OCS Study MMS 2002-047

FINAL REPORT

VOLUME II

Alternative Oil Spill Occurrence Estimators for the Beaufort and Chukchi Seas – Fault Tree Method

MMS Contract Number 01-00-PO-17199

August, 2002

By

Bercha International Inc.
Calgary, Alberta, Canada

U.S. Department of the Interior
Minerals Management Service
Alaska Outer Continental Shelf Region

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TABLE OF CONTENTS

VOLUME II - APPENDICES

APPENDIX **PAGE**

A Historical Data
Table of Contents ..... *A.i*

B Future Development Scenarios
Table of Contents ..... *B.i*

C Monte Carlo Calculations
Table of Contents ..... *C.i*

D Expected Value Calculations
Table of Contents ..... *D.i*

APPENDIX A

HISTORICAL DATA

TABLE OF CONTENTS

SECTION **PAGE**

Table of Contents ..... *A.i*
List of Tables ..... *A.iii*

A.1 Introduction **A.1.1**
A.1.1 General Introduction A.1.1
A.1.2 Summary of Data Files A.1.1
A.1.2.1 GOM Pipeline Analysis *A.1.1*
A.1.2.2 GOM Platform-based Spills *A.1.3*
A.1.2.3 E&P Forum Pipeline Analysis *A.1.3*
A.1.2.4 Crude Oil Tanker Summary *A.1.3*
A.1.2.5 Offloading Spill Rates *A.1.3*
A.1.2.6 Above Ground Storage Tanks (ASTs) *A.1.3*
A.1.2.7 Gas and Oil Blowouts *A.1.3*

A.2 Pipeline Spills in the OCS of the GOM: Analysis for 1972-1999 and 1985-1999 ..... **A.2.1**
A.2.1 Introduction A.2.1
A.2.2 Exposure to Risk A.2.1
A.2.3 Pipeline Spill Statistics A.2.5
A.2.4 Deficiencies in MMS Pipeline Databases A.2.5

A.3 Platform Spills in the OCS and the GOM: Analysis for 1972-1999 and 1985-1999 ..... **A.3.1**
A.3.1 Introduction on Platform Spills A.3.1
A.3.2 Exposure to Risk A.3.1
A.3.3 Platform Spill Statistics A.3.1

A.4 North Sea Pipeline Data **A.4.1**
A.4.1 Risers and Pipeline in Platform Safety Zone A.4.1
A.4.2 Pipeline Failure Frequencies for Different Conditions A.4.2

A.5 Crude Oil Tanker Spills **A.5.1**

A.6 Offloading Spill Rates **A.6.1**

A.7 Summary of Above Ground Storage Tank (AST) Spill Statistics **A.7.1**

A.8 Gas Blowouts **A.8.1**

A.9 Blowouts with Oil **A.9.1**

A.10 Oil Tanker Spills A.10.1

A.11 Spills During Tanker Loadings at Offshore Platforms A.11.1
A.11.1 Introduction A.11.1
A.11.2 Experience in the U.K. Sector of the North Sea A.11.1
A.11.3 Experience during 1976-1979 as Reported in Gulf 1981 ..... A.11.1
A.11.4 Experience during 1975-1993 as Reported by E&P Forum 1996 ..... A.11.1
A.11.5 Statoil Experience in the North Sea, 1979-1995..... A.11.3
A.11.6 Conclusion A.11.3

References A.R.1

LIST OF TABLES

TABLE **PAGE**

A.1.1 North Sea and Gulf of Mexico Data Summary A.1.2

A.2.1 GOM Pipeline Exposure Data (1948-2001) A.2.2
A.2.2 GOM OCS Pipeline Spill Statistics (1972-1999) A.2.6
A.2.3 GOM OCS Pipeline Spill Statistics (1985-1999) A.2.7
A.2.4 Cause Distribution of Pipeline Spills, GOM OCS (1972-1999) A.2.8

A.3.1 Platform Spills – Exposure to Risk A.3.2
A.3.2 Platform Spills Statistics (1972-1999) A.3.2

A.4.1 North Sea Spill Frequency (per 10,000 km-yrs) for Risers A.4.1
A.4.2 North Sea Spill Frequency (per 10,000 km-yrs) for Risers and pipelines damaged by anchoring and impact incidents in the platform safety zone (within 500 m of platform) A.4.1
A.4.3 North Sea Spill Frequency (per 10,000 km-yrs) for Risers and pipelines damaged by anchoring and impact incidents in the subsea well safety zone (within 500 m of subsea platform) A.4.1
A.4.4 North Sea Spill Frequency (per 10,000 km-yrs) for Pipelines damaged by anchoring and impact incidents in the mid-line of pipelines A.4.2
A.4.5 North Sea Spill Frequency (per 10,000 km-yrs) for Pipelines damaged by corrosion and material defects for pipelines less than 2 km in length A.4.2
A.4.6 North Sea Spill Frequency (per 10,000 km-yrs) for Pipelines damaged by corrosion and material defects for pipelines 2 to 5 km in length A.4.2
A.4.7 North Sea Spill Frequency (per 10,000 km-yrs) for Pipelines damaged by corrosion and material defects for pipelines greater than 5 km in length A.4.3

A.5.1 Crude Oil Tanker Spills of Various Sizes and Locations A.5.1

A.6.1 Spills from Offshore Platforms Lifting Crude Oil to Tankers A.6.1

A.7.1 Summary of AST Statistics A.7.1
A.7.2 Number of ASTs by Capacity Range, Production, bbl A.7.1
A.7.3 Production AST Release Frequency Distribution A.7.1
A.7.4 Frequencies for all ASTs – No Spill Sizes Given A.7.1

A.8.1 Gas Blowouts Statistical Summary A.8.1

A.9.1 Oil Blowouts Statistical Summary A.9.1

A.10.1 Crude Oil Tanker Spills of Various Sizes and Locations A.10.1

A.11.1 Pollution Incidents – UK Offshore Loading 1975-93 (non-CALM systems) A.11.2

A.1 INTRODUCTION

A.1.1 General Introduction

Historical data and its statistical analysis are used as a starting point for the fault tree application to oil spill indicator quantification. In the present application only data on Gulf of Mexico (GOM) pipelines, platforms, and oil well spills are considered. The data utilized in this study and their analysis for the purposes of the fault tree application are summarized in Chapter 2 of Volume I of the Final Report. However, as part of Task 1 of the scope of work, a broader spectrum of oil spill data (including North Sea and tanker spill data) was assimilated and analyzed; the results of this data processing are reported in this Appendix A. The work described in this Appendix was substantially carried out and reported by S.L. Ross Environmental Research.

A.1.2 Summary of Data Files

The file names that follow refer to the files on the CD [11].

A.1.2.1 GOM Pipeline Analysis *Files on CD: Original Data, DatedOilPPL.xls, GreaterThan5Obbl.xls, Pipeline Spills in the OCS of the GOM.doc*

The first section is the analysis and report for the GOM pipeline work. This may be the most important part of the study inasmuch as pipeline spills are of significant interest on the Slope. The section contains a breakdown of pipeline spills in terms of pipe diameter, pipeline length, water depth, spill size, exposure period (1972 to 1999, and 1985 to 1999), and cause of accident. The work was restricted to pipelines carrying oil to correspond to the focus on oil spills.

It was not possible to complete a similar analysis for the North Sea situation because of lack of raw data. The main data available are those from E&P Forum 1996. This study contained some errors and lacked in crucial information (such as spill size and type [oil or gas] data). In any case, the data from E&P is summarized in the next section along with other spill-type data. It is difficult to compare the GOM statistics to the North Sea (NS) statistics shown in E&P Forum 1996 because breakdowns are different. The following, however, shows that both studies produce frequencies in the same order of magnitude.

Table A.1.1 summarizes the exposure factors and very high level results form the NS and GOM data.

Table A.1.1
North Sea and Gulf of Mexico Data Summary

AREA	TOTAL RISER AND PIPELINE EXPERIENCE (km-yrs)	NUMBER OF SPILLS	FREQUENCY (per 10,000 km-yrs)	COMMENTS
North Sea (NS)	130,000	48 gas and oil	3.7 (gas and oil)	No spill sizes provided, but probably < 50 bbl included.
Gulf of Mexico (GOM)	254,000	31 oil	1.3 (oil only)	For spills > 50 bbl

Considering that the North Sea data probably includes spills less than 50 bbl, the numbers may well compare favorably.

It should be pointed out that over the course of the analysis, it was noticed there is some discrepancy between the spills reported in the pipeline masters file provided to Bercha by MMS and the spills reported in the "events" database that Cheryl Anderson of MMS uses to calculate pipeline frequencies for the Gulf. The analysis presented here is based entirely on the pipeline masters database from MMS Alaska [11].

A.1.2.2 GOM Platform-based Spills (PlatformSpills.xls, Platform Spills in the OCS of the GOM.doc

This two-page report summarizes data from MMS (Cheryl Anderson) on spills that have taken place on the platforms, including blowouts, storage tank ruptures, and other causes and sources.

A.1.2.3 E&P Forum Pipeline Analysis (Summary of Spill Frequency Statistics_no GOMpipelines.xls)

This is simply a copy of the statistics in the publication [6].

A.1.2.4 Crude Oil Tanker Summary

This is based on Anderson and LaBelle, 1994 [2] and 2001, and on various SL Ross analyses [13, 15, 18]. See section 9 below for a SL Ross internal report, which discusses the derivation of the statistics. This report has not been updated in view of the new, in-press Anderson and LaBelle 2001 study, but the table in the xls file was updated.

A.1.2.5 Offloading Spill Rates

These are taken from MMS 1997 [10] and the SL Ross report [13, 15].

A.1.2.6 Above Ground Storage Tanks (AST)

The data from E&P Forum does not have spill sizes, so original data was analyzed from IOSR annual summaries and the results and raw data are in the worksheets.

A.1.2.7 Gas and Oil Blowouts

Blowouts are covered extensively in E&P Forum and in the SL Ross study for BP Exploration Alaska [17]. The two sheets here cover the basics. The E&P Forum analysis seems detailed and complete. Again, spill sizes are not provided in the E&P Forum analysis, but they are in the sheets provided here.

