥ 10,000 bbl. Average and median spill sizes: both 4.9 million bbl for the one spill in trend; and and for five spills ≥ 10,000 bbl over entire record - 1.0 million bbl and 65,000 bbl respectively.

5 None of the 9 spills in previously identified trend on 1964-2010 OCS Pipelines record was ≥ 10,000 bbl. Average and median spill sizes for 4 spills ≥ 10,000 over entire record were 52,618 and 17,705 bbl respectively.

Sources: DOI/BOEMRE OCS Spill Database, October 2010; DOI/BOEMRE Worldwide Tanker Spill Database, January 2011.

Table 16. Overall OCS Petroleum Spills Size Characterization By Spill Source, 1996 through 2010

Spill Size	Number of Petroleum[1] Spills			Barrels[2] Spilled			Spill Rate[5] Platforms & Pipelines Combined	Average Spill Size Barrels[2]			Median Spill Size Barrels[2]		
	Total	Platforms	Pipelines	Total	Platforms	Pipelines		Total	Platforms	Pipelines	Total	Platforms	Pipelines
< 1 Gallon (0.024 bbl)[3]	10,460	9,866	594	39.9	37.4	2.6	2,020.38	0.004	0.004	0.004	less than one gallon		
≥ 1 Gallon to < 1 bbl[3]	5,703	5,263	440	782.3	729.1	53.2		0.137	0.139	0.121			
≥ 1 to < 5 bbl	380	276	104	827.6	592.7	234.9	57.38	2.2	2.1	2.3	3.0	2.0	3.6
≥ 5 to < 10 bbl	79	48	31	533.9	327.3	206.6		6.8	6.8	6.7			
≥ 10 to < 20 bbl	79	52	27	1111.4	744.2	367.2	17.38	14.1	14.3	13.6			
≥ 20 to < 50 bbl	60	47	13	1865.0	1494.7	370.3		31.1	31.8	28.5			
≥ 50 to < 100 bbl	39	31	8	2,401.7	1,885.4	516.3	11.25	61.6	60.8	64.5	126.0	125.9	126.0
≥ 100 to < 500 bbl	51	39	12	9,655.2	7,584.3	2,070.9		189.3	194.5	172.6			
≥ 500 to < 1,000 bbl	13	8	5	8,963.8	4,800.8	4,163.0	1.63	689.5	600.1	832.6			
≥ 1,000 to < 2,000 bbl	4	0	4	5,747.0	0.0	5,747.0	1.00	1,436.8	None	1,436.8	1,980.0	5,066.0	1,720.0
≥ 2,000 to < 3,000 bbl	1	0	1	2,240.0	0.0	2,240.0		2,240.0	None	2,240.0			
≥ 3,000 to < 10,000 bbl	3	1	2	16,478.0	5066.0[4]	11,412.0		5,492.7	5,066.0	5,706.0			
≥ 10,000 Barrels	1	1	0	4,900,000	4,900,000	0	0.13	4,900,000	4,900,000	None	4,900,000	4,900,000	None
All Spills	16,873	15,632	1,241	4,950,646	4,923,262	27,384	2109.13	293.4	314.9	22.1	Less than one gallon		

[1] Petroleum includes crude oil, condensate and diesel.

[2] Barrel = bbl = 42 U.S. gallons

[3] Spills less than one bbl: 1999 to 2010 National Response Center (NRC) data; used average of 1999-2010 NRC data as proxy for 1996-1998 spills less than one bbl.

[4] The three spills from Hurricane Rita in 2005 are counted as a single 5,066 bbl event.

[5] Spill Rates based on 8.0 Bbbl production.

Sources: DOI/BOEMRE OCS Spill Database, May 2011

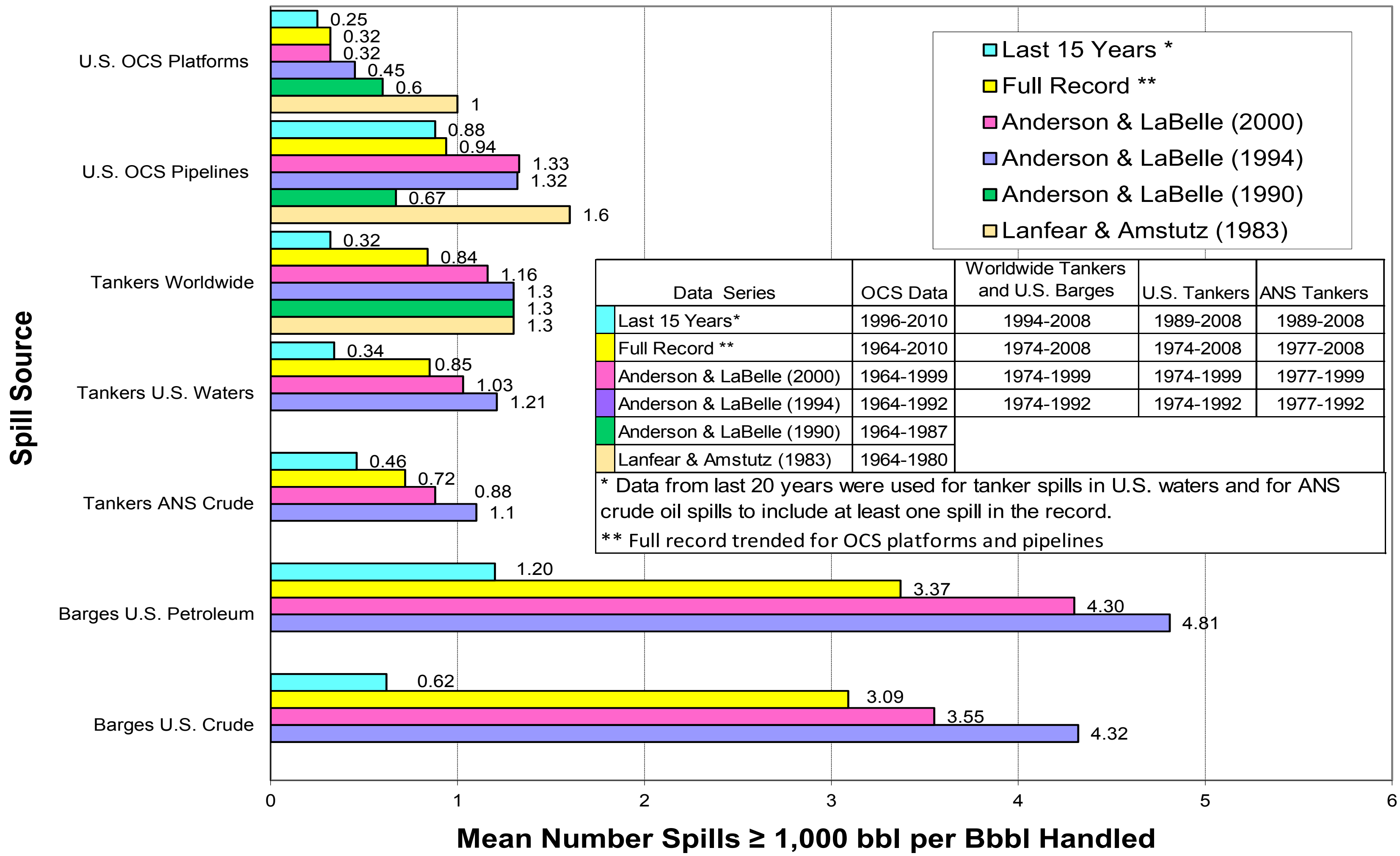
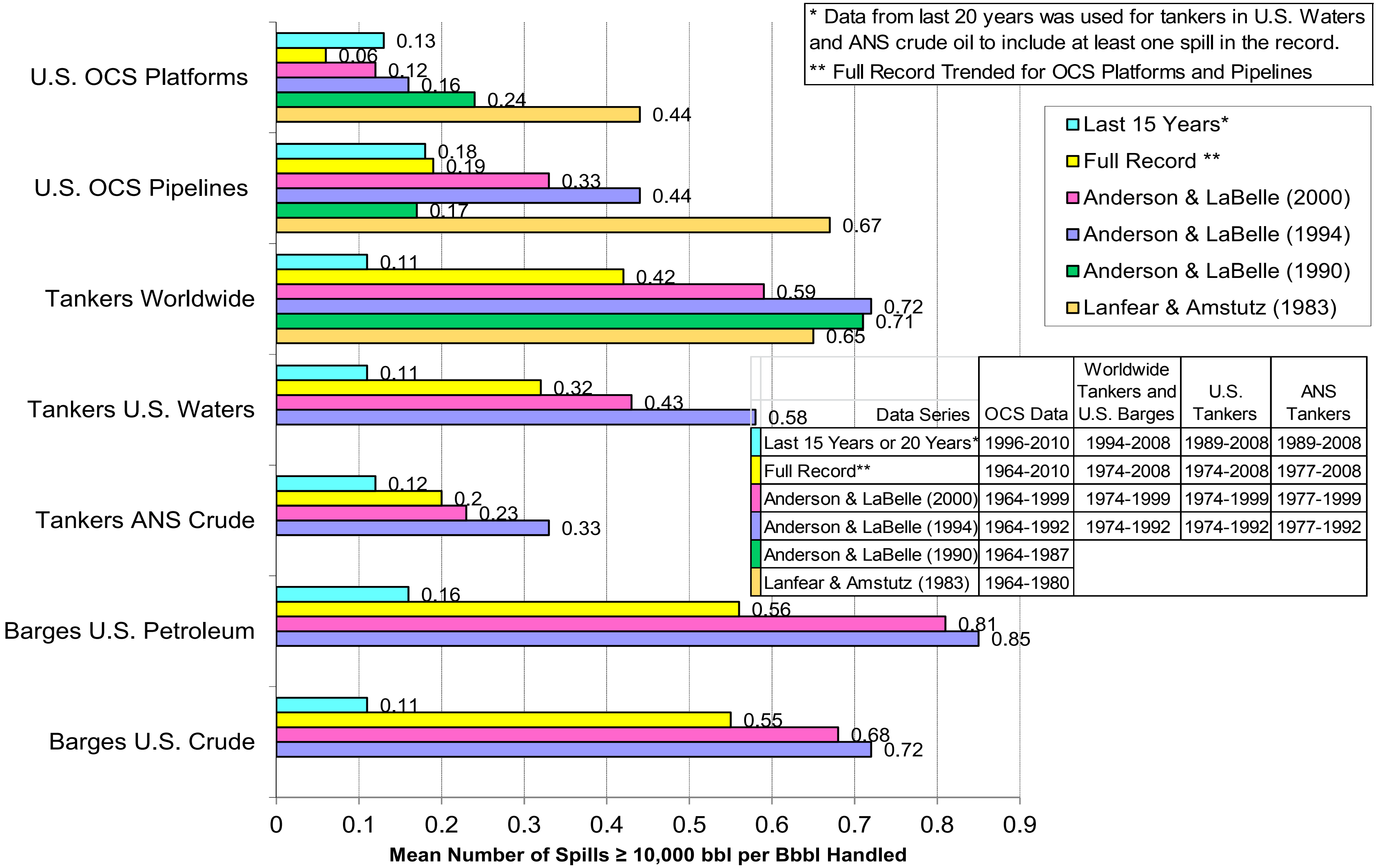


Figure 11. Comparison of Historic Spill Rates for Spills ≥ 1,000 Barrel



Data Series	OCS Data	Worldwide Tankers and U.S. Barges	U.S. Tankers	ANS Tankers
Last 15 Years or 20 Years*	1996-2010	1994-2008	1989-2008	1989-2008
Full Record**	1964-2010	1974-2008	1974-2008	1977-2008
Anderson & LaBelle (2000)	1964-1999	1974-1999	1974-1999	1977-1999
Anderson & LaBelle (1994)	1964-1992	1974-1992	1974-1992	1977-1992
Anderson & LaBelle (1990)	1964-1987			
Lanfear & Amstutz (1983)	1964-1980			

Figure 12. Comparison of Historic Spill Rates for Spills ≥ 10,000 Barrels

7.0 DISCUSSION AND CONCLUSIONS

Rates for spills ≥1,000 bbl or ≥10,000 bbl are estimated updates of previously calculated rates based on data through 1999 (Anderson and LaBelle, 2000).

