APPENDIX V

OFFSHORE OIL SPILL RISK MODELS

APPENDIX V - OFFSHORE OIL SPILL RISK MODELS

Contents

V.1 INTRODUCTION

V.1.1 Objective

This appendix describes the models of oil spill risks in offshore operations that are used in the project. The models are based on an analysis of offshore accident experience, mainly in the North Sea and the Gulf of Mexico.

V.1.2 Data Sources

The main current data source is the International Association of Oil & Gas Producers (OGP). This is appropriate for current oil spill frequencies.

Another source is the Oil Spill Risk Database (OSRD) model that was developed by DNV from oil spills in the North Sea and the Gulf of Mexico during 1975-90, and was used in the previous risk assessment for Australian waters (DNV 1999). Although this source is old, the relatively high numbers of accidents in that period are useful for spill size distributions. These are considered still be applicable today in the absence of better size distributions.

These results are compared to the experience of offshore oil spills in Australian waters from Appendix III, taking account of the level of activity that is documented in Appendix I.

V.1.3 Accident Types

The following accident types are modelled:

- Blowouts during well drilling, production and workover.
- Leaks from risers and pipelines
- Leaks from process equipment
- Leaks from crude oil storage and loading
- Leaks from diesel use and loading

These accident types are considered separately below.

V.2 BLOWOUTS

V.2.1 Blowouts in Exploration Drilling

The frequency of blowouts from normal exploration wells, excluding shallow gas blowouts, is estimated as 3.1×10^{-4} per well drilled (OGP 2010a). This is based on data from the Gulf of Mexico, UK and Norway during 1980-2004, with adjustment for trends. It applies to well operations of North Sea standard, defined as operations with blowout preventer (BOP) installed including shear rams, and a two-barrier principle followed. Shallow gas blowouts are excluded because these are not expected to result in oil spills.

This is expected to be appropriate for offshore operations in Australian waters, but it is desirable to check against actual experience. At present there are approximately 60 exploration/appraisal wells drilled in Australia each year (Appendix I), so the frequency implies a 2% chance of an exploration/appraisal well blowout somewhere in Australian waters each year. This is consistent with the fact that no such blowouts have occurred. However, a similar comparison for development wells gives the opposite conclusion (see Section V.2.2), and since similar management and oversight are applied to both types of wells it may be appropriate to reconsider the validity of generic data to Australian exploration/appraisal wells once the underlying causes of the Montara blowout are fully understood.

The OSRD model included a frequency of oil spills due to exploration well drilling of $6.7 \times 10^{-4}\ Q^{-0.3}$ per well drilled for spill size Q in barrels. This is $6.7 \times 10^{-4} \times 7.3^{-0.3} = 3.7 \times 10^{-4}\ Q^{-0.3}$ per well drilled for Q in tonnes. This is slightly higher than the OGP data, probably due to the data being older. Although the frequency is now obsolete, this is the only available source that gives a size distribution.

Combining the OGP frequency with the OSRD size distribution, the selected blowout frequency distribution is:

$$F = 3.1 \times 10^{-4}\ Q^{-0.3} \qquad \text{for spill size Q in tonnes}$$

The 2010 Macondo blowout in the Gulf of Mexico is consistent with this distribution, The outflow quantity in that event was 4.9 million barrels (approximately 670,000 tonnes). The probability of a spill exceeding this size is $670{,}000^{-0.3} = 0.018$. In other words, approximately 1 in 55 blowouts of 1 tonne or more would be expected to exceed 670,000 tonnes outflow.

V.2.2 Blowouts in Development Drilling

The frequency of blowouts from normal development wells, excluding shallow gas blowouts, is estimated as 6.0×10^{-5} per well drilled (OGP 2010a). This is based on data from the Gulf of Mexico, UK and Norway during 1980-2004, with adjustment for trends. It applies to well operations of North Sea standard, as above. Including completions, the frequency increases to 1.6×10^{-4} per well.

At present there are approximately 35 development wells drilled in Australia each year (Appendix I), so the frequency implies a 0.6% chance of a development well blowout somewhere in Australian waters each year. The occurrence of the Montara blowout in 2009 could therefore be considered extremely unfortunate or could be taken as evidence that the risk in Australian waters is much higher. In general, when there is large uncertainty in a risk assessment, it is appropriate to use the more pessimistic approach. However, a single event can only give a very uncertain frequency estimate, so the following calculation is only indicative. If the Montara blowout was compared to approximately 30 years of drilling 35 development wells per year, it would imply a blowout frequency of approximately 10^{-3} per well drilled. This is an order of magnitude higher than the OGP value above.