A.2 PIPELINE SPILLS IN THE OCS OF THE GOM: ANALYSIS FOR 1972-1999 AND 1985-1999

A.2.1 Introduction

This chapter describes the steps taken in analyzing the historic risk of pipeline oil spills of size 50 bbls and greater.

The data for the analysis comes from two sources: the *PPL_MASTERS* database describing pipeline built and abandoned since 1948, published monthly (Mar 15, 2001 version used) on the MMS website at:
http://www.gomr.mms.gov/homepg/pubinfo/freeasci/pipeline/zipped/fixed/PipelineMastersFixeddfn.html
[8] and the *PPL_REPAIRS* database, received from MMS on a CD labeled: US DOI, MMS Leaks Database (Copy – Feb 26/01) [11].

Note that Anderson and LaBelle [2] use a different list that contains 4 or 5 >100bbl spills not contained in *PPL_REPAIRS* and that *PPL_REPAIRS* has a similar number of spills not contained in *A&B's OCSPIPE.xls*.

A.2.2 Exposure to Risk

PPL_MASTERS is a database of ALL pipeline constructed in the GOM, containing details that are not needed for this current study. For our purposes, a report was generated from the database containing only records for "BLKO" Or "BLOH" Or "BO/H" Or "BO/S" Or "C/S" Or "COND" Or "OILH" Or "G/O" Or "GC/S" Or "OIL" Or "O/W" Or "G/C" pipeline, any pipeline used for Condensate or Oil. Fields relating to date, size, Federal length and water depth were retained. Table 2.1 summarizes the results of this compilation.

The dates included are the Static Test Date, Construction Date, Date of Application and Date Marked Abandoned. Many records did not contain all or, in fact, any dates. For purposes of analysis the Build Date was taken to be the Static Test Date OR Construction Date OR Date of Application, in that order. About 1,000km out of the total of about 20,000km of pipeline had no Build Date. The undated pipeline was distributed equally over the 53 years of built totals for use in the estimation of exposure.

Pipeline exposure was accumulated over two date ranges: 1972-1999 and 1985-1999 in order to match some other existing analyses. Exposure was accumulated for three different aspects of pipeline segments: Depth ranges, Diameter ranges and Length ranges. Where a pipeline segment record shows a Date Marked Abandoned, the segment was removed from that year's total of pipeline. The work and results can be found in *DatedOilPPL.xls*. The result sheets are shown here as Table A.2.1.

Table A.2.1
GOM Pipeline Exposure Data (1948-2001)
(a) Exposure to Risk by Depth of Pipeline in OCS

Exposure to Risk by Depth of Pipeline in OCS																			
Date	PPL Masters: Mar 15, 2001 Pipeline Built by Size (km)			Add about 2% of Undated to each year (1/53 years)			PPL Masters: Mar 15, 2001 Abandoned by Size (km)			Pipe Size Exposure Net Pipe (Built - Abandoned)		Cumulative, 1972 - 1999		Exposure, 1972 - 1999			Exposure, 1985 - 1999		
	Less than 10m	10m and Greater	Grand Total	Less than 10m	10m and Greater	Grand Total	Less than 10m	10m and greater	Grand Total	Less than 10m	10m and greater	Less than 10m	10m and greater	Less than 10m	10m and greater	All Depths (km-year 1972 - 1999)	Less than 10m	10m and greater	All Depths (km-year 1985 - 1999)
				ADD 13.2	ADD 6.0														
Undated	700	318	1019																
1948 - 1971	1940	441	2381	2125	525	2650				2117	525	2117	525						
1970 - 1971							8		8										
1972	372	44	416	385	50	435				385	50	2502	575	2502	575				
1973	294	11	305	307	17	324	1		1	306	17	2808	592	5309	1167				
1974	188	6	195	202	12	214				202	12	3009	604	8318	1772				
1975	175	163	339	189	169	358				189	169	3198	774	11516	2545				
1976	487	20	507	500	26	526				500	26	3698	800	15214	3345				
1977	315	39	354	328	45	373				328	45	4026	845	19240	4190				
1978	589	48	637	602	54	657				602	54	4628	899	23868	5089				
1979	310	10	320	323	16	339	0		0	323	16	4951	915	28819	6004				
1980	189	134	324	203	140	343	0		0	202	140	5154	1055	33972	7059				
1981	303	186	489	316	192	508	5		5	311	192	5465	1247	39437	8306				
1982	151	230	381	164	236	400	0	2	2	164	234	5629	1481	45066	9787				
1983	91	328	419	105	334	439	5		5	99	334	5728	1815	50794	11603				
1984	149	300	450	163	306	469	1		1	162	306	5890	2122	56683	13724				
1985	123	283	406	136	289	425		11	11	136	278	6026	2399	62709	16124		6026	2399	
1986	97	269	366	110	275	385	2		2	109	275	6135	2674	68844	18798		12160	5074	
1987	113	267	380	126	273	399				126	273	6261	2948	75104	21746		18421	8022	
1988	115	476	591	128	482	610	2		2	125	482	6386	3430	81490	25176		24807	11452	
1989	174	489	663	187	495	682	6		6	181	495	6567	3925	88057	29101		31373	15377	
1990	293	495	789	307	501	808	7	2	9	300	499	6866	4424	94923	33526		38240	19801	
1991	135	346	482	148	352	501	36	0	36	113	352	6979	4777	101902	38302		45219	24578	
1992	106	269	375	119	275	394	4	11	15	115	265	7094	5041	108997	43344		52313	29619	
1993	39	233	272	52	239	291	13	0	14	39	239	7133	5280	116129	48624		59446	34900	
1994	146	657	802	159	663	821	26	15	41	133	648	7266	5928	123395	54552		66712	40828	
1995	67	581	648	80	587	667	41	11	53	39	575	7305	6504	130700	61056		74016	47331	
1996	391	948	1339	405	954	1358	53	140	193	352	814	7656	7317	138356	68373		81672	54649	
1997	163	814	978	177	820	997	56	48	104	121	772	7777	8089	146133	76462		89449	62738	
1998	153	775	928	166	781	947	34	43	77	132	738	7909	8827	154041	85290		97358	71565	
1999	63	585	648	76	591	667	61	67	127	16	524	7924	9351	161966	94641	256607	105283	80917	186199
2000	67	841	908	80	847	927	70	19	89	10	828								
2001	29	119	147	42	125	166	2	9	11	40	116								
Grand Total	10636	8068	18704	8408	10675	19082	434	379	814	7974	10295								
Net Pipe										18269									

Table A.2.1
GOM Pipeline Exposure Data (1948-2001)
(b) Exposure to Risk by Size of Pipeline in OCS

Exposure to Risk by Size of Pipeline in OCS																							
Date	PPL Masters: Mar 15, 2001 Pipeline Built by Size (km)				Add about 2% of Undated to each year (1/53 years)				PPL Masters: Mar 15, 2001 Abandoned by Size (km)				Pipe Size Exposure Net Pipe (Built - Abandoned)		Cumulative, 1972 - 1999			Exposure, 1972 - 1999			Exposure, 1985 - 1999		
	Less than 10"	10" and Greater	Unknown Size Code	Grand Total	Less than 10"	10" and Greater	Unknown Size Code	Grand Total	Less than 10"	10" and greater	Unknown Size code	Grand Total	Less than 10"	10" and greater	Less than 10"	10" and greater	Uncoded	Less than 10"	10" and greater	All Diameters (km-year 1972 - 1999)	Less than 10"	10" and greater	All Diameters (km-year 1985 - 1999)
					ADD 16.0	ADD 3.2	ADD 0.01																
Undated	848	170	1	1019																			
1948 - 1971	1129	1220	32	2381	1353	1265	32	2650					1345	1265	1345	1265							
1970 - 1971									8			8											
1972	321	89	6	416	337	93	6	435					337	93	1682	1357		1682	1357				
1973	141	164		305	157	167	0	324	1			1	156	167	1838	1524		3520	2881				
1974	156	35	4	195	172	38	4	214					172	38	2010	1562		5531	4443				
1975	141	186	12	339	157	189	12	358					157	189	2167	1751		7698	6194				
1976	178	326	2	507	194	329	2	526					194	329	2362	2080		10060	8274				
1977	134	216	4	354	150	219	4	373					150	219	2512	2299		12572	10574				
1978	223	415		637	239	418	0	657					239	418	2751	2717		15323	13291				
1979	218	99	3	320	234	102	3	339		0		0	234	102	2985	2819		18308	16110				
1980	202	119	3	324	218	122	3	343	0			0	218	122	3202	2941		21510	19051				
1981	339	150		489	355	153	0	508		5		5	355	149	3557	3090		25068	22141				
1982	265	116		381	281	119	0	400	2			2	279	119	3836	3209		28904	25350				
1983	267	131	22	419	283	134	22	439	5			5	277	134	4114	3343		33017	28693				
1984	356	93	1	450	372	96	1	469	1			1	371	96	4485	3439		37502	32132				
1985	327	75	4	406	343	78	4	425	11			11	332	78	4817	3517		42319	35648		4817	3517	
1986	165	187	14	366	181	190	14	385	2			2	180	190	4996	3707		47315	39355		9813	7223	
1987	229	151	0	380	245	154	0	399					245	154	5241	3861		52557	43216		15055	11084	
1988	304	286	0	591	320	289	0	610	2			2	318	289	5559	4150		58116	47366		20614	15234	
1989	277	364	21	663	293	367	21	682	6			6	288	367	5847	4517		63963	51883		26461	19752	
1990	509	279	1	789	525	282	1	808	9			9	516	282	6363	4799		70326	56682		32824	24551	
1991	434	44	4	482	450	47	4	501	18	18		36	432	30	6795	4829		77120	61511		39618	29379	
1992	313	57	5	375	329	60	5	394	15			15	314	60	7109	4889		84229	66400		46727	34268	
1993	190	81	2	272	206	84	2	291	13	0		14	192	83	7301	4972		91530	71372		54028	39240	
1994	428	372	2	802	444	375	2	821	40	1		41	403	375	7705	5347		99235	76719		61733	44587	
1995	375	272		648	391	276	0	667	46	6		53	345	269	8050	5616		107285	82335		69782	50204	
1996	519	821		1339	535	824	0	1358	128	65		193	407	758	8457	6375		115741	88710		78239	56578	
1997	351	627		978	367	630	0	997	98	4	2	104	268	626	8725	7001		124466	95711		86964	63580	
1998	385	540	3	928	401	543	3	947	74	4		77	328	539	9053	7540		133519	103251		96017	71120	
1999	419	229		648	435	232	0	667	114	12	1	127	321	220	9373	7760		142892	111011	253903	105390	78879	184269
2000	361	141	406	908	377	144	406	927	79	11		89	298	133									
2001	130	17		147	146	20	0	166	2	9		11	144	11									
Grand Total	10636	8068	552	19255	10492	8039	552	19082	676	135	3	814	9816	7904									
Uncoded																							
Built																	519						
Abandoned																	-3						