7.1 Spill Rates ≥1,000 Barrels

This section addresses historic and current spill rates by spill sources for spills ≥ 1,000 barrels. Figure 13 shows these rates.

7.1.1 OCS Platforms: Spill Rates ≥ 1,000 Barrels

In previous revisions, spill rates for OCS platform spills ≥1,000 bbl had continued to decline since they were first calculated by Stewart (1975, 1976) and in subsequent updates by Lanfear and Amstutz (1983) and Anderson and LaBelle (1990, 1994, 2000). In this latest revision, the rate for spills ≥1,000 bbl was unchanged at 0.32 (compared to Anderson and LaBelle, 2000) over the trend period (intervals numbered 3 to 18, Fig. 6).

The rate for the most recent 15 years of data increased to 0.25 (1996 through 2010) as compared to 0.13 (15-year period from Anderson and LaBelle 2000: 1985 through 1999). This increase was due to the two recent platform spill occurrences, one from structures destroyed in Hurricane Rita in 2005 and the other from the Macondo spill in 2010. Prior to these two incidents, the last OCS platform spill ≥1,000 bbl was in 1980.

7.1.2 OCS Pipelines: Spill Rates ≥ 1,000 Barrels

The OCS pipeline spill rate over the entire record had been relatively unchanged from the previous two revisions of spill rate estimates (Anderson and LaBelle 1994 and 2000). In this study, the OCS pipeline spill rate for spills ≥1,000 bbl declined since it was last calculated (Anderson and LaBelle, 2000), from 1.33 to 0.94 spills per Bbbl produced over the trend period (intervals numbered 18 to 36), and from 1.38 to 0.88 spills per Bbbl produced for the last 15 years of each dataset.

7.1.3 Worldwide Tankers: Spill Rates ≥ 1,000 Barrels

The worldwide tanker spills rate for spills ≥1,000 bbl over the entire record continued the dramatic decline identified in the previous analysis (Anderson and LaBelle, 2000). In earlier examinations, the worldwide tanker spill rate had remained constant at 1.30 spills per Bbbl handled (Lanfear and Amstutz ,1983 and Anderson and LaBelle,1990 and 1994).

Based on the 1974 through1999 data (Anderson and LaBelle, 2000), the rate dropped to 1.16 spills per Bbbl handled. In this analysis, the worldwide tanker spill rate declined to 0.84 spills per Bbbl over the entire record (1974 through 2008) and declined even further to 0.32 spills per Bbbl handled when examined for the last 15 years (1994 through 2008).

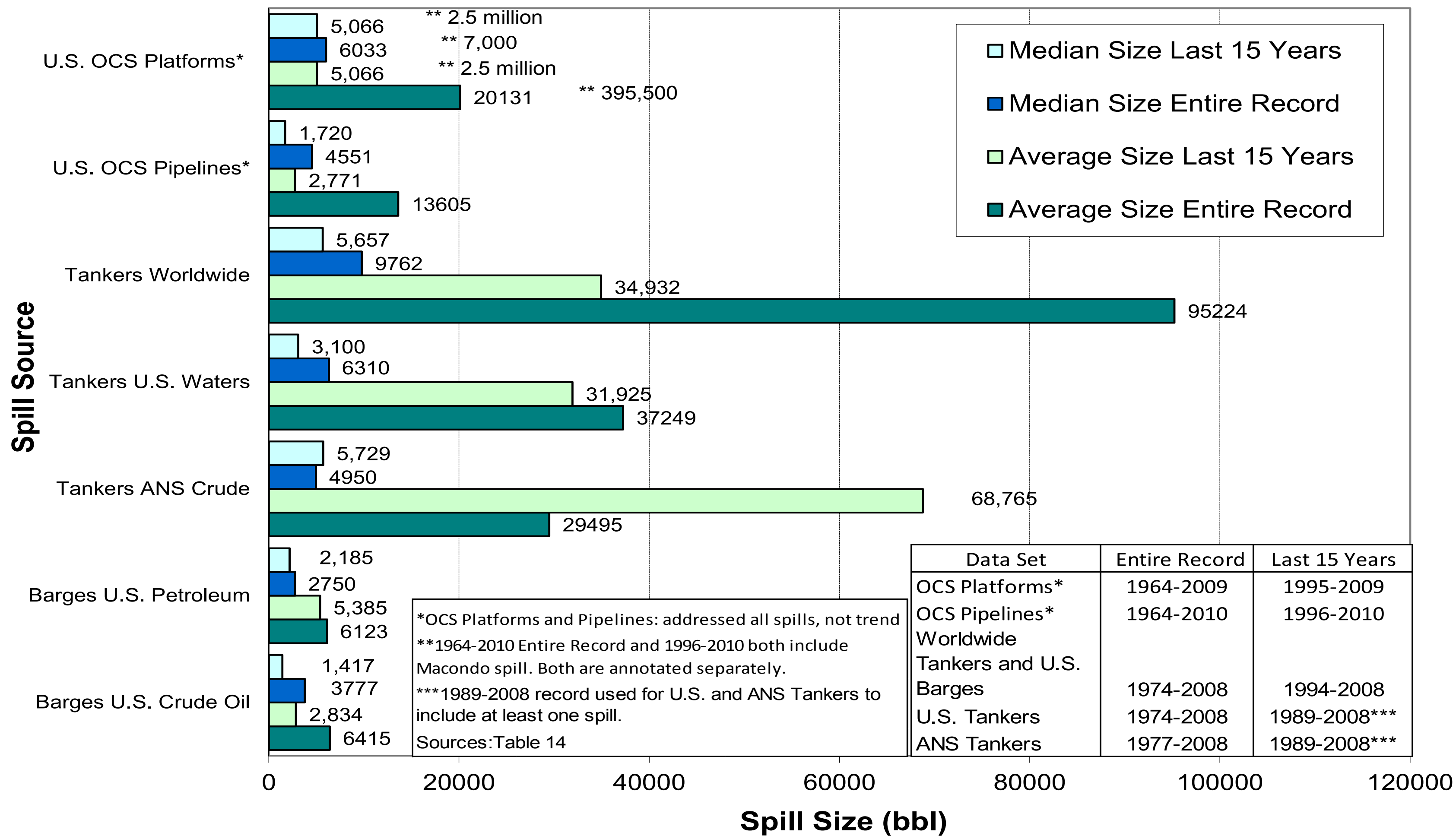


Figure 13. Comparison of Average and Median Spill Size by Spill Source for Spills ≥ 1,000 Barrels

The declines reflect reductions in both the "In Port" and "At Sea" spill rates that comprise the combined rates. It is likely the worldwide transition to double-hull tanker vessels (or their equivalent) which was mostly completed in 2005 (as mandated both by Oil Pollution Act of 1990, OPA 90) in the U.S. and the 1992 changes to MARPOL 73/78, the International Convention for the Prevention of Pollution by Ships) is a primary reason for the greatly improved worldwide tanker spill rates. (See http://www.ecy.wa.gov/programs/spills/prevention/bap/TAPS%20Trade%20Tanker%20Report.pdf.)

7.1.4 U.S. Tankers: Spill Rates ≥ 1,000 Barrels

The spill rate for tankers in U.S. waters also continued to decrease dramatically, from 1.03 (Anderson and LaBelle (2000) to 0.85 spills per Bbbl handled based on the entire 1974 through 2008 record, and declined further to 0.34 spills per Bbbl handled when the last 20 years were examined (1989 through 2008). These rate reductions reflected a decline in both the "In Port" and "At Sea" spill rates that comprise the combined rates. In prior examinations, the rates for tanker spills in U.S. waters were lower than the worldwide tanker spill rates; based on the latest data over the entire record and the last 15-years, the spill rates in U.S. waters are now basically the same (slightly, but not significantly, higher) as the worldwide tanker spill rates.

7.1.5 ANS Tankers: Spill Rates ≥ 1,000 Barrels

The updated spill rate for tankers carrying ANS crude oil continued the decline seen in previous studies (Anderson and LaBelle 1994, 2000) based on the entire 1977 through 2008 record from 0.88 to 0.72 spills per Bbbl handled compared to the previous revision (Anderson and LaBelle, 2000). The ANS crude oil tanker rate declined further to 0.46 spills per Bbbl handled when calculated for the last 20 years (1989 through 2008) compared to the previous 15-year rate of 0.92 (15-year period from Anderson and LaBelle 2000:1985 through 1999). There were no tanker spills of ANS crude oil ≥1,000 bbl in the last 15 years (1994 through 2008).

7.1.6 U.S. Barges: Petroleum Spill Rates ≥ 1,000 Barrels

The rate for all petroleum spills (including crude oil and petroleum product spills) from barges in U.S. coastal, offshore, and inland waters declined from 4.30 (Anderson and LaBelle, 2000) to 3.37 spills per Bbbl handled based on the entire 1974 through 2008 record. This rate declined further when examining the last 15 years (1994 through 2008) to 1.20 spills per Bbbl handled.

7.1.7 U.S. Barges: Crude Oil Spill Rates ≥ 1,000 Barrels

The rate for crude oil spills from barges in U.S. coastal, offshore, and inland waters declined from 3.55 (Anderson and LaBelle, 2000) to 3.09 spills per Bbbl handled based on the entire 1974 through 2008 record in this report. This rate declined more dramatically in the last 15 years (1994 through 2008) to 0.62 spills per Bbbl handled. This spill rate for crude oil spills from barges continues to be significantly lower than the rates for "All Petroleum" spills from barges.

7.2 Spill Rates ≥ 10,000 Barrels

This section addresses historic and current spill rates by spill sources for spills ≥ 1,000 barrels. Figure 14 shows these rates.

7.2.1 OCS Platforms: Spill Rates ≥ 10,000 Barrels

Spill rates for OCS platform spills ≥10,000 bbl declined from 0.12 (Anderson and LaBelle, 2000) to 0.06 over the trend period, January 1973 through 2010 (intervals numbered 3 to 18, Fig. 6). This a continuation of declining rates identified in previous revisions (Lanfear and Amstutz (1983), and Anderson and LaBelle (1990, 1994, 2000)). The rate for the most recent 15 years of data increased to 0.13 (1996 through 2010) as compared to 0.05 (Anderson and LaBelle, 2000, 1985 through 1999). This increase was due to the Macondo well spill in 2010. Prior to this incident, the last OCS platform spill ≥10,000 bbl was in 1970.