The OSRD model included a frequency of oil spills over 1 tonne due to development well drilling and completion of $4.5 \times 10^{-4} \times 7.3^{-0.3} = 2.5 \times 10^{-4}$ per well. This is slightly higher than the OGP data. It is therefore adopted as an interim reflection of the uncertainty that the Montara blowout creates about the applicability of North Sea standards in Australian waters. It may be appropriate to reconsider this once the underlying causes of the Montara blowout are fully understood

The spill size distribution, based on the OSRD model, is:

$$F = 2.5 \times 10^{-4} Q^{-0.3} \qquad \text{for spill size Q in tonnes}$$

The outflow quantity in the Montara blowout was estimated as 400 barrels per day (64 tonnes per day at the density of the Montara oil). The duration was 74 days, giving a total spill quantity of 4736 tonnes. Based on the OSRD model, the probability of a spill exceeding this size is $4736^{-0.3} = 0.078$. In other words, approximately 1 in 13 blowouts of 1 tonne or more would be expected to exceed 4736 tonnes outflow. It is impossible to evaluate whether this model is valid without a detailed assessment of reservoirs and drilling programmes in Australian waters.

V.2.3 Blowouts in Production

The frequency of blowouts from oil production wells, including external causes, is estimated as 3.9×10^{-5} per well year (OGP 2010a). This is based on data from the Gulf of Mexico, UK and Norway during 1980-2004, with adjustment for trends. It applies to well operations of North Sea standard, as above. Including workovers (0.2 per well year) and wirelining (1.7 per well year) the frequency increases to 6.9×10^{-5} per well year.

This is expected to be appropriate for offshore operations in Australian waters, but it is desirable to check against actual experience. At present there are approximately 410 oil/condensate wells in production in Australian waters (Appendix I), so the frequency implies a 3% chance of a production well blowout somewhere in Australian waters each year. This is consistent with the fact that no production blowouts with significant oil spills have occurred.

The OSRD model included a frequency of oil spills over 1 tonne due to production blowouts of $3.6 \times 10^{-5} \times 7.3^{-0.3} = 2.0 \times 10^{-5}$ per well year. Including workovers (0.5 per well year in the previous study) the frequency increases to 8.9×10^{-5} per well year. This is slightly higher than the OGP data, probably due to the data being older. Although the frequency is now obsolete, this is the only available source that gives a size distribution.

Combining the OGP frequency with the OSRD size distribution, the selected blowout frequency distribution is:

$$F = 6.9 \times 10^{-5} Q^{-0.3} \qquad \text{for spill size Q in tonnes}$$

V.3 RISERS AND PIPELINES

V.3.1 Risers

The frequency of leaks from steel risers is estimated as 9.1×10^{-4} per riser year (OGP 2010b). This is for risers of 16" or less, and is based on North Sea data.

At present there are approximately 139 production risers in Australia (Appendix I), so the frequency implies a 13% chance of a riser leak somewhere in Australian waters each year. This is consistent with 2 such events with spill quantity over 1 tonne being recorded in the AMSA data from 1982-2010. Both of these were associated with risers on mobile production units.

The OSRD model included a frequency of oil spills over 1 tonne due to risers of $6.3 \times 10^{-4} \times 7.3^{-0.7} = 1.6 \times 10^{-4}$ per riser year. This is much lower than the OGP data, possibly due to the assumption of a minimum spill size of 1 tonne. Because leaks from risers are likely to be detected, there is a high probability of spills less than 1 tonne. If a size threshold of 0.1 tonnes was used, the frequency from the OSRD model would be 5x higher, i.e. 8.0×10^{-4} per riser year. This is roughly consistent with the OGP data, if it is assumed that OGP includes all leaks of 0.1 tonnes or more.

The spill size distribution, based on the OSRD model, is:

$F = 1.6 \times 10^{-4} Q^{-0.7}$ for spill size Q in tonnes

V.3.2 Pipelines in Safety Zone

The frequency of leaks from subsea pipelines within the platform safety zones is estimated as 7.9×10^{-4} per pipeline year (OGP 2010b). This is for pipelines of 16" or less, and is based on North Sea data.

At present there are approximately 139 production risers in Australia (Appendix I), implying the same number of pipelines within safety zones, so the frequency implies a 11% chance of a leak from a pipeline within a safety zone somewhere in Australian waters each year. No such events are recorded in the AMSA data from 1982-2010.