Table A.2.1
GOM Pipeline Exposure Data (1948-2001)
(c) Exposure to Risk by Length of Pipeline in OCS

Exposure to Risk by Length of Pipeline in OCS																															
Date	PPL Masters: Mar 15, 2001 Pipeline Built by Size (km)					Add about 2% of Undated to each year (1/53 years)					PPL Masters: Mar 15, 2001 Abandoned by Size (km)					Pipe Size Exposure Net Pipe (Built - Abandoned)				Cumulative, 1972 - 1999				Exposure, 1972 - 1999					Exposure, 1985 - 1999				
	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	Grand Total	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	Grand Total	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	Grand Total	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	All Lengths	< 0.5 km	0.5 - 2 km	2 - 5 km	> 5 km	All Lengths
						ADD 1.3	ADD 7.4	ADD 3.6	ADD 6.8																								
Undated	71	394	191	362	1019																												
1948-1971	14	209	280	1878	2381	33	313	331	1973	2304						31	313	324	1973	31	313	324	1973										
1970-1971											2		6		8																	
1972	6	47	72	291	416	7	54	76	298	373						7	54	76	298	38	367	400	2271	38	367	400	2271						
1973	3	36	34	232	305	5	43	38	239	276	1				1	3	43	38	239	42	410	438	2510	80	778	838	4781						
1974	1	12	20	162	195	2	19	23	169	192						2	19	23	169	44	430	461	2679	124	1208	1299	7459						
1975	1	20	24	294	339	2	27	27	301	328						2	27	27	301	46	457	488	2980	170	1665	1787	10439						
1976	4	38	59	407	507	5	45	62	414	476						5	45	62	414	51	502	551	3394	222	2167	2338	13833						
1977	3	31	52	269	354	4	38	55	276	331						4	38	55	276	55	540	606	3669	277	2707	2944	17502						
1978	2	33	35	567	637	4	41	38	574	612						4	41	38	574	59	581	644	4243	336	3288	3588	21745						
1979	4	48	60	208	320	5	56	63	215	278					0	5	56	63	215	64	637	708	4458	400	3924	4296	26203						
1980	4	22	76	222	324	5	29	79	229	308					0	5	29	79	229	69	666	787	4687	469	4590	5082	30890						
1981	5	35	87	363	489	6	42	90	370	460		5			5	6	37	90	370	75	703	877	5057	544	5294	5960	35947						
1982	4	45	73	259	381	5	52	77	266	343		2		2	5	5	50	77	264	80	753	954	5321	624	6047	6913	41268						
1983	4	51	64	301	419	5	58	68	308	375			5		5	5	58	62	308	85	811	1016	5629	709	6858	7929	46897						
1984	4	67	97	282	450	5	75	100	289	389	1				1	5	75	100	289	90	886	1117	5917	799	7744	9046	52814						
1985	7	54	127	218	406	9	61	130	225	356			11	11	23	9	61	119	214	98	947	1235	6131	897	8691	10281	58945		98	947	1235	6131	
1986	3	23	29	312	366	4	30	32	319	351	2				2	3	30	32	319	101	977	1268	6450	999	9668	11549	65395		200	1924	2503	12581	
1987	4	27	63	286	380	5	35	67	293	360						5	35	67	293	106	1012	1335	6742	1105	10679	12884	72137		306	2935	3838	19323	
1988	5	32	70	484	591	6	40	73	491	564		2			2	6	37	73	491	112	1049	1408	7233	1217	11728	14292	79371		419	3984	5246	26557	
1989	5	35	90	532	663	7	42	94	539	633	5				6	2	42	94	539	114	1091	1502	7773	1332	12819	15794	87143		533	5075	6748	34329	
1990	3	34	130	621	789	5	41	134	628	762	1	2	6	2	11	4	39	128	626	118	1130	1629	8399	1450	13949	17423	95542		651	6205	8377	42728	
1991	1	39	104	338	482	3	46	107	344	452	5		29	0	36	-2	46	78	344	116	1176	1707	8743	1566	15126	19130	104285		767	7382	10084	51471	
1992	2	15	87	271	375	4	22	90	278	369	1	6	6	11	25	2	16	84	268	118	1192	1792	9011	1684	16318	20922	113296		886	8574	11876	60482	
1993	2	36	67	167	272	4	43	70	174	245	1	3	8	0	14	3	40	63	174	121	1232	1854	9185	1806	17549	22776	122481		1007	9805	13730	69667	
1994	2	49	142	609	802	3	56	146	616	762	13	16	9	15	56	-10	40	138	601	112	1271	1992	9786	1917	18820	24768	132267		1119	11076	15722	79453	
1995	4	29	117	499	648	5	36	120	506	626	11	15	24	11	64	-6	21	96	495	105	1292	2088	10281	2023	20113	26856	142548		1224	12369	17810	89734	
1996	3	47	85	1205	1339	4	54	88	1211	1300	10	35	143	140	333	-6	20	-55	1071	99	1312	2033	11352	2122	21425	28889	153900		1323	13681	19843	101086	
1997	4	44	112	817	978	6	51	116	824	940	15	36	51	48	153	-10	15	65	775	90	1327	2098	12127	2212	22752	30987	166028		1413	15008	21941	113213	
1998	5	37	90	797	928	6	45	93	803	897	14	11	52	43	121	-8	34	42	760	82	1361	2140	12888	2294	24113	33127	178915		1495	16369	24081	126101	
1999	2	33	85	527	648	4	41	89	534	623	20	30	77	67	194	-16	11	12	467	66	1371	2152	13355	2359	25484	35279	192270		1561	17740	26233	139456	
2000	4	46	84	774	908	5	53	88	781	869	17	25	45	19	109	-12	28	43	762														
2001	0	2	10	135	147	1	10	14	142	155		2	9	9	20	1	7	5	133														
Grand Total	185	1666	2714	14690	19255	173	1599	2681	14629	19082	118	192	481	379	1193	55	1407	2201	14249									255393					165689
Net Pipe																17912												km-year					km-year

A.2.3 Pipeline Spill Statistics

The *PPL_Repairs* database contains records of all spills from pipeline in the GOM. A report was generated from the database for *OIL and CONDENSATE* spills of 50bbl or larger size in the date range of Jan 1, 1972 to Dec 31, 1999. There were 31 spills that satisfied those criteria.

Those spills were further broken down, for the two date ranges, into volume ranges, pipeline diameter ranges, pipeline segment length ranges, pipeline segment depth ranges and by cause.

The work and results can be found in *GreaterThan50BBL.xls*. The result sheets are included here as follows:

- Table A.2.2 – GOM OCS Pipeline Spill Statistics (1972-1999)
- Table A.2.3 – GOM OCS Pipeline Spill Statistics (1985-1999)
- Table A.2.4 – Cause Distribution of Pipeline Spills, GOM OCS (1972-1999)

A.2.4 Deficiencies in MMS Pipeline Databases

Several reviews of MMS databases were initiated as a result of the database applications in the current project. Detailed discussion and information exchanges were conducted among MMS personnel and members of the Bercha consulting team in regard to possible inconsistencies, ambiguities, and errors in the databases. The following specific areas were identified as ones of possible deficiency in the MMS pipeline databases:

- Inadequate definition or application of pipeline product codes.
- Lack of clarity of pipeline segment definitions.
- Lack of clarity or ambiguity of information on pipeline lengths.
- Ambiguity on exposure categories of pipeline size, pipeline length, and water depth.
- Ambiguity of spill records, resulting in at least one potential additional spill, and possible ambiguities on spill sizes for other spills.

As it was not within the scope of work of the present study to rectify these deficiencies, the present report is restricted to the above references to them. It should be noted, however, that the rectification of these deficiencies is not expected to change the conclusions of the study, although some adjustments in the numerical results could occur without any significant impact on the trends predicted.

Table A.2.2
GOM OCS Pipeline Spill Statistics (1972-1999)

GOM OCS Pipeline Spills, Categorized 1972-99		Spill Statistics**			Exposure (km-years)	Frequency (spill per 10^4 km-yr)
		Number of Spills	Average Volume (bbl)	Median Volume (bbl)		
By Pipe Diameter	**<10"**	16	2141	173	142,892	1.1197
	=10"	15	4070	1211	111,011	1.3512
By Pipeline Minimum Depth	**Bad Depth Data***	14				
	< 10 m	6	2310	1211	161,966	0.3704
	= 10 m	11	3165	1040	94,641	1.1623
By Segment Length	**< 0.5 km**	0	0	0	2,359	0.0000
	= 0.5 < 2 km	2	2335	2335	25,484	0.7848
	= 2 < 5 km	7	820	100	35,279	1.9842
	= 5 km	22	3859	850	192,270	1.1442
By Spill Size***	**Small**	6	58	50	253,903	0.2363
	Medium	12	317	230	253,903	0.4726
	Large	10	4133	4267	253,903	0.3939
	Huge	3	16611	15576	253,903	0.1182
By Diameter, By Spill Size						
<10"	**Small**	4	58	50	142,892	0.2799
	Medium	7	266	135	142,892	0.4899
	Large	4	4436	4551	142,892	0.2799
	Huge	1	14423	14423	142,892	0.0700
= 10"	**Small**	2	58	58	111,011	0.1802
	Medium	5	387	312	111,011	0.4504
	Large	6	3932	3600	111,011	0.5405
	Huge	2	17705	17705	111,011	0.1802

* 14 of the 31 records have both MIN_WATER_DEPTH and MAX_WATER_DEPTH set to "0".