7.2.2 OCS Pipelines: Spill Rates ≥ 10,000 Barrels

Spill rates for OCS pipeline spills ≥10,000 bbl declined from 0.33 to 0.19 spills per Bbbl handled for the trend period, December 1992 through 2010 (intervals numbered 18 to 36, Fig. 7) and from 0.34 to 0.18 spills per Bbbl handled for the last 15 years (compared to Anderson and LaBelle, 2000). This is a continuation of a decline identified in the previous two revisions (Anderson and LaBelle, 1994, 2000). The last OCS pipeline spill ≥10,000 bbl occurred in 1990.

7.2.3 Worldwide Tankers: Spill Rates ≥ 10,000 Barrels

The worldwide tanker spill rate declined from 0.59 to 0.42 spills per Bbbl handled over the entire 1974 through 2008 record when compared to the previous study (Anderson and LaBelle, 2000). The rate drops even further to 0.11 spills per Bbbl handled when examined over the last 15 years (1994 through 2008).

7.2.4 U.S. Tankers: Spill Rates ≥ 10,000 Barrels

The spill rate for tankers in U.S. waters dropped from 0.43 to 0.32 spills per Bbbl handled for the entire 1974 through 2009 record when compared to the previous study (Anderson and LaBelle, 2000), and even further to 0.11 spills per Bbbl handled in the last 20 years (1989 through 2008). The 0.32 spills per Bbbl rate over the entire record continues to be lower than the rate for tanker spills worldwide. The 0.11 spills per Bbbl for tanker spills in U.S. waters over the last 20 years matches the rate over the last 15 years for worldwide tanker spills.

There were no tanker spills at sea in U.S. waters ≥10,000 bbl in the last 15 years; the most recent tanker spill in U.S waters was the 12,800 bbl Westchester spill in 2000 which was an in-port spill.

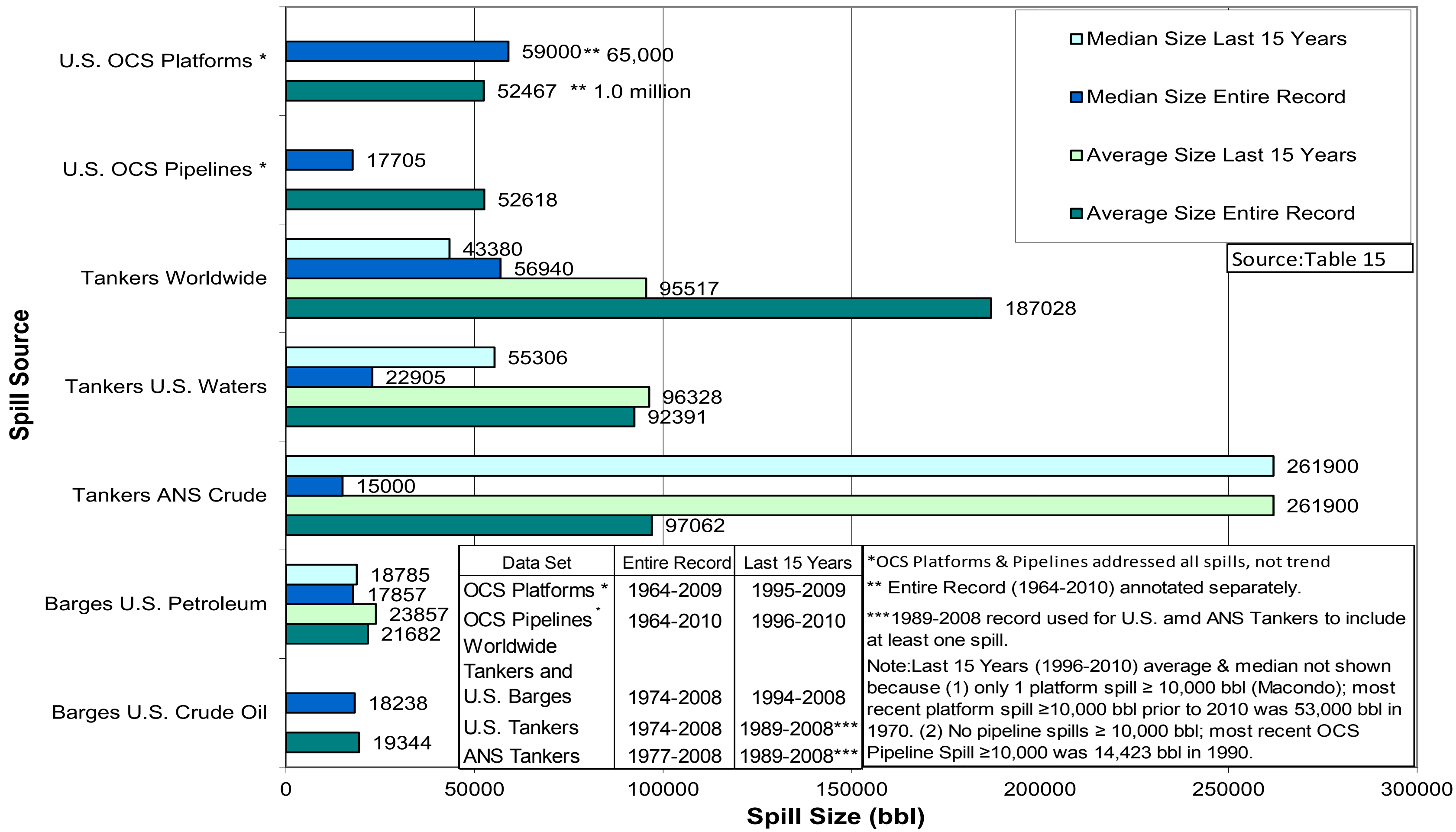


Figure 14. Comparison of Average and Median Spill Size by Spill Source for Spills ≥ 10,000 Barrels

7.2.5 ANS Tankers: Spill Rates ≥ 10,000 Barrels

The spill rate for tankers carrying ANS crude oil dropped from 0.23 (Anderson and LaBelle, 2000) to 0.20 spills per Bbbl handled for the entire 1977 through 2008 record. The spill rate decreased further to 0.12 spills per Bbbl handled when examined for the last 20 years (1989 through 2008). There were no Tanker spills of ANS crude oil ≥10,000 bbl in the last 15 years; the most recent was the 262,000 bbl Exxon Valdez spill in 1989.

7.2.6 U.S. Barges: Petroleum Spill Rates ≥ 10,000 Barrels

The rate for "All Petroleum" spills (including crude oil and petroleum product spills) from barges in U.S. coastal, offshore, and inland waters declined from 0.81 (Anderson and LaBelle 2000) to 0.56 spills per Bbbl handled based on the entire 1974 through 2008 record. This rate declined further when examined for the last 15 years (1994 through 2008) to 0.16 spills per Bbbl handled.

7.2.7 6 U.S. Barges: Crude Oil Spill Rates ≥ 10,000 Barrels

The rate for crude oil spills from barges in U.S. coastal, offshore, and inland waters declined from 0.68 (Anderson and LaBelle, 2000) to 0.55 spills per Bbbl handled based on the entire 1974 through 2008 record. This rate declined more dramatically in the last 15 years (1994 through 2008) to 0.12 spills per Bbbl which was calculated from the 15-year rate for spills ≥1,000 bbl since no crude oil spills from barges ≥10,000 were observed from1994 through 2008 (Table 13). The last crude oil spill ≥ 10,000 bbl from barges in U.S. coastal waters was in 1984.

8.0 ACKNOWLEDGEMENTS

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References related to the BOEM Oil Spill Modeling Program can be found on these two pages:

http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill.aspx.

http://www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill-Modeling-Program

Some other early spill rate-related references can be found at: http://www.boemre.gov/eppd/sciences/osmp/spillraterefs.htm

APPENDIX A. TREND ANALYSIS FOR OIL SPILL OCCURRENCE RATES

This appendix describes historic and recent tests on the oil spill occurrence frequency on the OCS from pipelines and platforms as related to volume of production. These analyses were conducted to identify trends that may occur.

A. 1 Spill Rates Trend Analyses

All references to spills in this discussion refers to petroleum spills ≥ 1,000 bbl resulting from OCS offshore oil and gas activities beginning in 1964 (through 2010 in this report). Historically, most of the spills of this size have been crude oil or condensate (a liquid product of natural gas production) but the few diesel spills ≥ 1,000 bbl are also included because they are associated with oil and gas activities from platforms.

BOEM and BSEE use spill rates based on historic spills from OCS offshore oil and gas activities to estimate future oil spill occurrences. These rates are expressed in terms of number of spills per Bbbl "handled", which means produced by OCS platforms or OCS pipelines, or transported by barges or tankers. From1964 through 2010, there have been 18.1 Bbbl of crude oil and condensate produced and this is associated with 13 platform spills (platform spills include spills related to operations at both drilling rigs and production platforms) and 20 pipeline spills. Spill rates calculated over this entire record are: (13 spills / 18.1 Bbbl) or 0.72 spills per Bbbl for platforms; and (20 spills /18.1 Bbbl) or 1.10 spills per Bbbl for pipelines.

If the spill occurrence record were to improve over time, it would be reflected in a lower spill rate, i.e. fewer spills per Bbbl handled when some portion of the oldest record is excluded from the calculation. In fact, when the rates were calculated for the most recent 15 years of data (1996 through 2010) the spill rates are 0.25 spills per Bbbl for platforms and 0.88 spills per Bbbl for pipelines because there were 2 platform spills and 7 pipeline spills during the production of over 8.0 Bbbl (See Table 9). So (2/8 = 0.25, which is 0.25 spills per Bbbl for the platforms and 7/8 = 0.875, which rounds to 0.88 spills per Bbbl for pipelines). This is a dramatic reduction in both platform and pipeline spill rates when considering that the most recent 15 years captures 44% of the program's production experience and 27 % of the spills, and suggests an observed decline (improvement trend) in spill rates over time.

To support the existence of a trend, the analyses below specifically focuses on the volume of production between spills, (hereafter referred to as VPBS). The VPBS is expressed in millions of bbl (MMbbl). If the VPBS increases for <u>every</u> spill, i.e. 50 MMbbl produced between the first and second spill, 60 MMbbl produced between the second and third spill, 70 MMbbl between third and fourth spill, and so on, then the VPBS would be a strictly monotonic data series and would clearly represent an improvement trend. If the VPBS isn't strictly monotonic, but increases between spills most of the time, it still probably reveals an improvement trend. Testing is done on the VPBS data to determine whether there is an improvement trend, or whether the variation in VPBS is just random.

The hypothesis that there had been gradual improvement in the offshore oil production safety using data on OCS platform spills ≥ 1,000 bbl from1964 through1979 was supported in Nakassis (1982). Statistical tests were used to demonstrate there was a general tendency (not strictly monotonic) for the VPBS to increase between spills over time, and to reject the hypothesis that the tendency was a random phenomenon. Nakassis's report documents the extensive statistical analysis. http://www.boemre.gov/eppd/sciences/osmp/pdfs/Nakassis1982.pdf.