The OSRD model included a frequency of oil spills over 1 tonne due to pipelines within the safety zone of $6.3 \times 10^{-4} \times 7.3^{-0.46} = 2.5 \times 10^{-4}$ per pipeline year. This is much lower than the OGP data, possibly due to the assumption of a minimum spill size of 1 tonne. Because leaks from pipelines in the safety zone are likely to be detected, there is a high probability of spills less than 1 tonne. If a size threshold of 0.1 tonnes was used, the frequency from the OSRD model would be 3x higher, i.e. 7.5×10^{-4} per pipeline year. This is roughly consistent with the OGP data, if it is assumed that OGP includes all leaks of 0.1 tonnes or more.

The spill size distribution, based on the OSRD model, is:

$F = 2.5 \times 10^{-4} Q^{-0.46}$ for spill size Q in tonnes

V.3.3 Pipelines in Open Sea

The frequency of leaks from subsea pipelines in the open sea (i.e. between the platform safety zone and the pipeline landfall) is estimated as 5.1×10^{-5} per pipeline-km year (OGP 2010b). This is for pipelines of 24" or less, and is based on North Sea data.

At present there are approximately 1135 offshore pipeline km in Australia (Appendix I), so the frequency implies a 6% chance of a pipeline leak somewhere in Australian waters each year. No such events are recorded in the AMSA data from 1982-2010.

The OSRD model included a frequency of oil spills over 1 tonne due to pipelines in the open sea of $4.9 \times 10^{-5} \times 7.3^{-0.46} = 2.0 \times 10^{-5}$ per pipeline-km year. This is much lower than the OGP data, possibly due to the assumption of a minimum spill size of 1 tonne. If a size threshold of 0.1 tonnes was used, the frequency from the OSRD model would be 3x higher, i.e. 6.0×10^{-5} per pipeline year. This is roughly consistent with the OGP data, if it is assumed that OGP includes all leaks of 0.1 tonnes or more.

The spill size distribution, based on the OSRD model, is:

$$F = 2.0 \times 10^{-5} Q^{-0.46} L$$ for spill size Q in tonnes and pipeline length L in km

V.3.4 Subsea Flowlines

The frequency of leaks from subsea flowlines (i.e. small pipelines containing unprocessed well fluid) is estimated as 5.0×10^{-4} per pipeline-km year (OGP 2010b). This is based on North Sea data.

At present there are approximately 200 subsea flowline km in Australia (to be added to Appendix I), so the frequency implies a 10% chance of a riser leak somewhere in Australian waters each year. This is consistent with the occurrence of 2 flowline leaks in the AMSA data from 1982-2010, one of which had a spill quantity over 1 tonne.

The spill size distribution, based on the OSRD model for pipelines, is:

$$F = 5.0 \times 10^{-4} Q^{-0.46} L$$

This is based on spill size Q in tonnes and flowline length L in km. It assumes the pipeline leak frequency includes leaks of 1 tonne or more.

V.4 PROCESS EQUIPMENT

The OSRD model included a frequency of oil spills over 1 tonne due to oil processing of 0.68 x $7.3^{-0.988}$ = 0.095 per million tonnes of oil processed per year. In the absence of any more recent data, this frequency is retained. In the previous study (DNV 1999), the spill frequencies were reduced by a factor of 5 to match historical data, so the frequency was 1.9 x 10^{-2} per platform year.

The spill size distribution, based on the OSRD model, is:

$$F = 0.019\ Q^{-0.988}\ P$$

This is based on spill size Q in tonnes, and oil processing P in million tonnes per year.

The frequency above is for oil platforms. The effect of platform type is:

Oil platforms	$MF_{type} = 1.0$
Gas platforms	$MF_{type} = 0.0$

The frequency is for large platforms characteristic of North Sea operations. The effect of platform size and design is assumed as follows, as in the previous study:

FPSOs	$MF_{type} = 1.0$
Unattended platforms	$MF_{type} = 0.25$
Subsea production	$MF_{type} = 0.12$

V.5 OIL STORAGE AND LOADING

V.5.1 Crude Oil Storage

The OSRD model included a frequency of oil spills over 1 tonne due to crude oil storage of $1.6 \times 7.3^{-0.5} = 0.6$ per million tonnes of oil storage capacity per year. In the absence of any more recent data, this frequency is retained.

The spill size distribution, based on the OSRD model, is:

$$F = 0.6\ Q^{-0.5}\ C \qquad \text{if } Q<C$$

This is based on spill size Q in tonnes, and oil storage capacity C in million tonnes.