** Exposure comes from an analysis of PPL_MASTERS database as published on February 15, 2001.

*** Spill Size:

- Small (S) - = 50 < 100 bbl
- Medium (M) - = 100 < 1,000 bbl
- Large (L) - = 1,000 < 10,000 bbl
- Huge (H) - = 10,000 bbl

Table A.2.3
GOM OCS Pipeline Spill Statistics (1985-1999)

GOM OCS Pipeline Spills, Categorized 1985-99		Spill Statistics			Exposure (km-years)	Frequency (spill per 10^4 km-yr)
		Number of Spills	Average Volume (bbl)	Median Volume (bbl)		
By Pipe Diameter	**<10"**	7	3425	2372	105,390	0.6642
	=10"	8	3924	1606	78,879	1.0142
By Pipeline Minimum Depth	**Bad Depth Data**	4				
	< 10 m	5	2070	1025	105,283	0.4749
	= 10 m	6	4718	3867	80,917	0.7415
By Segment Length	**< 0.5 km**	0	0	0	1,561	0.0000
	= 0.5 < 2 km	2	2320	4569	17,740	1.1274
	= 2 < 5 km	2	631	631	26,233	0.7624
	= 5 km	11	4497	2000	139,456	0.7888
By Spill Size*	**Small**	3	57	50	184,269	0.1628
	Medium	4	376	292	184,269	0.2171
	Large	6	3949	3867	184,269	0.3256
	Huge	2	15000	15000	184,269	0.1085
By Diameter, By Spill Size						
<10"	**Small**	2	60	60	105,390	0.1898
	Medium	2	165	165	105,390	0.1898
	Large	2	4551	4551	105,390	0.1898
	Huge	1	14423	14423	105,390	0.0949
= 10"	**Small**	1	50	50	78,879	0.1268
	Medium	2	587	587	78,879	0.2536
	Large	4	3648	2600	78,879	0.5071
	Huge	1	15576	15576	78,879	0.1268

* Spill Size:

- Small (S) - = 50 < 100 bbl
- Medium (M) - = 100 < 1,000 bbl
- Large (L) - = 1,000 < 10,000 bbl
- Huge (H) - = 10,000 bbl

Table A.2.4
Cause Distribution of Pipeline Spills, GOM OCS (1972-1999)

Cause		Spill Statistics		Frequency
Primary Cause	**Secondary Cause**	**Number of Spills**	**Average Volume (BBLS)**	**spill / (10^4 km-yrs)**
Anchoring	Rig or Construction	1	2000	0.0394
	Supply Boat	1	50	0.0394
Total Anchoring		***2***	***2050***	***0.0788***
Corrosion	External	1	100	0.0394
	Internal	3	1838	0.1182
Total Corrosion		***4***	***1938***	***0.1575***
Impact	Anchor Drag	11	4027	0.4332
	Jackup Rig	2	1625	0.0788
	Trawl/Fishing Net	5	5525	0.1969
Total Impact		***18***	***11177***	***0.7089***
Natural Hazard	Mud Slide	3	2837	0.1182
	Storm/Hurricane	1	3500	0.0394
Total Natural Hazard		***4***	***6337***	***0.1575***
Structural	Connector Failure	1	135	0.0394
	Material Fatigue	1	210	0.0394
Total Structural		***2***	***345***	***0.0788***
Other		1	119	0.0394
Total Other		***1***	***119***	***0.0394***
Total		**31**	**21966**	**1.2209**

Note: Total exposure is 253,093 km-yrs

A.3 PLATFORM SPILLS IN THE OCS AND THE GOM: ANALYSIS FOR 1972-1999 AND 1985-1999

A.3.1 Introduction on Platform Spills

This chapter describes the steps taken in analyzing the historical data on platform oil spills of size 50 bbls and greater.

The data for the analysis comes from two sources: Federal Offshore Statistics report, October 2000, on the MMS website [8] as:
http://www.mms.gov/stats/xls/CH4ProdW-Ooperatorrank.xls (sheet: 4-2. State-Fed Oil Prod) and,
http://www.mms.gov/stats/xls/DevActOct2000.xls (sheet: 3-4.Completions by YEAR)
and the *OCS_Plat.xls* database, received from Cheryl Anderson in February 2001 (a list of platform spills)

A.3.2 Exposure to Risk

Exposure was determined from the Active Well count (Table 3-4) and the Oil Production (Table 4-2) of the Federal Offshore Statistics report, October 2000 [12]. Platform exposure was accumulated over two date ranges: 1972-1999 and 1985-1999 in order to match some other existing analyses. The work and results can be found in *PlatformSpills.xls*. The result sheet is included here as Table A.3.1.

A.3.3 Platform Spill Statistics

The *OCS_Plat.xls* database contains records of all spills related to platforms in the GOM. A report was generated from the database for *OIL and CONDENSATE* spills of 50 bbl or larger size in the date range of January 1, 1972 to December 31, 1999. There were 21 spills that satisfied those criteria. Those spills were further broken down, for the two date ranges, into volume ranges. The work and results can be found in *PlatformSpills.xls*. The result sheet is included here as Table A.3.2.

Table A.3.1
Platform Spills – Exposure to Risk

Well and Crude Oil Exposure of Platforms

Year	Active Oil Wells	Exposure 1972-99 Well-years	Exposure 1985-99 Well-years	Crude Oil and Condensate (bbl)	Exposure 1972-99 (bbl)	Exposure 1985-99 (bbl)	Exposure 1972-99 Bbbl	Exposure 1985-99 Bbbl
1972	3,744	3,744		395,869,226	395,869,226			
1973	3,814	7,558		384,794,041	780,663,267			
1974	3,686	11,244		354,922,586	1,135,585,853			
1975	3,477	14,721		325,273,941	1,460,859,794			
1976	3,555	18,276		314,523,413	1,775,383,207			
1977	3,747	22,023		295,929,333	2,071,312,540			
1978	3,648	25,671		287,949,081	2,359,261,621			
1979	2,781	28,452		334,235,468	2,693,497,089			
1980	5,375	33,827		274,729,436	2,968,226,525			
1981	4,522	38,349		282,896,851	3,251,123,376			
1982	4,734	43,083		314,535,001	3,565,658,377			
1983	4,142	47,225		350,776,930	3,916,435,307			
1984	4,138	51,363		385,125,576	4,301,560,883			
1985	4,321	55,684	4,321	379,961,697	4,681,522,580	379,961,697		
1986	4,406	60,090	8,727	384,310,840	5,065,833,420	764,272,537		
1987	4,543	64,633	13,270	358,638,660	5,424,472,080	1,122,911,197		
1988	4,627	69,260	17,897	332,717,807	5,757,189,887	1,455,629,004		
1989	4,507	73,767	22,404	323,703,458	6,080,893,345	1,779,332,462		
1990	4,515	78,282	26,919	304,394,527	6,385,287,872	2,083,726,989		
1991	4,549	82,831	31,468	326,338,234	6,711,626,106	2,410,065,223		
1992	4,612	87,443	36,080	347,515,732	7,059,141,838	2,757,580,955		
1993	4,774	92,217	40,854	359,153,993	7,418,295,831	3,116,734,948		
1994	4,846	97,063	45,700	372,265,212	7,790,561,043	3,489,000,160		
1995	4,950	102,013	50,650	417,435,444	8,207,996,487	3,906,435,604		
1996	5,040	107,053	55,690	433,144,661	8,641,141,148	4,339,580,265		
1997	4,727	111,780	60,417	465,944,624	9,107,085,772	4,805,524,889		
1998	4,731	116,511	65,148	490,528,140	9,597,613,912	5,296,053,029		
1999	3,203	119,714	68,351	534,174,140	10,131,788,052	5,830,227,169	10.13	5.83

Table A.3.2
Platform Spill Statistics (1972-1999)

GOM OCS Platform Spills
1972-99

	Spill Statistics			Exposure		Frequency	
	Number of Spills	Average Volume (BBLS)	Median Volume (BBLS)	(well-years)	Bbbls	spill/ (10^4well-years)	spill/ Bbbls
By Spill Size							
50-99bbls	8	64	62	119714	10.13	0.6683	0.7897
100-999bbls	10	254	185	119714	10.13	0.8353	0.9872
1,000-9,999bbls	3	6130	7000	119714	10.13	0.2506	0.2962
>10,000bbls	0	15000	0	119714	10.13	0.0000	0.0000
Total	21	1021	120	119714	10.13	1.7542	2.0731

GOM OCS Platform Spills
1985-99

	Spill Statistics			Exposure		Frequency	
	Number of Spills	Average Volume (BBLS)	Median Volume (BBLS)	(well-years)	Bbbls	spill/ (10^4well-years)	spill/ Bbbls
By Spill Size							
50-99bbls	4	64	63	68351	5.83	0.5852	0.6861
100-999bbls	6	331	340	68351	5.83	0.8778	1.0292
1,000-9,999bbls	0	0	0	68351	5.83	0.0000	0.0000
>10,000bbls	0	0	0	68351	5.83	0.0000	0.0000
Total	10	224	135	68351	5.83	1.4630	1.7153

A.4 NORTH SEA PIPELINE DATA

A.4.1 Risers and Pipeline in Platform Safety Zone

Tables A.4.1 and A.4.2 give spill frequency estimates for risers and pipelines damaged by anchoring and impacts in the platform safety zone.

Table A.4.3 gives spill frequencies for risers and pipelines damaged in the subsea well safety zone.