Anderson and LaBelle, 1990, repeated several of Nakassis' tests using OCS platform and pipeline data for spills ≥ 1,000 bbl that occurred from1964 through 1987. Improving trends were identified in both the OCS platform and pipeline spill rates. Specific starting points in the spill data were selected to represent the beginning of the platform spill and pipeline spill trends (these designated starting points were somewhat subjective). (The platform trend starting point parses between two January1973 spills.)
http://www.boemre.gov/eppd/sciences/osmp/pdfs/AndersonAndLaBelle/AndersonAndLaBelle1990.pdf

Anderson and LaBelle (1994 and 2000) reaffirmed the trend in the platform spill record as the OCS data set was expanded to spills of ≥1,000 bbl that occurred from1964 through 1992 and 1964 through 1999 respectively. For pipeline spills ≥1,000 bbl, however, neither Anderson and LaBelle, (1994) nor Anderson and LaBelle (2000) could reaffirm the trend identified in the OCS spill rate previously identified in Anderson and LaBelle, 1990http://www.boemre.gov/eppd/sciences/osmp/pdfs/AndersonAndLaBelle/Anderson_LaBelle1944.pdf
http://www.boemre.gov/eppd/sciences/osmp/pdfs/AndersonAndLaBelle/AndersonAndLaBelle2000.pdf

For this report, a sensitivity analysis was again conducted to determine an appropriate starting point for a trend, if the existence of a trend was apparent. An appropriate starting point for the trend was selected by identifying the point in the data where major increases or decreases in the spill rate were no longer apparent. Data were examined for platform spills and pipeline spills ≥1,000 bbl that occurred from 1964 through 2010.

Table A-1 contains data for OCS platform spills ≥ 1,000 bbls, listing the date of each spill along with the volume of production between spills (VBPS). Adjacent columns summarize the cumulative number of spills, cumulative production volume, the percentage of spills, and the percent production volume that had occurred from each spill forward through 2010 as the earlier (older) spill records are excluded.

Beginning with the 2/10/1970 platform spill (excluding the previous five platform spills and the production from the1960's) and incorporating all subsequent spills through 2010, will include 94% of the production record (17.1 of 18.1 Bbbl) and 62% (8 of 13) of the platform spills.

Table A-1. Cumulative Percent of OCS Platform Spills and Production Volume as Older Spills are Sequentially Eliminated

Spill[1] #	Platform Spill Dates	VPBS[2]	Cumulative Numbers: Number of Spills	% of Spills Included	Million bbl Production	% Production Included
1	4/8/1964	29.874	13	100.00%	18,127.232	100.00%
2	10/3/1964	54.261	12	92.31%	18,097.358	99.84%
3	7/19/1965	101.634	11	84.62%	18,043.097	99.54%
4	1/28/1969	725.577	10	76.92%	17,941.462	98.98%
5	3/16/1969	38.911	9	69.23%	17,215.885	94.97%
6	2/10/1970	279.875	8	61.54%	17,176.974	94.76%
7	12/1/1970	285.281	7	53.85%	16,897.099	93.21%
8	1/9/1973	841.380	6	46.15%	16,611.819	91.64%
9	1/26/1973	17.922	5	38.46%	15,770.438	87.00%
10	11/23/1979	2,235.420	4	30.77%	15,752.517	86.90%
11	11/14/1980	274.150	3	23.08%	13,517.097	74.57%
12	9/24/2005	10,481.314	2	15.38%	13,242.947	73.06%
13	4/20/2010	2,350.862	1	7.69%	2,761.633	15.23%
Balance[3]		410.771	0	0.00%	410.771	2.27%
Total Production[4]		18,127.232				

[1] Includes all OCS platform spills ≥ 1,000 barrels

[2] Volume of Production Between Spills, in Mbbl (millions of barrels); a barrel is 42 U.S. gal.

[3] Balance=the amount of production between the last spill and the end of the study period.

[4] Total production= Total OCS production through the end of the study period; 2010 OCS production data was used, and was updated as of May 2011 using ONRR data.

Source: U.S. DOI/BOEMRE OCS Oil Spill Database, May 2011; U.S. DOI/ONRR OCS Production Data, May 2011). (http://www.boemre.gov/stats/OCSProduction.htm).

In Anderson and LaBelle (1990) the platform record from the 1/26/1973 spill forward was selected (somewhat subjectively) to represent the beginning of the platform spill trend as indicated by statistical tests. Anderson and LaBelle (1994 and 2000) also used the 1/26/1973 spill to represent the beginning of the platform spill trend. Using the OCS platform spill data through 2010, Table A-1 shows that the platform spill record from 1/26/1973 forward captures 87% of the production record and includes 38.5% (5 of 13) of the platform spills.

The same analysis was conducted for OCS pipeline spills ≥1,000 bbl. Table A-2 displays similar data for OCS pipeline spills, but no trend in the cumulative pipeline spill data is particularly apparent. As the oldest pipeline spills are dropped, the cumulative percentage of pipeline spills included continues to be roughly similar to the percentage of the production record included.

Table A-2. Cumulative Percent OCS Pipeline Spills and Production Volume as Older Pipeline Spills are Sequentially Eliminated

			Cumulative Numbers			
Spill[1] #	Pipeline Spill Dates	VPBS [2]	Number of Spills	% of Spills Included	Million bbl Production	% Production Included
1	10/15/1967	588.040	20	100.000%	18,127.232	100.00%
2	3/12/1968	93.986	19	95.000%	17,539.192	96.76%
3	2/11/1969	240.911	18	90.000%	17,445.206	96.24%
4	5/12/1973	1,563.527	17	85.000%	17,204.295	94.91%
5	4/17/1974	349.682	16	80.000%	15,640.769	86.28%
6	9/11/1974	142.942	15	75.000%	15,291.087	84.35%
7	12/18/1976	736.530	14	70.000%	15,148.145	83.57%
8	12/11/1981	1,471.440	13	65.000%	14,411.615	79.50%
9	2/7/1988	2,223.490	12	60.000%	12,940.175	71.39%
10	1/24/1990	641.797	11	55.000%	10,716.685	59.12%
11	5/6/1990	105.079	10	50.000%	10,074.888	55.58%
12	8/31/1992	737.025	9	45.000%	9,969.809	55.00%
13	11/16/1994	801.686	8	40.000%	9,232.784	50.93%
14	1/26/1998	1,397.560	7	35.000%	8,431.099	46.51%
15	9/29/1998	365.602	6	30.000%	7,033.539	38.80%
16	7/23/1999	388.749	5	25.000%	6,667.937	36.78%
17	1/21/2000	267.907	4	20.000%	6,279.189	34.64%
18	9/15/2004	2,719.374	3	15.000%	6,011.282	33.16%
19	9/13/2008	1,975.691	2	10.000%	3,291.909	18.16%
20	7/25/2009	469.485	1	5.000%	1,316.218	7.26%
Balance[3]		846.733	0	0.000%	846.733	4.67%
Total Production[4]		18,127.232				

[1] Includes all OCS pipeline spills ≥ 1,000 barrels

[2] Volume of Production Between Spills, in MMbbl (millions of barrels); a barrel is 42 U.S. gal.

[3] Balance=the amount of production between the last spill and the end of the study period.

[4] Total production= Total OCS production through the end of the study period; 2010 OCS production data was used, and was updated as of May 2011 using ONRR data.

Source: U.S. DOI/BOEMRE OCS Oil Spill Database, May 2011; U.S. DOI/ONRR OCS Production Data, May 2011). (http://www.boemre.gov/stats/OCSProduction.htm).

A.2 Statistical Tests

This section describes the statistical tests conducted in this study on the entire record (1964 through 2010) for both OCS platform and pipeline spills ≥ 1,000 bbl.

The 1964 through 2010 platform and pipeline data was subjected to three of the nonparametric statistical tests presented in Nakassis, 1982. All three tests involve a measure of the volume of production between spills (VPBS). These tests attempt to discern whether the VPBS is generally increasing over time, which would indicate an improvement trend, or whether the VPBS sequences are relatively random. The tests are:

- Kendall's Test for Correlation
- Hotelling and Pabst's Test for Rank-Order Correlation
- Runs Up, Runs Down Test for Randomness

The OCS production data utilized for these tests was production data through 2010, as updated in the production database as of May 2011.

A.2.1 Statistical Treatment of Variations in Data Sets

Two earlier spill rate papers identified trends in the data for OCS Platform spills ≥1,000 bbl.

Nakassis (1982) either treated the two 1973 spills that occurred 17 days apart as one spill, or possibly the second 1973 spill was not yet identified as a spill ≥1,000 bbl when Nakassis did his analysis.

Anderson and LaBelle (1990) used the two 1973 spills in their analysis, and a slightly different dataset for OCS production. This data was arrayed in their Figure 3, comparing cumulative production and cumulative spills over time, which is similar to the concept in Table A-1 (a, b, and c) of this paper. However, their Figure 3 dropped oldest intervals of 0.5 Bbbl of production, rather than dropping the oldest spills in each step. In this case, the first 1973 spill happened to fall into a separate 0.5 Bbbl production interval than the second 1973 spill. This allowed them to select from the second 1973 spill forward, which represented 67% of the production record and only 27% of the spill record. In Section 3.1.1 of Anderson and LaBelle (1990), it implies that Kendall's Test for Correlation supported the statement "the volume of oil handled between spills appeared to be nonrandom and to increase over time" indicated that the one brief spill interval between the two 1973 spills did not invalidate the likelihood that overall a positive non-random trend was present.

One could argue that the two January 1973 spills should be treated as one event. We do this for the three October 1964 spills that occurred during Hurricane Hilda and for the three September 2005 spills that occurred during Hurricane Rita. Since we are analyzing production volume between spills to test the distribution of spill occurrence, and both the October 1964 and September 2005 spills are clusters of three hurricane-related spills which had no production between the spill occurrences, this is reasonable. The two January 1973 spills occurred 17 days apart, and were very close in terms of the volume of production between spills. The two platform spills from 1973 were analyzed as a single spill event and as two separate spills in this report.