The frequency is for large platforms characteristic of North Sea operations. The effect of platform size and design is assumed as follows:

FPSOs $MF_{type} = 0.1$

V.5.2 Crude Oil Loading

Based on experience of offshore crude oil loading in the Norwegian Sector up to 1995, the frequency of leaks exceeding 1 tonne was estimated as 4.2×10^{-4} per cargo loaded, with the following size distribution:

$$F = 4.2 \times 10^{-4}\ Q^{-0.3}\ T$$

This is based on spill size Q in tonnes, and number of transfers T per year.

The AMSA data from 1982-2010 records 10 spills with known quantities associated with crude loading, including 8 from the pipeline and 2 from the ship. Of these, 4 exceeded 1 tonne. At present there are approximately 120 offshore crude loadings per year. Assuming this has been roughly constant for most of the historical period, the frequency of spills over 1 tonne would be $4/(120 \times 29) = 1.1 \times 10^{-3}$ per loading.

Based on spill reports to the Department of Energy covering crude oil loading in the UK Sector during 1982-88, the frequency of leaks exceeding 1 tonne was estimated as 1.0×10^{-2} per cargo loaded. A frequency function, which attempts to correct for under-reporting of small spills, was estimated as (Technica 1992):

$$F = 0.0103\ Q^{-0.662}\ T$$

This was also used in the OSRD model and the previous study (DNV 1999).

The wide difference between the UK and Norwegian estimates means that the overall frequencies are very uncertain, although the frequencies of large spills are similar. It is possible that the Norwegian data may have under-reported small spills, but it is also likely that practices have improved since the UK data was collected. The Australian data may also be incomplete, but since it is in between the other two datasets it is considered the most reliable and so is used in the present study in combination with the UK size distribution:

$$F = 1.1 \times 10^{-3}\ Q^{-0.662}\ T$$

V.6 DIESEL USE AND LOADING

V.6.1 Diesel Use and Storage

The OSRD model included a frequency of oil spills over 1 tonne due to diesel use and storage of $0.14 \times 7.3^{-0.8} = 2.9 \times 10^{-2}$ per platform year. In the previous study (DNV 1999), the spill frequencies were reduced by a factor of 5 to match historical data, so the frequency was 5.8×10^{-3} per platform year.

At present there are approximately 72 oil/condensate production platforms in Australia (Appendix I), so the frequency implies 2 diesel spills per year. The AMSA data from 1982-2010 records 7 diesel spills with known quantities, of which 4 exceeded 1 tonne. The average platform exposure during this period is estimated to be 40 platforms, based on the number in the previous study (DNV 1999). The historical spill frequency is then 4/(40 x 29) = 3.4×10^{-3} per platform year

The spill size distribution, based on the OSRD model, is:

$$F = 3.4 \times 10^{-3}\, Q^{-0.8}$$

The frequency above is for oil platforms. The effect of platform type is:

Oil platforms	$MF_{type} = 1.0$
Gas platforms	$MF_{type} = 0.0$

The frequency above is for large platform characteristic of North Sea operations. The effect of platform size and design is assumed as follows:

FPSOs	$MF_{type} = 1.0$
Unattended platforms	$MF_{type} = 0.1$
Subsea production	$MF_{type} = 0.0$

V.6.2 Diesel Loading

The OSRD model for diesel loading is almost identical to that for diesel use and storage.

The AMSA data from 1982-2010 records only one diesel loading spill with known quantities, which did not exceed 1 tonne. The average platform exposure during this period is estimated to be 40 platforms, The historical spill frequency is then less than 1/(40 x 29) = 8.6×10^{-4} per platform year.

The spill size distribution, based on the OSRD model, is:

$$F = 8.6 \times 10^{-4}\, Q^{-0.8}$$

V.7 REFERENCES

1. DNV (1997), “Risk Assessment of Ship-to-Ship Transfer”, Report for Marine Safety Agency, DNV Project C7912, November 1997.
2. DNV (1999), “Risk Assessment of Pollution from Oil and Chemical Spills in Australian Ports and Waters”, Det Norske Veritas Project 9330-3972, December 1999.
3. OGP (2010a), “Risk Assessment Data Directory: Blowout Frequencies”, International Association of Oil & Gas Producers, Report 434-2, March 2010.
4. OGP (2010b), “Risk Assessment Data Directory: Riser & Pipeline Release Frequencies”, International Association of Oil & Gas Producers, Report 434-4, March 2010.
5. Technica (1992), “Oil Spill Risk Database”, Confidential Report for VROM, Technica Project I574, February 1992.