Table A.4.1
North Sea Spill Frequency (per 10,000 km-yrs) for risers

Area	Line Type	Diameter (inches)	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data	Comments
North Sea	Steel	2 to 8	2083	1	4.80	E&P Forum [6]	No water depth or distance from land info for the North Sea data. The following was found to have no effect on frequency of spills from steel risers: length of pipeline that the riser is attached, riser diameter, riser contents, location of riser internal or external steel jacket.
		>10	5249.2	5	9.53		
	Flexible	all	404.1	2	49.49		

Table A.4.2
North Sea Spill Frequency (per 10,000 km-yrs) for risers and pipelines damaged by anchoring and impact incidents in the platform safety zone (within 500 m of platform)

Area	Line Type	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data	Comments
North Sea	Steel	2 to 8	2334	2	8.57	E&P Forum [6]	The table in E&P Forum 1996 does not indicate if the data is for risers only or for pipelines and risers. The experience numbers, which match closely to those in Table 1, suggest risers only.
		>10	5323.3	4	7.51		
	Flexible	all	550.8	0			

Table A.4.3
North Sea Spill Frequency (per 10,000 km-yrs) for risers and pipelines damaged by anchoring and impact incidents in the subsea well safety zone (within 500 m of subsea platform)

Area	Line Type	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data
North Sea	Steel	2 to 8	841.6	0		E&P Forum [6]
		>10	89.3	0		
	Flexible	all	657	3	45.66	

A.4.2 Pipeline Failure Frequencies for Different Conditions

Table A.4.4 gives pipeline spill frequencies for pipelines damaged by anchoring and impact incidents in mid-line areas. Table A.4.5 provides the same four pipelines less than 10 kilometers in length, while Table A.4.6 provides these for pipelines between 2 and 5 kilometers in length. Table A.4.7 gives spill frequencies resulting from corrosion and material defect damage to pipeline greater than 5 kilometers in length. It is expected, however, that these same corrosion and material defect frequencies should apply to pipelines less than 5 kilometers in length, as well as pipelines in the safety zone for platforms or subsea wells.

Table A.4.4
North Sea Spill Frequency (per 10,000 km-yrs) for pipelines damaged by anchoring and impact incidents in the mid-line of pipelines

Area	Line Type	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data
North Sea	Steel	2 to 8	13669.1	3	2.19	E&P Forum [6]
		>10	110084.1	1	0.09	
	Flexible	all	808.8	1	12.36	

Table A.4.5
North Sea Spill Frequency (per 10,000 km-yrs) for pipelines damaged by corrosion and material defects for pipelines less than 2 km in length

Area	Line Type/ Contents	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data
North Sea	Steel/gas	all	254.9	1	39.23	E&P Forum [6]
	Steel/oil	all	280.6	6	213.83	
	Flexible	all	298.5	5	167.50	

Table A.4.6
North Sea Spill Frequency (per 10,000 km-yrs) for pipelines damaged by corrosion and material defects for pipelines 2 to 5 km in length

Area	Line Type	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data
North Sea	Steel/gas	all	2280.8	0		E&P Forum [6]
	Steel/oil	all	1654.4	0		
	Flexible	all	609.3	2	32.82	

Table A.4.7
North Sea Spill Frequency (per 10,000 km-yrs) for pipelines damaged by corrosion and material defects for pipelines greater than 5 km in length

Area	Line Type	Diameter inches	Experience (pipeline-yrs)	No. of spills	Best Estimate of North Sea Spill Frequency	Source of data
North Sea	Steel/gas	all	78160.1	0		E&P Forum [6]
	Steel/oil	all	35026.9	3	0.856	
	Flexible	all	340.4	0		

A.5 CRUDE OIL TANKER SPILLS

Table A.5.1 gives a summary of worldwide and US tanker oil spill statistics.

All numbers represent the spill frequency for either inbound or outbound journeys for tankers. The numbers must be doubled to calculate the spill frequency of the tankers on a trip or voyage basis which would include both an outbound portion (when the tanker is loaded) and the inbound portion (when the cargo is unloaded). If, for example, 278 large (>1000 bbl) occurred on a worldwide basis from 1964 to 1999 and the volume of crude oil moved or transported during this period was 239.67 billion barrels, the spill frequency would be 278/239.67 or 1.16 spills per billion barrels, half of which would occur on outbound portions of journeys and half on the inbound.

A trip or a voyage includes the outbound and the inbound portions. The average size of worldwide crude oil tanker is 826,000 bbl.

All references in the table are Anderson and Labelle 2001 except where noted. Statistics based on the years 1974 to 1999.

Table A.5.1
Crude Oil Tanker Spills of Various Sizes and Locations

Location	Size Range(bbl)	Spills/ Billion bbl Loaded or Unloaded	Spills/10,000 Voyages or Trips	Average Spill Size (bbl)	Median Spill Size (bbl)	References:
Worldwide						
all locations	>200,000	0.05	0.83	539,000	382,000	[15]
all locations	>100,000	0.12	1.98	374,000	244,000	[2, 3]
all locations	>10,000	0.295	4.87	178,700	66,000	[2, 3]
in port	>10,000	0.09	1.49	175,500	49,500	[2, 3]
at sea	>10,000	0.205	3.39	180,200	71,400	[2, 3]
all locations	>1000	0.58	9.58	93,900	11,300	[2, 3]
in port	>1000	0.245	4.05	68,300	6,300	[2, 3]
"at Sea" total	>1000	0.335	5.53	112,400	17,000	[2, 3]
"at Sea"-open water >50 nmi	>1000	0.060	1.00			[2, 3]
"at Sea"-restricted water <50nmi	>1000	0.275	4.54			[2, 3]
	50 to 999	1.5	24.8	233	132	[13]
	1 to 49	7.8	129	10	5	[13]
US Coastal & Offshore						
all locations	>10,000	0.215	3.6	62,100	20,000	[2, 3, 17]
in port	>10,000	0.100	1.65	23,700	20,000	[2, 3]
at sea	>10,000	0.115	1.90	96,700	43,200	[2, 3]
all locations	>1000	0.515	8.51	28,000	7,000	[2, 3]
in port	>1000	0.335	5.53	10,000	6,000	[2, 3]
at sea	>1000	0.18	2.97	61,900	16,100	[19, 20]

A.6 OFFLOADING SPILL RATES

Table A.6.1 gives a summary of tankers/platform oil spills occurring tanker loading at the platform. Spills greater than 1,000 bbl data was based on UK experience, from 1975-1993, where two spills (4,000 bbl each) occurred from 3,409 liftings involving 1,700 million barrels and Statoil experience in Norway, from 1979-1995, where two spills (4,000 and 5,800 bbl) involved 5,000 liftings of 4 billion barrels.

Table A.6.1
Spills from offshore platforms lifting crude oil to tankers

Spill Size Range	Spills/ 10,000 Liftings	Spills/ Billion bbl	Average Spill Size (bbl)	References
all sizes	40.00	5.90		[10]
100 –1,000 bbl	10.00	1.47		[10]
>1,000 bbl *	4.76	0.70	4450	[6, 19, 20,]
>10,000 bbl	0			[17, 19]

A.7 SUMMARY OF ABOVE GROUND STORAGE TANK (AST) SPILL STATISTICS

This chapter presents a summary of above ground storage tank (AST) spill statistics. Tables A.7.1 and A.7.2 provide the exposure data. Table A.7.3 provides the causal distribution of AST releases. Table A.7.4 gives the spill frequencies for all ASTs.

Table A.7.1
Summary of AST Statistics [6]

API Segment	Surveyed Above Ground Tanks	Estimated National Total	Total Capacity	Average Age
Production	54,046	572,620	280,595	15.1

Table A.7.2
Number of ASTs by Capacity Range, Production, bbl [6]

25-500	500-1,000	1000 - 10,000	100,000 - 500,000	> 500,000	total
510,045	37,628	17,977	974	27	572,620

Table A.7.3
Production AST Release Frequency Distribution [6]

Causes (for all ASTs)	%
Corrosion	60
Improper Installation and tank failure	18
Loose fittings	12
Overfills and spills	10
TOTAL	**100**

Table A.7.4
Frequencies for all ASTs—no spill sizes given

Release	Description	Frequency	Spill Size (bbl)	
			Average	Median
small/medium leaks		1.1 x 10^-2 to 3.9 x 10^-2	6500	700
serious release	(say, > 10,000 gallons) ?	9.6 x 10^-5		
major release	(say, >1000 bbl)	6.9 x 10^-6		

A.8 GAS BLOWOUTS

Based on the SL Ross Northstar study [17], Table A.8.1 gives a summary for gas blowouts associated with different well conditions ranging from drilling to production.

Table A.8.1
Gas Blowouts Statistical Summary

	Worldwide 1955-1980	US GOM 1955-1980	US OCS 1971-1990	Norwegian North Sea 1976-1980	UK North Sea 1955-1980	USGOM & North Sea combined, 1980-1992 (selected)	North Sea-Norway & UK Combined, 1980-1993
Wells Drilled	36633	17184	21425	11116	1559	15294	4704
Exploration Wells	11737	4794	6610	4175	838	5781	2315
Development Wells	24896	12390	14815	6941	721	9513	2389
Exploration Well Blowouts incl. Shallow Gas Blowouts	96	30	40	32	?	43	16
Development Well Blowouts incl. S.G. Blowouts	66	36	34	14	?	25	4
Production/workover Blowouts	52	32	36	?	?	43	4
Total Blowouts incl. S.G. & Production Blowouts	214	98	110	46	6	111	24
Shallow Gas Blowouts	54	29	?	?	0	46	?
Blowout Incidence: total exp.& dev. Blowouts / total drilled	one in 230	one in 260	one in 290	one in 240	one in 260	one in 230	one in 290
Blowout Incidence: Exploration Drilling Only only	one in 120	one in 160	one in 170	one in 130	-	one in 130	one in 170
Blowout Incidence: Development Drilling Only.	one in 380	one in 340	one in 440	one in 500	-	one in 380	one in 440

A.9 BLOWOUTS WITH OIL

Based on the same reference, the SL Ross Northstar study [17], Table A.9.1 gives oil blowout summary for a range of well types. The Figures cited are probabilities of blowouts as described in that table.