Figure A-1. Kendall's Test for Correlation for OCS Platform Spills ≥1,000 Barrels

Figure A-1(a) Kendall's Test using Data from Nakassis (1982)

		Spills of ≥ 1,000 bbl[2] from OCS Platforms									
		Spill #	1	2	3	4	5	6	7	8	9
Spill Date	Spill #	VPBS[1]	31.3	55.9	103.1	712.9	43.5	270.5	272.5	804.9	2,054.3
4/8/1964	1	31.3									
10/3/1964	2	55.9	T								
7/19/1965	3	103.1	T	T							
1/28/1969	4	712.9	T	T	T						
3/16/1969	5	43.5	T	I	I	I					
2/10/1970	6	270.5	T	T	T	I	T				
12/1/1970	7	272.5	T	T	T	I	T	T			
1/9/1973	8	804.9	T	T	T	T	T	T	T		
11/23/1979	9	2,054.3	T	T	T	T	T	T	T	T	
Total Production		4,348.9									
		T	8	6	5	2	4	3	2	1	
		I	0	1	1	3	0	0	0	0	

[1] VPBS= Volume of oil proudced between spills, in millions of barrels (MMbbl)

[2] bbl = barrels; 1 barrel= 42 U.S. gallons

T = smaller before larger, I = larger before smaller

Source: Data from Table II of Nakassis (1982)

ANALYSIS: 9 observations, T = 31, I = 5, no ties. S = T - I = 26

Prob (S ≥ 26 | n = 9) ≤ 0.5% (Bradley, 1968, Table XI)

NOTES: Nakassis' paper had T=33, I = 3, S=30; his counts are in error

Prob of 0.5% cited by Nakassis is for S=26 rather than S=30

A.2.2 Kendall's Test for Correlation for OCS Platform Spills

In Kendall's Test for Correlation, the VPBS is compared between spills in pairs; each spill is compared to every other spill. A pairing is marked "T" if the earlier spill's VPBS is smaller than the latter spill's, or marked "I" if the earlier spill's VPBS is larger than the latter spills. Ties are noted but thrown out. The Kendall statistic, S = T – I is calculated and then S is looked up in Table XI, of Bradley (1968). If S is high because T is high compared to I, it indicates an improving record because it generally means the most recent incidents have more production between spills.

Figure A-1 presents three separate iterations of applying Kendall's Test for Correlation to OCS platform spill data ≥ 1,000 bbl:

1. Reproduction of the Kendall's Test from Nakassis (1982) with 9 platform spill observations from1964 through1979 that included one January 1973 spill
2. Results of the Kendall's Test with 12 platform spill observations from1964 through 2010 that treated the two January 1973 spills as a single spill event.
3. Results of the Kendall's Test with 13 platform spill observations from 1964 through 2010 that included two separate January 1973 spills

Conclusions on Kendall's Test for Correlation, as Related to Platform Spill Data

1. Nakassis's results indicate the relatively high S value of 26 with 9 observations (based on a net calculation from 31 spill pairs with the earlier spill having a lower

Figure A-1. Kendall's Test for Correlation for OCS Platform Spills (continued)

Figure A-1(b) Kendall’s Test including
One January 1973 Spill and OCS Production Data as of May 2011

					Spills of ≥ 1,000 bbl[2] from OCS Platforms								
Spill		Spill #	1	2	3	4	5	6	7	8	9	10	11	12
Date	Spill #	VPBS[1]	29.9	54.3	101.6	725.6	38.9	279.9	285.3	859.3	2,235.4	274.2	10,481.3	2,350.9
4/8/1964	1	29.9												
10/3/1964	2	54.3	T											
7/19/1965	3	101.6	T	T										
1/28/1969	4	725.6	T	T	T									
3/16/1969	5	38.9	T	I	I	I								
2/10/1970	6	279.9	T	T	T	I	T							
12/1/1970	7	285.3	T	T	T	I	T	T						
1/9/1973	8	859.3	T	T	T	T	T	T	T					
11/23/1979	9	2,235.4	T	T	T	T	T	T	T	T				
11/14/1980	10	274.2	T	T	T	T	T	I	I	I	I			
9/24/2005	11	10,481.3	T	T	T	T	T	T	T	T	T	T		
4/20/2010	12	2,350.9	T	T	T	T	T	T	T	T	T	T	I	
Balance[3]		410.7												
Total Production[4]		18,127.3												
		T	11	9	8	5	7	5	4	3	2	2	0	
		I	0	1	1	3	0	1	1	1	1	0	1	

[1] VPBS= Volume of oil proudced between spills, expressed in millions of barrels (MMbbl)

[2] bbl = barrels; 1 barrel= 42 U.S. gallons

[3] Balance= balance of production since the last spill

[4] Total Production includes 2010 production data, updated as of May 2011 from ONRR data.

T = smaller before larger, I = larger before smaller

NOTE: Includes one January 1973 spill.

12 observations, T = 56, I = 10, no ties. S = T - I = 46

Prob (S ≥ 46 | n = 12) < Prob (S ≥ 38 | 13) ≤ 0.5% (Bradley, 1968, Table XI)

Figure A-1. Kendall's Test for Correlation for OCS Platform Spills (continued)

Figure A-1(c) Kendall's Test for OCS Platform Spills including Both January 1973 Spills and OCS Production Data as of May 2011

			Spills of ≥ 1,000 bbl[2] from OCS Platforms												
		Spill #	1	2	3	4	5	6	7	8	9	10	11	12	13
Spill Date	Spill #	VPBS[1]	29.9	54.3	101.6	725.6	38.9	279.9	285.3	841.4	17.9	2,235.4	274.2	10,481.3	2,350.9
4/8/1964	1	29.9													
10/3/1964	2	54.3	T												
7/19/1965	3	101.6	T	T											
1/28/1969	4	725.6	T	T	T										
3/16/1969	5	38.9	T	I	I	I									
2/10/1970	6	279.9	T	T	T	I	T								
12/1/1970	7	285.3	T	T	T	I	T	T							
1/9/1973	8	841.4	T	T	T	T	T	T	T						
1/26/1973	9	17.9	I	I	I	I	I	I	I	I					
11/23/1979	10	2,235.4	T	T	T	T	T	T	T	T	T				
11/14/1980	11	274.2	T	T	T	I	T	I	I	I	T	I			
9/24/2005	12	10,481.3	T	T	T	T	T	T	T	T	T	T	T		
4/20/2010	13	2,350.9	T	T	T	T	T	T	T	T	T	T	T	I	
Balance[3]		410.7													
Total Production[4]		18,127.3													
		T	11	9	8	4	7	5	4	3	4	2	2	0	
		I	1	2	2	5	1	2	2	2	0	1	0	1	

[1] VPBS= Volume of oil proudced between spills, expressed in millions of barrels (MMbbl)

[2] bbl = barrels; 1 barrel= 42 U.S. gallons

[3] Balance= balance of production since the last spill

[4] Total Production includes 2010 production data, updated as of May 2011 from ONRR data.

T = smaller before larger, I = larger before smaller

NOTE: Includes both January 1973 spills.

13 observations, T = 59, I = 19, no ties S = T - I = 40

Prob (S ≥ 59 | n = 13) < Prob (S ≥ 44 | 13) < 1% (Bradley, 1968, Table XI)

VPBS and 5 spill pairs with the earlier spill having a higher VPBS) was unlikely to be a random result (probability ≤0.5%).
2. Extending the platform data through to 2010 and treating the two January 1973 spills as a single event indicate the relatively high S value of 46 with 12 observations (based on a net calculation from 56 spill pairs with the earlier spill having a lower VPBS and 10 spill pairs with the earlier spill having a higher VPBS) is unlikely to be a random result (probability ≤ 0.5%), so it could be considered a trend.
3. Extending the platform data through to 2010 with two separate January 1973 spills indicate the relatively high S value of 40 with 13 observations (based on a net calculation from 59 spill pairs with the earlier spill having a lower VPBS and 19 spill pairs with the earlier spill having a higher VPBS) is unlikely to be a random result (probability of < 1%), so it could be considered a trend (Fig. A-1(c).

A.2.3 Runs Up, Runs Down Test for OCS Platform Spills

In the Runs Up, Runs Down Test for randomness, the VPBS between each spill and the previous spill are compared and marked "+" if the more recent spill has a higher VPBS than the previous spill and marked "- " if the VPBS is less than the previous spills. The resulting sequence is examined for the number of runs where runs are discrete sequences of pluses or minuses. For example, "+ + - + + + + + - -" is based on 10 observations, has 4 runs, and the longest run is 4. The probability of the number of sequences (or fewer) not being random is looked up in Table X, of Bradley (1968). More pluses in the sequence may indicate an improvement trend, especially if they occur in the latter part of the sequence because the plus indicates more production between spills than observed for the previous spill.

Table A-3 presents three separate iterations of applying the Runs Up, Runs Down Test on platform spill data:

1. Reproduction of the Runs Up, Runs Down Test from Nakassis, 1982, with 9 platform spill observations from1964 through1979 that included one January 1973 spill
2. Results of the Runs Up, Runs Down Test with 12 platform spill observations from1964 through 2010 that includes the two January 1973 spills as a single event
3. Results of the Runs Up, Runs Down Test with 13 platform spill observations from 1964 through 2010 with two separate January 1973 spills

Conclusions on the Runs Up, Runs Down Test, as Related to OCS Platform Spill Data:

1. Nakassis's results indicate having 3 runs with 9 observations was unlikely to be a random result (probability of 2.57%).
2. Extending the platform data through to 2010 and treating the two January 1973 spills as a single spill event generated 6 runs with 12 observations; the test results

Table A-3. Runs Up, Runs Down Test for OCS Platform Spills ≥ 1,000 Barrels

Spill Number (by Date) Including One 1973 Spill[1]	Spill Number (by Date) Including Two 1973 Spills	Spill Date	VPBS[2] (MMbbl[3]) Two 1973 Spills	One Spill	VPBS[2] Rank, Nakassis (1982)	VPBS[2] Rank in this Report, One 1973 Spill	VPBS[2] Rank in this Report, Two 1973 Spills
1	1	4/8/1964	29.874		1	1	2
2	2	10/3/1964	54.261		3	3	4
3	3	7/19/1965	101.634		4	4	5
4	4	1/28/1969	725.577		7	8	9
5	5	3/16/1969	38.911		2	2	3
6	6	2/10/1970	279.875		5	6	7
7	7	12/1/1970	285.281		6	7	8
X	8	1/9/1973	841.380	-	X	X	10
8	9	1/26/1973	17.922	859.302	8	9	1
9	10	11/23/1979	2,235.420		9	10	11
10	11	11/14/1980	274.150			5	6
11	12	9/24/2005	10,481.314			12	13
12	13	4/20/2010	2,350.862			11	12
Balance[4]			410.771				
Total Production[5]			18,127.232				
[1]Nakassis (1982) included only one spill from January 1973. His spill record ended in 1979.							
[2]VPBS volume of oil produced between spills, in millions of bbl (MMbbl)							
[3]MMbbl= million barrels. A barrel is 42 U.S. gallons							
[4]Balance=the amount of production between the last spill and the end of the study period.							
[5]Total production= Total OCS production through the end of the study period; 2010 OCS production data was used, and was updated as of May 2011, using ONRR data.							
Source: U.S. DOI/BOEMRE OCS Oil Spill Database, May 2011; U.S. DOI/ONRR OCS Production Data, May 2011). (http://www.boemre.gov/stats/OCSProduction.htm).							
NOTE: Anderson and Labelle (1990) included one spill from January 1973.							
Analysis of Nakassis (1982):							
9 observations, 3 runs, longest run 4.				+ + + - + + + +			
Prob (3 runs or fewer| 9) = 2.57% (Bradley, 1968, Table X)							
Analysis Including One January 1973 Spill							
12 observations, 6 runs, longest run 4				+ + + - + + + + - + -			
Prob (6 runs or fewer | 12) = 19.18% (Bradley, 1968, Table X)							
Analysis Including Two January 1973 Spills							
13 observations, 8 runs, longest run 3				+ + + - + + + - + - + -			
Prob (8 runs or fewer | 13) = 54.13% (Bradley, 1968, Table X)							

suggest the VPBS sequence of runs still could be relatively random (probability of 19.18%).
3. Extending the platform data through to 2010 with two separate January 1973 spills generated 8 runs with 13 observations; the test results suggest the VPBS sequence of runs could be relatively random (probability of 54.13%).

A.2.4 Hotelling and Pabst's Test for OCS Platform Spills

The Hotelling and Pabst's Test for Rank-Order Correlation is a measure of the tendency of our observations to form a monotonic sequence, with small D values indicating an increasing sequence. Each spill is assigned an order number, and each spills' VPBS is ranked from low to high, i.e., for 20 spill observations, spills are assigned an order number of 1 to 20, where 1 is the earliest spill, and each VPBS is ranked from 1 to 20, where 1 is the smallest VPBS. The D value is calculated by subtracting each spill's VPBS rank from the spill's order number, square the result, and add the results for a sum of squares. The resulting sum D is looked up in Table I, Bradley (1968). The smaller the value of D, the more likely there is an improvement trend because a small D indicates the earliest spills have the smaller VPBS rank and the more recent spills have the higher VPBS rank so the subtraction of the spill order number from the spill VPBS rank would produce many zeros, ones and twos to square and sum together to equal D.

Table A-4 presents three separate iterations of applying the Hotelling and Pabst's Test to platform spill data:

1. Reproduction of the Hotelling and Pabst's Test from Nakassis (1982) with 9 platform spill observations from 1964 through1979 that included one January 1973 spill
2. Results of the Hotelling and Pabst's Test with 12 platform spill observations from1964 through 2010 that treated the two January 1973 spills as a single spill event.
3. Results of the Hotelling and Pabst's Test with 13 platform spill observations from1964 through 2010 with two separate January 1973 spills.

Conclusions on Hotelling and Pabst's Test, as Related to OCS Platform Spill Data:

1. Nakassis' results indicate that the low D value of 22 with 9 observations, calculated from the sum of squares of the difference between the spill number of 1 to 9 (based on spill date) and the VPBS rank of 1 to 9 (based on relative VPBS amount low to high order), was unlikely to be a random result (probability ≤1%).
2. Extending the platform data through to 2010 and treating the two January 1973 spills as a single event results in a low D value of 56 with 12 observations, calculated from the sum of squares of the difference between the spill number of 1 to 12 (based on spill date) and the VPBS rank of 1 to 12 (based on relative VPBS amount low to high order), and is unlikely to be a random result (probability ≤ 0.5%).

Table A-4. Hoteling and Pabst Rank-Order Correlation Test for OCS Platform Spills ≥1,000 Barrels

Analysis Using Data from Nakassis (1982):		
D = (1-1)^2 + (2-3)^2 + (3-4)^2 + (4-7)^2 + (5-2)^2 + (6-5)^2		
	+ (7-6)^2 + (8-8)^2 + (9-9)^2	
=	22	Prob (D ≤ 22 | 9) < Prob (D ≤ 26 | 9) ≤ 1 %
		[Bradley (1968) Table I]
Analysis Including One January 1973 Spill:		
D = (1-1)^2 + (2-3)^2 + (3-4)^2 + (4-8)^2 + (5-2)^2 + (6-6)^2 + (7-7)^2		
	+ (8-9)^2 + (9-10)^2 + (10-5)^2	
	+ (11-12)^2 + (12-11)^2	
=	56	Prob (D ≤ 56 | 12) < Prob (D ≤ 76 | 12) ≤ 0.5 %
[Bradley (1968) Table I]		
Analysis Including Two January 1973 Spills:		
D = (1-2)^2 + (2-4)^2 + (3-5)^2 + (4-9)^2 + (5-3)^2 + (6-7)^2 + (7-8)^2		
	+ (8-10)^2 + (9-1)^2 + (10-11)^2	
	+ (11-6)^2 + (12-13)^2 + (13-12)^2	
=	136	Prob (D ≤ 136 | 13) < Prob (D ≤ 160 | 13) ≤ 2.5 %
[Bradley (1968) Table I]		

3. Extending the platform data through to 2010 with two separate January 1973 spills still generates a relatively low D value of 136 with 13 observations, calculated from the sum of squares of the difference between the spill number of 1 to 13 (based on spill date) and the VPBS rank of 1 to 13 (based on relative VPBS amount low to high order), is unlikely to be a random result (probability of less than ≤ 2.5%).

A.2.5 Kendall's Test for Correlation for OCS Pipeline Spills

Figure A-2 presents the application of Kendall's Test for Correlation to the 20 pipeline spill observations from1964 through 2010 using May 2011 production data. This test is calculated as was described earlier for Figure A-1. If S is high because T is high compared to I, it indicates an improving record because it generally means the most recent incidents have more production between spills.

Conclusions on Kendall's Test for Correlation, as Related to OCS Pipeline Spill Data:

The application of Kendall's Test to the 1964 – 2010 pipeline spill data generated a relatively low S value of 38 with 20 observations (based on a net calculation from 114 spill pairs with the earlier spill having a lower VPBS and 76 spill pairs with the earlier spill having a higher VPBS) and is possibly a relatively random result (probability >10%).

Figure A-2. Kendall's Test for Correlation, OCS Pipeline Spills ≥1,000 Barrels

Spill			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date	#	VPBS[1]	588.0	94.0	240.9	1,563.5	349.7	142.9	736.5	1,471.4	2,223.5	641.8	105.1	737.0	801.7	1,397.6	365.6	388.7	267.9	2,719.4	1,975.7	469.5
10/15/1967	1	588.0																				
3/12/1968	2	94.0	I																			
2/11/1969	3	240.9	I	T																		
5/12/1973	4	1,563.5	T	T	T																	
4/17/1974	5	349.7	I	T	T	I																
9/11/1974	6	142.9	I	T	I	I	I															
12/18/1976	7	736.5	T	T	T	I	T	T														
12/11/1981	8	1,471.4	T	T	T	I	T	T	T													
2/7/1988	9	2,223.5	T	T	T	T	T	T	T	T												
1/24/1990	10	641.8	T	T	T	I	T	T	I	I	I											
5/6/1990	11	105.1	I	T	I	I	I	I	I	I	I	I										
8/31/1992	12	737.0	T	T	T	I	T	T	T	I	I	I	T									
11/16/1994	13	801.7	T	T	T	I	T	T	T	I	I	T	T	T								
1/26/1998	14	1,397.6	T	T	T	I	T	T	T	I	I	T	T	T	T							
9/29/1998	15	365.6	I	T	T	I	T	T	I	I	I	I	T	I	I	I						
7/23/1999	16	388.7	I	T	T	I	T	T	I	I	I	I	T	I	I	I	T					
1/21/2000	17	267.9	I	T	T	I	I	T	I	I	I	I	T	I	I	I	I	I				
9/15/2004	18	2,719.4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T			
9/13/2008	19	1,975.7	T	T	T	T	T	T	T	T	I	T	T	T	T	T	T	T	T	I		
7/25/2009	20	469.5	I	T	T	I	T	T	I	I	I	I	T	I	I	I	T	T	T	I	I	
Balance[3]		846.7																				
Total Production		18,127.2																				
		T	10	18	15	3	12	13	7	3	1	4	9	4	3	2	4	3	3	0	0	
		I	9	0	2	13	3	1	6	9	10	6	0	4	4	4	1	1	0	2	1	

[1] VPBS= Volume of oil proudced between spills, in millions of barrels[2] (MMbbl)

[2] bbl = barrels; 1 barrel= 42 U.S. gallons

[3] Balance= balance of production since the last spill

[4] Total Production includes 2010 production data, updated as of May 2011 from ONRR data.

T = smaller before larger, I = larger before smaller

Source: Data from Table II of Nakassis (1982)

Analysis: 20 observations, T = 114, I = 76, no ties S = T - I = 38

Prob (S ≥ 38 | n = 20) > Prob (S ≥ 42 | 20) > 10% (Bradley, 1968, Table XI)

A.2.6 Runs Up, Runs Down Test for OCS Pipeline Spills

Table A-5 presents the application of the Runs Up, Runs Down Test to the 20 pipeline spill observations from1964 through 2010 and using OC production data as of May 2011. The description of the Runs Up, Runs Down Test is described in Section A.2.3.

Conclusions on the Runs Up, Runs Down Test, as Related to Pipeline Data: The application of the Runs Up, Runs Down Test to the 1964 through 2010 pipeline spill data generated 11 runs with 20 observations, the test results suggest the VPBS sequence of runs could be random (probability of 20.12%).

A.2.7 Hotelling and Pabst's Test for Pipeline Spills

Table A-6 presents the application of the Hotelling and Pabst's Test to the 20 pipeline spill observations from1964 through 2010 and using May 2011 production data, and for the period of the last twenty years (1990-2009).

Conclusions on Hotelling and Pabst's Test, as Related to Pipeline Spill Data: The application of the Hotelling and Pabst's Test to the 1964-2010 pipeline spill data generated a D value of 934 with 20 observations, calculated from the sum of squares of the difference between the spill number of 1 to 20 (based on spill date) and the VPBS rank of 1 to 20 (based on relative VPBS amount low-to-high order), may not be a random result (probability of > 10%).

Table A-5. Runs Up, Runs Down Tests for OCS Pipeline Spills ≥1,000 Barrels, 1964 through 2010

Spill #	Pipeline Spill Date	VPBS[1] (MMbbl[2]) Two 1973 Spills	VPBS[3] Rank	Runs Up, Runs Down
1	10/15/1967	588.040	10	
2	3/12/1968	93.986	1	-
3	2/11/1969	240.911	4	+
4	5/12/1973	1,563.527	17	+
5	4/17/1974	349.682	6	-
6	9/11/1974	142.942	3	-
7	12/18/1976	736.530	12	+
8	12/11/1981	1,471.440	16	+
9	2/7/1988	2,223.490	19	+
10	1/24/1990	641.797	11	-
11	5/6/1990	105.079	2	-
12	8/31/1992	737.025	13	+
13	11/16/1994	801.686	14	+
14	1/26/1998	1,397.560	15	+
15	9/29/1998	365.602	7	-
16	7/23/1999	388.749	8	+
17	1/21/2000	267.907	5	-
18	9/15/2004	2,719.374	20	+
19	9/13/2008	1,975.691	18	-
20	7/25/2009	469.485	9	-
	Balance 2010	846.733		
	Total	18,127.232		

[1]VPBS = volume of oil produced between spills, expressed in millions of bbl (MMbbl)

[2]MMbbl = million barrels. A barrel is 42 U.S. gallons

[3] Balance=the amount of production between the last spill and the end of the study period.

[4] Total production= Total OCS production through the end of the study period; 2010 OCS production data was used, and was updated as of May 2011 using ONRR data.