Table A.9.1
Oil Blowout Data Summary

Event	Historical Frequency	Experience
BLOWOUTS		
1. Gas blowout during development drilling	2.5×10^{-3}/wells drilled	US OCS, 1964-1995
2. Gas blowout during exploration drilling	5.4×10^{-3}/wells drilled	US OCS, 1964-1995
3. Blowout during production and workovers involving some oil discharge >1 bbl	6.5×10^{-5}/well-years	US OCS, 1964-1995
4. Development drilling blowout with oil spill > 10,000 bbl	7.8×10^{-5}/wells drilled	Worldwide, 1970-present
5. Exploration drilling blowout with oil spill > 10,000 bbl	1.5×10^{-4}/wells drilled	Worldwide, 1970-present
6. Development drilling blowout with oil spill > 150,000 bbl	3.9×10^{-5}/wells drilled	Worldwide, 1970-present
7. Exploration drilling blowout with oil spill > 150,000 bbl	5.5×10^{-5}/wells drilled	Worldwide, 1970-present
8. Production/workover blowout with oil spill > 10,000 bbl	2.5×10^{-5}/well-year	Worldwide, 1970-present
9. Production/workover blowout with oil spill > 150,000 bbl	1.0×10^{-5}/well-year	Worldwide, 1970-present
PLATFORM SPILLS (incl. blowouts)		
1. Oil spill > 10,000 bbl	1.3×10^{-5}/well-year	US OCS, 1964-1995
2. Oil spill > 1,000 bbl	3.6×10^{-5}/well-year	US OCS, 1964-1995
3. Oil spill > 50 bbl	8.3×10^{-4}/well-year	US OCS, 1964-1995
4. Oil spill 1-50 bbl	1.7×10^{-2}/well-year	US OCS, 1964-1995

A.10 OIL TANKER SPILLS

Table A.10.1 provides a summary of crude oil tanker spill characteristics including size ranges, tanker capacities, spill frequencies per trip, average spill size, and median spill size.

All numbers represent the spill frequency for either inbound or outbound journeys for tankers. The numbers must be doubled to calculate the spill frequency of the tankers on a trip or voyage basis which would include both an outbound portion (when the tanker is loaded) and an inbound portion (when the cargo is unloaded). If, for example, 278 large (>1,000 bbl) occurred on a worldwide basis from 1964 to 1999 (which is true) and the volume of crude oil moved or transported during this period was 239.67 billion barrels, the spill frequency would be 278/239.67 or 1.16 spills per billion barrels, half of which would occur on outbound portions of journeys and half on the inbound.

A trip or a voyage includes the outbound and the inbound portions. All references are Anderson and Labelle, 2001, except where noted. Statistics are based on the years 1974 to 1999.

Table A.10.1
Crude Oil Tanker Spills of Various Sizes and Locations

Location	Size Range (spills/bbl)	Billion bbl Loaded or Unloaded	Spills/10,000 Voyages or Trips	Average Spill Size (bbl)	Median Spill Size (bbl)	References
Worldwide						
All Locations	>200,000	0.05	0.83	539,000	382,000	[2]
All Locations	>100,000	0.12	1.98	373,800	243,600	[2, 3]
In Port	>100,000	0.35	5.78	310,300	251,000	[2, 3]
At Sea	>100,000	0.085	1.40	392,900	243,600	[2, 3]
All Locations	>10,000	0.295	4.87	178,700	66,000	[2, 3]
In Port	>10,000	0.09	1.49	175,500	49,500	[2, 3]
At Sea	>10,000	0.205	3.39	180,200	71,400	[2, 3]
All Locations	>1,000	0.58	9.58	93,900	11,300	[2, 3]
In Port	>1,000	0.245	4.05	68,300	6,300	[2, 3]
"At Sea" Total	>1,000	0.335	5.53	112,400	17,000	[2, 3]
"At Sea" – Open Water >50 nmi	>1,000	0.060	1.00	-	-	[2, 3]
"At Sea" – Restricted water < 50 nmi	>1,000	0.275	4.54	-	-	[13, 15]
	50 to 999	1.5	24.8	233	132	[13, 15]
	1 to 49	7.8	129	10	5	[13, 15]
US Coastal and Offshore						
All Locations	>10,000	0.215	3.6	62,100	20,000	[2, 3]
In Port	>10,000	0.100	1.65	23,700	20,000	[2, 3]
At Sea	>10,000	0.115	1.90	96,700	43,200	[2, 3]
All Locations	>1,000	0.515	8.51	28,000	7,000	[2, 3]
In Port	>1,000	0.335	5.53	10,000	6,000	[2, 3]
At Sea	>1,000	0.18	2.97	61,900	16,100	[2, 3]

A.11 SPILLS DURING TANKER LOADINGS AT OFFSHORE PLATFORMS

A.11.1 Introduction

Spills are possible when crude oil is transferred from production platforms to shuttle tankers. Developing predictions of frequencies for such spills is difficult at this time because the design of the loading/lifting system has not been finalized. As well, the technologies involved in offshore tanker loadings have changed significantly over the last few years, making questionable the use of historical spill statistics for predicting future spill frequencies; the literature seems to indicate a dramatic drop in spill frequencies over the last few years as better technologies have been adopted. The issue is discussed in three different ways below. Table A.11.1 summarizes offshore loading incidents.

A.11.2 Experience in the U.K. Sector of the North Sea

The area that has the most experience with the use of tankers to lift offshore oil is the North Sea. The U.K. sector has been using tankers since 1976 to transport oil from the offshore production facilities to shore using both Single Buoy Mooring (SBM) and Single Point Mooring (SPM) systems. There are two separate reports on this experience which provide somewhat different results, as described below.

A.11.3 Experience during 1976-1979 as reported in Gulf 1981

The breakdown of statistics from 1976 (when production began) to 1979 is available in Gulf (1981) [7]. Of all spills during E&P activities in the U.K. sector of the North Sea twenty three percent, that is 34 spills, involved offloading accidents and accounted for 73 percent of the total oil spilled. Ninety-four percent of these 34 spills were less than 100 barrels each, with an average spill size of 18 barrels.

There were two large spills (> 1000 barrels), each having a volume of 4000 barrels. The volume of oil lifted during 1976 to 1979 inclusive was 870 million barrels; therefore, the frequency of large spills was 2/0.87 or 2.3 spills per billion barrels offloaded.

A.11.4 Experience During 1975-1993 as Reported by E&P Forum 1996

It is noted in E&P Forum 1996 [6] that pollution incidents associated with liftings should be grouped according to the lifting system. Table 8 mainly covers non-CALM (Catenary Anchor Leg Mooring) systems, as the CALM system was a first generation system and have been phased out. The table uses offshore loading statistics from the UK Department of Trade and Industry (DTI) pollution reports over the years 1977-93 (*Offshore Pollution Reports from Field Operators, 1977-93*) [21].

Table A.11.1

Pollution Incidents - UK Offshore Loading 1975-93 (non-CALM systems)

Spill Source	Total Number	Total Volume (bbl)	Minimum Size (bbl)	Maximum Size (bbl)	Average Size (bbl)
Storage	36	4,343	0.1	4,000	121
Pipeline	1	19	19	19	19
System	10	9,455	0.25	9,400	946
Hose	14	1088	0.5	500	78
Tanker	2	7	2	5	4
TOTALS	***63***	***14,912***	***0.1***	***9,400***	***237***

Definitions:

Storage	-	storage containment, either on production installation or loading facility
Pipeline	-	pipelines between production, storage and loading facilities
System	-	loading buoy or facility, e.g. pipework, swivels etc. but excluding storage
Hose	-	hose system from loading facility to tanker, including coupler
Tanker	-	on board tanker

The total volume loaded over the above systems between 1977 and end-1993 is about 1700 million barrels, via 3409 liftings. There are two large spills (> 1000 barrels) shown in Table 8 (4000 bbl and 9,400 bbl). Therefore, the frequency of large spills was 2/1.7 or **1.2 spills per billion barrels offloaded.**

A.11.5 Statoil Experience in the North Sea, 1979-1995

Statoil, the national oil company of Norway, has more than 15 years of experience with offshore loading in the North Sea, starting with the Statfjord A platform in 1979. Initially, the operation was based on an articulated loading platform (ALP) and modified conventional tankers, but has evolved into today's submerged turret loading (STL) system and a large fleet of specialized vessels. A Statoil paper on the subject [4] indicates that 5000 cargoes of crude oil, involving about 4 billion barrels, have been lifted by Statoil-operated tankers up to May 1994. In that time only two large spills have occurred: a 4000-barrel spill in 1980 and a 5800-barrel spill in 1992[1]. This gives a spill frequency of $2/4 \times 10^9$ or. 0.5 large spills per billion barrels offloaded

In terms of smaller spills, Breivik [4] indicates that only two have occurred, each less than 150 barrels.

A.11.6 Conclusion

The existing data suggest that in the earlier days of offloading, the frequency of large spills was relatively high (2.3 spills per billion barrels produced) and very high for smaller spills, but has been reduced lately (to 0.5 large spills per billion barrels produced) as a result of better technologies. This change is clearly shown in the UK data [21] from 1975 to 1993, where the number of 1.2 spills per billion barrels is about the average of the other two numbers. If it is assumed that current projects will take advantage of these latest technologies and systems and operate them as well as Statoil claims to be doing, then a large-spill frequency of 0.5 spills $/10^9$ bbl produced might be a reasonable predictor. If not, a higher number, perhaps 2.3 spills$/10^9$ bbl, should be used. For want of further information, the middle number is recommended for current projects, i.e., 1.2 large spills (>1000 bbl) for every billion barrels offloaded.

[1] This latter spill, the second largest in Norwegian waters, was not referenced in the Breivik 1995 paper. According to the Oil Spill Intelligence Report (International Spill Statistics: 1992), the spill took place on July 9, 1992 at the Statfjord offshore oil field, 140 km offshore at Lat: 61.00N and Lon: 002.00E. The spill was suspected to be caused by workers who left a valve open while transferring oil from the platform to the oil tanker.