Analysis: 20 observations, 11 runs, longest run 3

Prob (11 runs or fewer | 20) = 20.12%

(Bradley 1968, Table X)

Table A-6. Hotelling and Pabst's Tests for OCS Pipeline Spills ≥ 1,000 Barrels, 1964 through 2009

For Full Record (1964-2009)					
D = (1-10)^2 + (2-1)^2 + (3-4)^2 + (4-17)^2 + (5-6)^2 + (6-3)^2 + (7-12)^2					
	+ (8-16)^2 + (9-19)^2 + (10-11)^2 + (11-2)^2				
	+ (12-13)^2 + (13-14)^2 + (14-15)^2 + (15-7)^2 + (16-8)^2				
	+ (17-5)^2 + (18-20)^2 + (19-18)^2+ (20-9)^2				
=	934	Prob (D ≤ 934 | 20) > Prob (D ≤ 932 | 20) > 10 %			
		(Bradley, 1968, Table I)			

APPENDIX B. SAMPLE CALCULATION OF ESTIMATED PROBABILITY OF SPILL OCCURRENCE USING 1964 TO 2008 WORLDWIDE TANKER SPILL RATE

Appendix shows how the spill rates can be used to estimate spill probabilities.

Since information on spill rates is used in public policymaking, it is useful to provide an example of how BOEM uses the spill rate and the Poisson distribution (see Section 2.4.2 Poisson Distribution Used in Spill-Rate Estimations). This appendix represents such an example. This procedure is adapted from Anderson and LaBelle (1994).

For the purpose of this example, we have assumed that 0.75 Bbbl (Bbbl = 10^9 bbl or 1,000,000,000 bbl) of crude oil would be transported during a10-year period. Using the spill rate (λ) for worldwide tanker spills (Table 10) of 0.84 spills ≥ 1,000 bbl per 10^9 bbl handled, and an estimated transport (*t*) of 0.75 x 10^9 bbl of crude oil by tanker, it is estimated that a mean number (λ x *t*), or 0.63 spills ≥ 1,000 bbl will occur over that 10-year period as a result of the transport 0.75 Bbbl of crude oil by tanker, or

(0.84 spills per 10^9 bbl x 0.75 x 10^9 bbl= 0.63 spills)

The estimated probability of zero (0) spills (P(0)) occurring over that 10-year period as a result of handling the 0.75 x 10^9 bbl of crude oil by tanker is calculated by substituting 0 for n and 0.63 for λ *t* in equation (1), or

$$P(0) = \left(\frac{0.63^0 \text{ X } e^{-0.63}}{0!}\right) = \left(\frac{1 \text{ X } 0.53}{1}\right) = 0.53 \text{ or } 53\%$$

Table B-1 shows the results of similar calculations for the probabilities of 1 spill occurring and the probabilities of 2 spills occurring in each of the three spill size categories (≥1,000 bbl, ≥10,000 bbl, and ≥100,000 bbl).

The estimated probability of one *or more* spills occurring is equal to 1.00 minus the probability of 0 spills occurring, or

1.0 – P(0) = 1.00 – 0 .53 or 0 .47 (47%)

Thus, one could estimate that the probability (expressed as percent chance) of one or more spills ≥1,000 bbl occurring due to the transportation of 0.75 Bbbl of crude oil by tanker would be 47% over the 10-year period.

Table B-1. Sample Calculation of Estimated Probability of Spill Occurrence using 1974 through 2008 Worldwide Tanker Spill Rates

Spill Size (bbl[1])	Assumed Volume Handled[2] (Bbbl)[3]	Estimated Spill Rate[4]	Estimated Mean Number of Spills	Probability of zero (0) spills occuring (%)	Probability of 1 spill occurring (%)	Probability of 2 spills occurring (%)	Probability of ≥ 3 spills occurring (%)
≥ 1,000 bbl	0.75	0.84	0.63	53.3	33.6	10.6	2.6
≥ 10,000 bbl	0.75	0.42	0.32	72.6	23.2	3.7	0.4
≥ 100,000 bbl	0.75	0.17	0.13	87.8	11.4	0.7	0.03

[1]bbl= Barrel= 42 U.S. gallons

[2]The number for the assumed volume handled (0.75 billion barrels) is an arbitrary figure, selected to make the example more manageable.

[3] Bbbl= billion (10^9) barrels

[4] Spill rate is spills per 10^9 bbl handled

Again, using the worldwide tanker spill rates (Table 10) and assuming the transportation of 0.75 x 10^9 bbl of crude oil, it can be shown that the estimated probability of one or more spills ≥ 10,000 bbl occurring is 1.0 minus the probability of 0 spills of that size occurring, or 0 .27 (27%), and the estimated probability of one or more spills ≥ 100,000 bbl occurring is 1.0 minus the probability of 0 spills of that size occurring, or 0 .13 (13%). In Table B-1, the probability of 3 or more spills ≥1,000 bbl occurring has been calculated in the same manner by subtracting the combined probabilities of 0, 1, and 2 spills of that size occurring from the number 1.0, or

$$1.0 - P(0) - P(1) - P(2) = 1.00 – 0.53 – 0.34 – 0.11 = 0.02 \ (2\%)$$

The probability of 3 or more spills occurring for spills of ≥ 10,000 bbl and 10,000 bbl were similarly calculated. It should be noted that spills ≥ 10,000 bbl and spills ≥ 100,000 bbl are subsets of spills ≥ 1,000 bbl.

To calculate the mean number of spills ≥ 1,000 bbl but ≤10,000 bbl, subtract the estimated mean number of spills of ≥ 10,000 bbl (0.32) from the estimated mean number of spills of ≥ 1,000 bbl (0.63) , so (0.63 – 0.32) is 0.31.

Although the estimated mean number of spills can be subtracted, the probabilities, cannot be subtracted, and must be recalculated using the estimated mean of 0 .31spills in the Poisson distribution (i.e., the estimated probability of one or more spills ≥ 1,000 bbl and less than 10,000 bbl occurring is 0 .27 (27%) and is not equal to (47% - 27%), and would be calculated as follows:

1.0 – P(0), where P(0) =

$$\frac{(0.31^0 \text{ X } e^{-0.31})}{0!} = \frac{(1 \text{ X } 0.73)}{1} = 0.73 \ (73\%)$$

Therefore, 1.0 – P(0) = 1.0 – 0.73 = 0.27 (or 27%).

APPENDIX C. DATA ON OCS OIL SPILLS

This appendix presents additional details about spills of crude oil and condensate on the OCS from1964 through 2010. It considers historic spill sizes versus spill occurrence numbers prior to 2009 and after 2010 (when the Macondo well spill occurred) and it addresses spills due to hurricane damage in the Gulf of Mexico.

C.1 OCS Petroleum Spills, 1964 through 2009

From 1964 through 2009, more than 17.5 billion bbl of crude oil and condensate were produced on the OCS while spilling less than 570,000 bbl of petroleum (crude oil, condensate and refined products such as diesel and gasoline used in exploration and development operations). Overall, this was more than 30,000 bbl petroleum produced per bbl spilled (Table 1 in the main report). This record improved over time, from 1964 through 2009:

- ❖ Slightly less than 4,000 bbl was produced per bbl spilled from 1964 through1970 (7 years). (This data category was selected to end in 1970, due to increased spill data quality after 1970.)
- ❖ Almost 60,000 bbl was produced per bbl spilled from 1971 through 1990 (20 years).
- ❖ More than 155,000 bbl was produced per bbl spilled from1991 through 2009 (19 years).

The improvement in the 46-year period from 1964 through 2009 was largely due to the elimination of larger spill events of 50,000, 20,000 or even 10,000 bbl or more in size. (See Table 2 in the main report). Specifically:

- ❖ From1964 through 1970, there were ten spills ≥ 1,000 bbl, four of which were ≥ 50,000 bbl (between 53,000 and 161,000 bbl).
- ❖ There were no single spills ≥ 20,000 bbl from1971 through 2009.
- ❖ There were no single spills ≥ 10,000 bbl from 1991 through 2009.
- ❖ There were no single spills ≥ 5,000 bbl from 2006 through 2009.

This continuity of improvement was broken by a spill in 2010 which, over a period of three months, may have released about 8.5 times more petroleum than had cumulatively spilled from OCS activities over the preceding 46 years of the program (from 1964 through 2009). The incident began on April 20, 2010 with a loss of well control, explosion, and fire on the *Deepwater Horizon* rig at BP's Macondo well located at Mississippi Canyon 252 (MC 252) more than 50 miles offshore in a water depth of just under 5,000 feet. The resulting release of tens of thousands of bbl of oil per day was not brought under control until July 15, 2010. This report assumes the volume of oil released from this incident was 4.9 billion bbl, the volume utilized in: "Oil Budget Calculator: Deepwater Horizon Technical Documentation", November 2010, Report by The Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team http://www.noaanews.noaa.gov/stories2010/PDFs/OilBudgetCalc_Full_HQ-Print_111110.pdf This spill volume may be revised in the future based on additional studies.

The vast majority of OCS spills are ≤ 1,000 barrels. If you include all OCS spills ≥ one barrel, for the 46-year time period from 1964 through 2009, you find that 98.9 percent of all OCS spills were <1,000 barrels in volume and 1.1 percent of spills were ≥ 1,000 barrels in volume. However, the spills of 1,000 barrels or more accounted for 90.6 percent by volume of the almost 570,000 bbl petroleum spilled in that time period (Fig. 10, main report) and more than 99.9 percent of the total spillage from 1964 through 2010 was due to the Macondo well spill.

Comparing the 1964 through 2009 period above (Figure 10, main report) with the 15-year period from1995 through 2009 (Fig. C-1), OCS spills ≥ 1,000 bbl were still 1.1 percent of all spills, but accounted for 48.1 percent of the spillage; and spills of 50 to 999 bbl (14.6% of spills) accounted for 43.5 percent of the spillage. The reduction in relative contribution of spills ≥ 1,000 bbl to the total spillage was because spills ≥ 1,000 bbl have tended to decrease in size over time through 2009; and there was an increase in reporting of spills between 50 and 999 bbl in size during this period, due to the damage from major hurricanes (Lili 2002, Ivan 2004, Katrina and Rita 2005, Gustav and Ike 2008).

C.2 OCS Petroleum Spills, Most Recent 15-Year Periods, 1995 through 2009 and 1996 through 2010

The effect of the Macondo well spill on the OCS spill record can also be seen by comparing data for all spills for two 15-year periods: 1) 1995 through 2009 (Figs. C-1 and C-2) and 2) 1996 through 2010 (Fig. C-3).

For this period (1995 through 2009) (Figs. C-1 and C-2):

- Most, 96.2%, of OCS petroleum spills were < one bbl (42 gallons), but these spills accounted for 1.9% of the spillage.
- More than 98% of these spills were < 10 bbl (96.2%+2.4%).
- Spills ≥ 1,000 bbl accounted for a very small percentage, 0.04%, of the total number of OCS petroleum spills that occurred.
- Spills ≥ 1,000 bbl accounted for a significant portion, 47.1%, of the volume spilled.

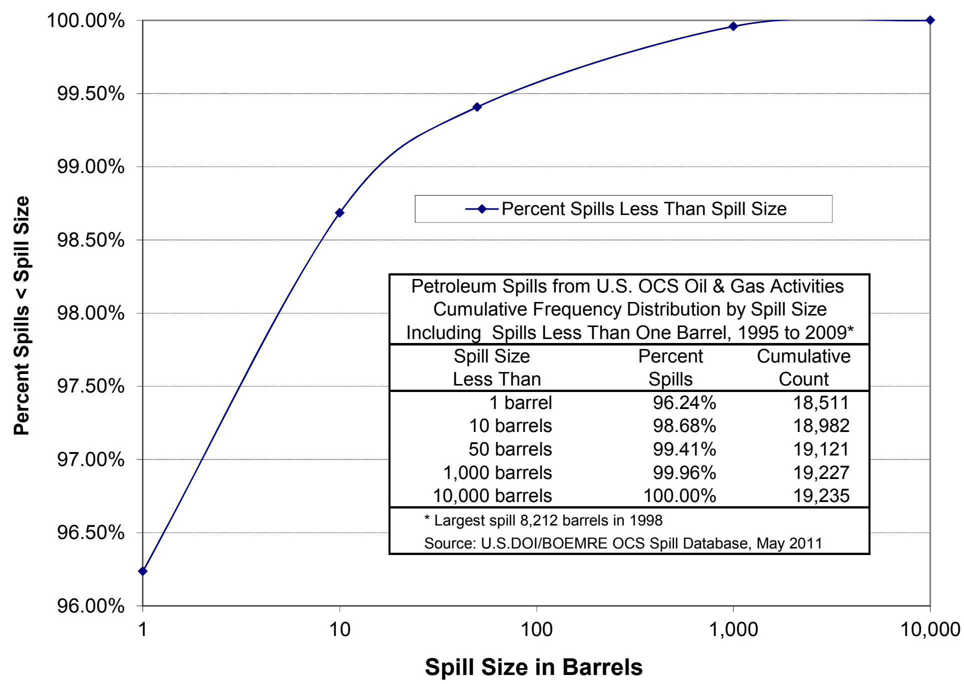


Figure C-1. Cumulative Frequency Distribution for All Petroleum Spills from OCS Oil and Gas Operations 1995 through 2009

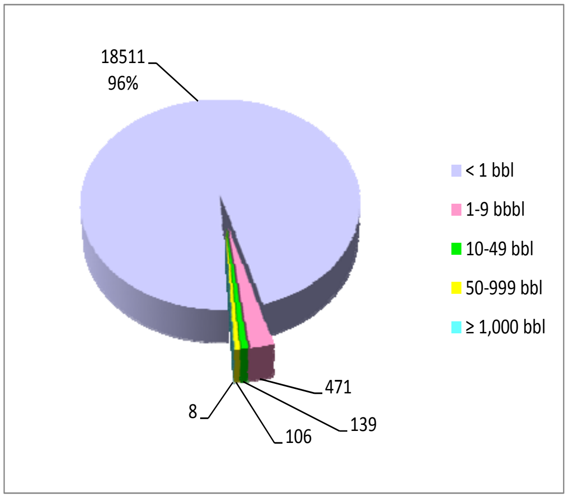
When the 15-year period including the Macondo well spill (1996 through 2010) is considered (Fig. C-3):

- Most, 95.8 %, OCS petroleum spills were still < one bbl, (42 gallons) but these spills accounted for and even smaller percentage (.017%) of the spillage.
- More than 98% of these spills were still < 10 bbl (95.8%+2.7%).
- Spills ≥1,000 bbl still accounted for a very small percentage, 0.05%, of the total number of OCS spills that occurred.
- However, spills ≥1,000 bbl accounted for most, 99.5%, of the volume spilled.

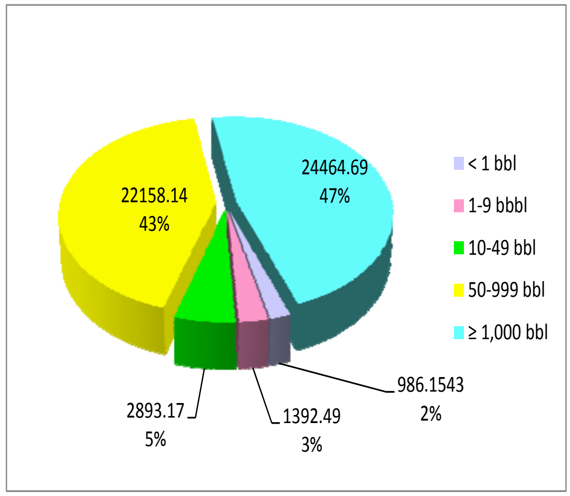
C.3 Hurricane-Related OCS Petroleum Spills ≥ One Barrel

Roughly half of the approximately 51,000 bbl of all OCS petroleum spills (≥ 1 bbl) from1995 through 2009 resulted from six highly destructive hurricanes from 2002 through 2008 which destroyed or extensively damaged: 305 platforms, 76 drilling rigs, and over 1,200 pipeline segments (BSEE, 2009) http://www.boemre.gov/incidents/PDFs/Hurricanes2002to2008.pdf.

Percentage of Spills in Each Size Category



Spill Size Categories vs. Spill Volume In Barrels



Number of Spills, All Spill Sizes
Total = 19,235
1995 through 2009

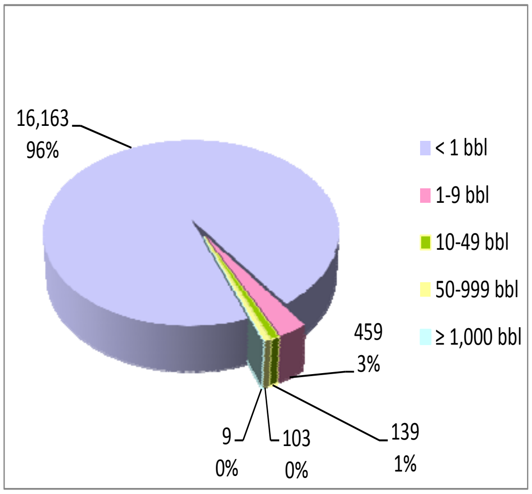
Spill Volume, All Spill Sizes
Total 51,895 Barrels
1995 through 2009

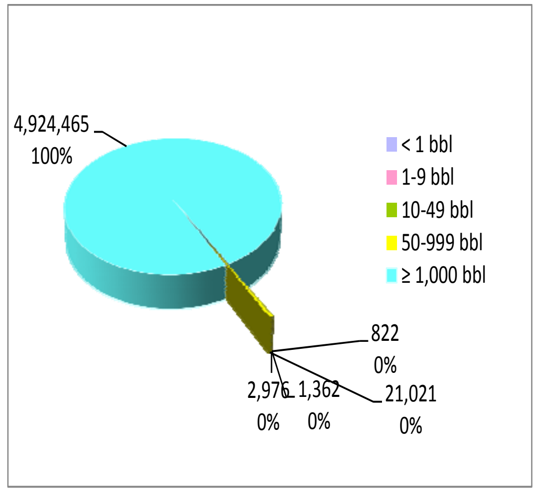
Petroleum Spills from OCS Oil & Gas Activities by Spill Size, 1995 through 2009

Spill Size	Number of Spills	Barrels Spilled	Average Spill Size	% Spills ≥ 1 bbl[1]	% Volume ≥ 1 bbl[1]	% of All Spills by Number	% of All Spills by Volume
< 1 bbl	18,511	986	0.0533			96.236%	1.900%
1-9 bbbl	471	1,392	2.9565	65.055%	2.735%	2.449%	2.683%
10-49 bbl	139	2,893	20.8142	19.199%	5.683%	0.723%	5.575%
50-999 bbl	106	22,158	209.0391	14.641%	43.525%	0.551%	42.698%
≥ 1,000 bbl	8	24,465	3058.0863	1.105%	48.056%	0.042%	47.143%
Total ≥ 1 bbl	724	50,908	70.3156	100.000%	100.000%		
All Spills	19,235	51,895	2.6979			100.000%	100.000%
bbl[1]= Barrel= 42 U.S. Gallons							

Figure C-2. Petroleum Spills from OCS Oil and Gas Activities by Spill Size and Volume, 1995-2009

Almost 26,000 bbl of crude and refined products were lost as a result of 231 petroleum spills ≥ 1 bbl during major Hurricanes: Lili (2002), Ivan (2004), Katrina (2005), Rita (2005), Gustav (2008), and Ike (2008). These six storms were responsible for three of the eight spill events ≥ 1,000 bbl (totaling 8,100 bbl); and 75 of the 106 spills of 50 to 999 bbl (totaling about 16,000 bbl) that occurred over the 15-year period (1995 through 2009). (A fourth spill ≥ 1,000 bbl in size was an 8,200 bbl pipeline spill caused by Hurricane Georges in 1998.)





Number of Spills, All Spill Sizes
Total = 16,873
1996 through 2010

Spill Volume, All Spill Sizes
Total = 4,950,646 Barrels
1996 through 2010

Petroleum Spills from U.S. OCS Oil & Gas Activities by Spill Size, 1996 to 2010							
Spill Size	Number of Spills	Spill Volume (bbl[1])	Average Spill Size	% Spills ≥ 1 bbl[1]	% Spill Volume ≥ 1 bbl[1]	% of All Spills by Number	% of All Spills by Number
< 1 bbl	16,163	822	0.0509			95.792%	0.017%
1-9 bbl	459	1,362	2.9662	64.648%	0.028%	2.720%	0.028%
10-49 bbl	139	2,976	21.4129	19.577%	0.060%	0.824%	0.060%
50-999 bbl	103	21,021	204.0845	14.507%	0.425%	0.610%	0.425%
≥ 1,000 bbl	9	4,924,465	547162.7778	1.268%	99.488%	0.053%	99.471%
Total ≥ 1 bbl	710	4,949,824	6971.5825	100.000%	100.000%		
All Spills	16,873	4,950,646	293.4064			100.0%	100.0%
[1] bbl= Barrel= 42 U.S. Gallons							

Figure C-3. Petroleum Spills from OCS Oil and Gas Activities by Spill Size and Volume, 1996 through 2010

Historically, OCS hurricane-related spills were mostly *active* spills from oil and gas facilities, i.e., spills that were observed and generally required some intervention after the storms. Beginning in 2004 with Hurricane Ivan, petroleum that was lost or missing from pre-storm inventories on OCS structures that were destroyed, heavily damaged, and/or missing (platforms and pipelines) were counted as spills by DOI (even though these spills were not observed and required no response). The change to specifically include these *passive* spills in the database resulted in an increase in the number and volume of spills attributed to these six hurricanes.

The loss of petroleum during these hurricanes was minimized by the successful operation of the safety valves that are required to be installed at least 100 feet below the mudline in each wellbore. Pipeline check valves limited the potential losses from damaged pipeline segments. All OCS facilities in areas threatened by the storms' approach were shut in prior to the hurricanes so that oil losses were mostly limited to the oil stored on the damaged platforms or contained in damaged pipeline sections between the check valves. The hydrocarbons released during the hurricanes were thoroughly dispersed offshore by the hostile sea conditions, which eliminated the potential for oiling shoreline.

There were no accounts of environmental consequences resulting from spills from OCS facilities which occurred during these major hurricanes from 2002 through 2008: no spill contacts to the shoreline; no reported oiling of marine mammals, birds, or other wildlife; no large volumes of oil on the ocean surface to be collected or cleaned up; and no identified environmental impacts from any OCS spills from these hurricanes (BSEE, 2009).