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APPENDIX B

FUTURE DEVELOPMENT SCENARIOS

TABLE OF CONTENTS

TABLE **PAGE**

B.1 Beaufort Sea Sale 1 Development Scenarios..... B.2
B.2 Beaufort Sea Sale 2 Development Scenarios..... B.5
B.3 Beaufort Sea Sale 3 Development Scenarios..... B.8
B.4 Beaufort Sea All Sale Development Scenarios..... B.11
B.5a Chuckchi Sea Base Case MidPoint Development Scenarios..... B.14
B.5b Chuckchi Sea High Case MidPoint Development Scenarios B.15

Table B.1
Beaufort Sea Sale 1 Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2004	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2005	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2006	Shallow	1	2											
	Medium													
	Deep													
	Total	**1**	**2**											
2007	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2008	Shallow		2											
	Medium	1												
	Deep													
	Total	**1**	**2**											
2009	Shallow			1	1	3	3							
	Medium	1												
	Deep													
	Total	**1**		**1**	**1**	**3**	**3**							
2010	Shallow				1	10	13			10	10	10	10	10.9
	Medium		2											
	Deep													
	Total		**2**		**1**	**10**	**13**			**10**	**10**	**10**	**10**	10.9
2011	Shallow			1	2	13	26				10		10	19.9
	Medium													
	Deep													
	Total			**1**	**2**	**13**	**26**				**10**		**10**	19.9
2012	Shallow				2	10	36			10	20	10	20	30.8
	Medium													
	Deep													
	Total				**2**	**10**	**36**			**10**	**20**	**10**	**20**	30.8
2013	Shallow				2	10	46				20		20	39.8
	Medium													
	Deep													
	Total				**2**	**10**	**46**				**20**		**20**	39.8
2014	Shallow				2		46				20		20	36.3
	Medium			1	1	3	3							
	Deep													
	Total			**1**	**3**	**3**	**49**				**20**		**20**	36.3

Table B.1 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2015	Shallow				2		46			10	30	10	30	33.4
	Medium				1	10	13			10	10	10	10	10.9
	Deep													
	Total				**3**	**10**	**59**			**20**	**40**	**20**	**40**	44.3
2016	Shallow				2		46				30		30	27.6
	Medium				1	10	23				10		10	19.9
	Deep													
	Total				**3**	**10**	**69**				**40**		**40**	47.5
2017	Shallow				2		46				30		30	22.7
	Medium				1		23				10		10	19.9
	Deep													
	Total				**3**		**69**				**40**		**40**	42.6
2018	Shallow				2		46				30		30	18.8
	Medium				1		23				10		10	19.9
	Deep													
	Total				**3**		**69**				**40**		**40**	38.7
2019	Shallow				2		46				30		30	15.5
	Medium				1		23				10		10	16.4
	Deep													
	Total				**3**		**69**				**40**		**40**	31.9
2020	Shallow				2		46				30		30	12.8
	Medium				1		23				10		10	13.5
	Deep													
	Total				**3**		**69**				**40**		**40**	26.3
2021	Shallow				2		46				30		30	10.5
	Medium				1		23				10		10	11.2
	Deep													
	Total				**3**		**69**				**40**		**40**	21.7
2022	Shallow				2		46				30		30	8.7
	Medium				1		23				10		10	9.2
	Deep													
	Total				**3**		**69**				**40**		**40**	17.9
2023	Shallow				2		46				30		30	7.3
	Medium				1		23				10		10	7.6
	Deep													
	Total				**3**		**69**				**40**		**40**	14.9
2024	Shallow				2		46				30		30	6.1
	Medium				1		23				10		10	6.3
	Deep													
	Total				**3**		**69**				**40**		**40**	12.4
2025	Shallow			-1	1	-23	23			-10	20	-10	20	3.0
	Medium				1		23				10		10	5.2
	Deep													
	Total			**-1**	**2**	**-23**	**46**			**-10**	**30**	**-10**	**30**	8.2
2026	Shallow				1		23				20		20	2.6
	Medium				1		23				10		10	4.3
	Deep													
	Total				**2**		**46**				**30**		**30**	6.9
2027	Shallow			-1		-23				-10	10	-10	10	
	Medium				1		23				10		10	3.5
	Deep													
	Total			**-1**	**1**	**-23**	**23**			**-10**	**20**	**-10**	**20**	3.5
2028	Shallow										10		10	
	Medium				1		23				10		10	3.0
	Deep													
	Total				**1**		**23**				**20**		**20**	3.0

Table B.1 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2029	Shallow										10		10	
	Medium				1		23				10		10	2.6
	Deep													
	Total				**1**		**23**				**20**		**20**	2.6
2030	Shallow									-10		-10		
	Medium			-1		-23				-10		-10		
	Deep													
	Total			**-1**		**-23**				**-20**		**-20**		
2031	Shallow													
	Medium													
	Deep													
	Total													
2032	Shallow													
	Medium													
	Deep													
	Total													
2033	Shallow													
	Medium													
	Deep													
	Total													
2034	Shallow													
	Medium													
	Deep													
	Total													
2035	Shallow													
	Medium													
	Deep													
	Total													
2036	Shallow													
	Medium													
	Deep													
	Total													
2037	Shallow													
	Medium													
	Deep													
	Total													
2038	Shallow													
	Medium													
	Deep													
	Total													

Table B.2
Beaufort Sea Sale 2 Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2004	Shallow													
	Medium													
	Deep													
	Total													
2005	Shallow													
	Medium													
	Deep													
	Total													
2006	Shallow													
	Medium													
	Deep													
	Total													
2007	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2008	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2009	Shallow		2											
	Medium													
	Deep													
	Total		**2**											
2010	Shallow													
	Medium	1												
	Deep													
	Total	**1**												
2011	Shallow													
	Medium													
	Deep													
	Total													
2012	Shallow			1	1	3	3							
	Medium	1												
	Deep	1												
	Total	**2**		**1**	**1**	**3**	**3**							
2013	Shallow				1	10	13			15	15	15	15	10.9
	Medium		2											
	Deep	1												
	Total	**1**	**2**		**1**	**10**	**13**			**15**	**15**	**15**	**15**	10.9
2014	Shallow				1	10	23				15		15	19.9
	Medium		2											
	Deep													
	Total		**2**		**1**	**10**	**23**				**15**		**15**	19.9

Table B.2 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2015	Shallow				1		23				15		15	19.9
	Medium													
	Deep													
	Total				**1**		**23**				**15**		**15**	19.9
2016	Shallow				1		23				15		15	19.9
	Medium			1	1	3	3							
	Deep													
	Total			**1**	**2**	**3**	**26**				**15**		**15**	19.9
2017	Shallow				1		23			10	25	10	25	16.4
	Medium			1	2	13	16	5	5	10	10	15	15	18.4
	Deep													
	Total			**1**	**3**	**13**	**39**	**5**	**5**	**20**	**35**	**25**	**40**	34.8
2018	Shallow				1		23				25		25	13.5
	Medium				2	20	36		5		10		15	30.7
	Deep													
	Total				**3**	**20**	**59**		**5**		**35**		**40**	44.2
2019	Shallow				1		23				25		25	11.2
	Medium				2	10	46		5		10		15	30.7
	Deep													
	Total				**3**	**10**	**69**		**5**		**35**		**40**	41.9
2020	Shallow				1		23				25		25	9.2
	Medium				2		46		5		10		15	30.7
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	39.9
2021	Shallow				1		23				25		25	7.6
	Medium				2		46		5		10		15	30.7
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	38.3
2022	Shallow				1		23				25		25	6.3
	Medium				2		46		5		10		15	26.4
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	32.7
2023	Shallow				1		23				25		25	5.2
	Medium				2		46		5		10		15	22.7
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	27.9
2024	Shallow				1		23				25		25	4.3
	Medium				2		46		5		10		15	19.5
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	23.8
2025	Shallow				1		23				25		25	3.5
	Medium				2		46		5		10		15	16.8
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	20.3
2026	Shallow				1		23				25		25	2.9
	Medium				2		46		5		10		15	14.4
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	17.3
2027	Shallow				1		23				25		25	2.4
	Medium				2		46		5		10		15	12.4
	Deep													
	Total				**3**		**69**		**5**		**35**		**40**	14.8
2028	Shallow			-1		-23				-15	10	-15	10	
	Medium				2		46		5		10		15	10.7
	Deep													
	Total			**-1**	**2**	**-23**	**46**		**5**	**-15**	**20**	**-15**	**25**	10.7

Table B.2 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2029	Shallow										10		10	
	Medium				2		46		5		10		15	9.2
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	9.2
2030	Shallow										10		10	
	Medium				2		46		5		10		15	7.9
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	7.9
2031	Shallow										10		10	
	Medium				2		46		5		10		15	6.8
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	6.8
2032	Shallow										10		10	
	Medium				2		46		5		10		15	5.8
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	5.8
2033	Shallow										10		10	
	Medium				2		46		5		10		15	5.0
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	5.0
2034	Shallow										10		10	
	Medium				2		46		5		10		15	4.3
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	4.3
2035	Shallow										10		10	
	Medium				2		46		5		10		15	3.7
	Deep													
	Total				**2**		**46**		**5**		**20**		**25**	3.7
2036	Shallow									-10		-10		
	Medium			-2		-46		-5		-10		-15		
	Deep													
	Total			**-2**		**-46**		**-5**		**-20**		**-25**		
2037	Shallow													
	Medium													
	Deep													
	Total													
2038	Shallow													
	Medium													
	Deep													
	Total													

Table B.3
Beaufort Sea Sale 3 Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2004	Shallow													
	Medium													
	Deep													
	Total													
2005	Shallow													
	Medium													
	Deep													
	Total													
2006	Shallow													
	Medium													
	Deep													
	Total													
2007	Shallow													
	Medium													
	Deep													
	Total													
2008	Shallow													
	Medium													
	Deep													
	Total													
2009	Shallow													
	Medium													
	Deep													
	Total													
2010	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2011	Shallow													
	Medium													
	Deep													
	Total													
2012	Shallow													
	Medium	1												
	Deep													
	Total	**1**												
2013	Shallow													
	Medium	1	1											
	Deep													
	Total	**1**	**1**											
2014	Shallow													
	Medium		2											
	Deep													
	Total		**2**											

Table B.3 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2015	Shallow													
	Medium		2											
	Deep	1												
	Total	**1**	**2**											
2016	Shallow													
	Medium													
	Deep													
	Total													
2017	Shallow													
	Medium													
	Deep	1												
	Total	**1**												
2018	Shallow													
	Medium			1	1	4	4							
	Deep	1												
	Total	**1**		**1**	**1**	**4**	**4**							
2019	Shallow									15	15	15	15	
	Medium			1	2	14	18	5	5	15	15	20	20	30.8
	Deep													
	Total			**1**	**2**	**14**	**18**	**5**	**5**	**30**	**30**	**35**	**35**	30.8
2020	Shallow										15		15	
	Medium				2	20	38		5		15		20	38.6
	Deep													
	Total				**2**	**20**	**38**		**5**		**30**		**35**	38.6
2021	Shallow										15		15	
	Medium				2	20	58		5		15		20	38.6
	Deep													
	Total				**2**	**20**	**58**		**5**		**30**		**35**	38.6
2022	Shallow										15		15	
	Medium				2	10	68		5		15		20	38.6
	Deep													
	Total				**2**	**10**	**68**		**5**		**30**		**35**	38.6
2023	Shallow										15		15	
	Medium				2		68		5		15		20	38.6
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	38.6
2024	Shallow										15		15	
	Medium				2		68		5		15		20	38.6
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	38.6
2025	Shallow										15		15	
	Medium				2		68		5		15		20	34.0
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	34.0
2026	Shallow										15		15	
	Medium				2		68		5		15		20	29.9
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	29.9
2027	Shallow										15		15	
	Medium				2		68		5		15		20	26.3
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	26.3
2028	Shallow										15		15	
	Medium				2		68		5		15		20	23.2
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	23.2

Table B.3 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2029	Shallow										15		15	
	Medium				2		68		5		15		20	20.4
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	20.4
2030	Shallow										15		15	
	Medium				2		68		5		15		20	17.9
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	17.9
2031	Shallow										15		15	
	Medium				2		68		5		15		20	15.8
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	15.8
2032	Shallow										15		15	
	Medium				2		68		5		15		20	13.9
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	13.9
2033	Shallow										15		15	
	Medium				2		68		5		15		20	12.2
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	12.2
2034	Shallow										15		15	
	Medium				2		68		5		15		20	10.8
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	10.8
2035	Shallow										15		15	
	Medium				2		68		5		15		20	9.5
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	9.5
2036	Shallow										15		15	
	Medium				2		68		5		15		20	8.3
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	8.3
2037	Shallow										15		15	
	Medium				2		68		5		15		20	7.3
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	7.3
2038	Shallow										15		15	
	Medium				2		68		5		15		20	6.5
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	6.5

Table B.4
Beaufort Sea All Sale Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2004	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2005	Shallow	1												
	Medium													
	Deep													
	Total	**1**												
2006	Shallow	1	2											
	Medium													
	Deep													
	Total	**1**	**2**											
2007	Shallow	2												
	Medium													
	Deep													
	Total	**2**												
2008	Shallow	1	2											
	Medium	1												
	Deep													
	Total	**2**	**2**											
2009	Shallow		2	1	1	3	3							
	Medium	1												
	Deep													
	Total	**1**	**2**	**1**	**1**	**3**	**3**							
2010	Shallow	1			1	10	13			10	10	10	10	10.9
	Medium	1	2											
	Deep													
	Total	**2**	**2**		**1**	**10**	**13**			**10**	**10**	**10**	**10**	10.9
2011	Shallow			1	2	13	26				10		10	19.9
	Medium													
	Deep													
	Total			**1**	**2**	**13**	**26**				**10**		**10**	19.9
2012	Shallow			1	3	13	39			10	20	10	20	30.8
	Medium	2												
	Deep	1												
	Total	**3**		**1**	**3**	**13**	**39**			**10**	**20**	**10**	**20**	30.8
2013	Shallow				3	20	59			15	35	15	35	50.7
	Medium	1	3											
	Deep	1												
	Total	**2**	**3**		**3**	**20**	**59**			**15**	**35**	**15**	**35**	50.7
2014	Shallow				3	10	69				35		35	56.2
	Medium		4	1	1	3	3							
	Deep													
	Total		**4**	**1**	**4**	**13**	**72**				**35**		**35**	56.2

Table B.4 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2015	Shallow				3		69			10	45	10	45	53.3
	Medium		2		1	10	13			10	10	10	10	10.9
	Deep	1												
	Total	**1**	**2**		**4**	**10**	**82**			**20**	**55**	**20**	**55**	64.2
2016	Shallow				3		69				45		45	47.5
	Medium			1	2	13	26				10		10	19.9
	Deep													
	Total			**1**	**5**	**13**	**95**				**55**		**55**	67.4
2017	Shallow				3		69			10	55	10	55	39.1
	Medium			1	3	13	39	5	5	10	20	15	25	38.3
	Deep	1												
	Total	**1**		**1**	**6**	**13**	**108**	**5**	**5**	**20**	**75**	**25**	**80**	77.4
2018	Shallow				3		69				55		55	32.3
	Medium			1	4	24	63		5		20		25	50.6
	Deep	1												
	Total	**1**		**1**	**7**	**24**	**132**		**5**		**75**		**80**	82.9
2019	Shallow				3		69			15	70	15	70	26.7
	Medium			1	5	24	87	5	10	15	35	20	45	77.9
	Deep													
	Total			**1**	**8**	**24**	**156**	**5**	**10**	**30**	**105**	**35**	**115**	104.6
2020	Shallow				3		69				70		70	22.0
	Medium				5	20	107		10		35		45	82.8
	Deep													
	Total				**8**	**20**	**176**		**10**		**105**		**115**	104.8
2021	Shallow				3		69				70		70	18.1
	Medium				5	20	127		10		35		45	80.5
	Deep													
	Total				**8**	**20**	**196**		**10**		**105**		**115**	98.6
2022	Shallow				3		69				70		70	15.0
	Medium				5	10	137		10		35		45	74.2
	Deep													
	Total				**8**	**10**	**206**		**10**		**105**		**115**	89.2
2023	Shallow				3		69				70		70	12.5
	Medium				5		137		10		35		45	68.9
	Deep													
	Total				**8**		**206**		**10**		**105**		**115**	81.4
2024	Shallow				3		69				70		70	10.4
	Medium				5		137		10		35		45	64.4
	Deep													
	Total				**8**		**206**		**10**		**105**		**115**	74.8
2025	Shallow			-1	2	-23	46			-10	60	-10	60	6.5
	Medium				5		137		10		35		45	56.0
	Deep													
	Total			**-1**	**7**	**-23**	**183**		**10**	**-10**	**95**	**-10**	**105**	62.5
2026	Shallow				2		46				60		60	5.5
	Medium				5		137		10		35		45	48.6
	Deep													
	Total				**7**		**183**		**10**		**95**		**105**	54.1
2027	Shallow			-1	1	-23	23			-10	50	-10	50	2.4
	Medium				5		137		10		35		45	42.2
	Deep													
	Total			**-1**	**6**	**-23**	**160**		**10**	**-10**	**85**	**-10**	**95**	44.6
2028	Shallow			-1		-23				-15	35	-15	35	
	Medium				5		137		10		35		45	36.9
	Deep													
	Total			**-1**	**5**	**-23**	**137**		**10**	**-15**	**70**	**-15**	**80**	36.9

Table B.4 - continued

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Production Wells		In-use Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
2029	Shallow										35		35	
	Medium				5		137		10		35		45	32.2
	Deep													
	Total				**5**		**137**		**10**		**70**		**80**	32.2
2030	Shallow									-10	25	-10	25	
	Medium			-1	4	-23	114		10	-10	25	-10	35	25.8
	Deep													
	Total			**-1**	**4**	**-23**	**114**		**10**	**-20**	**50**	**-20**	**60**	25.8
2031	Shallow										25		25	
	Medium				4		114		10		25		35	22.6
	Deep													
	Total				**4**		**114**		**10**		**50**		**60**	22.6
2032	Shallow										25		25	
	Medium				4		114		10		25		35	19.7
	Deep													
	Total				**4**		**114**		**10**		**50**		**60**	19.7
2033	Shallow										25		25	
	Medium				4		114		10		25		35	17.2
	Deep													
	Total				**4**		**114**		**10**		**50**		**60**	17.2
2034	Shallow										25		25	
	Medium				4		114		10		25		35	15.1
	Deep													
	Total				**4**		**114**		**10**		**50**		**60**	15.1
2035	Shallow										25		25	
	Medium				4		114		10		25		35	13.2
	Deep													
	Total				**4**		**114**		**10**		**50**		**60**	13.2
2036	Shallow									-10	15	-10	15	
	Medium			-2	2	-46	68	-5	5	-10	15	-15	20	8.3
	Deep													
	Total			**-2**	**2**	**-46**	**68**	**-5**	**5**	**-20**	**30**	**-25**	**35**	8.3
2037	Shallow										15		15	
	Medium				2		68		5		15		20	7.3
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	7.3
2038	Shallow										15		15	
	Medium				2		68		5		15		20	6.5
	Deep													
	Total				**2**		**68**		**5**		**30**		**35**	6.5

Table B.5a
Chuckchi Sea Base Case MidPoint Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Prod./Serv. Wells		Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
1998	Shallow													
	Medium													
	Deep	2	2											
	Total	**2**	**2**											0
1999	Shallow									5	5	5	5	
	Medium									60	60	60	60	
	Deep									135	135	135	135	
	Total									**200**	**200**	**200**	**200**	0
2000	Shallow										5		5	
	Medium										60		60	
	Deep			2	2	8	8				135		135	
	Total			**2**	**2**	**8**	**8**				**200**		**200**	0
2001	Shallow										5		5	
	Medium										60		60	
	Deep			2	4	40	48				135		135	
	Total			**2**	**4**	**40**	**48**				**200**		**200**	0
2002	Shallow										5		5	
	Medium										60		60	
	Deep			2	6	60	108				135		135	
	Total			**2**	**6**	**60**	**108**				**200**		**200**	101.0
2003	Shallow										5		5	
	Medium										60		60	
	Deep				6	80	188				135		135	
	Total				**6**	**80**	**188**				**200**		**200**	135.0
2004	Shallow										5		5	
	Medium										60		60	
	Deep				6	26	214				135		135	
	Total				**6**	**26**	**214**				**200**		**200**	135.0
2005	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	135.0
2006	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	135.0
2007	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	135.0
2008	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	119.0
2009	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	103.0
2010	Shallow										5		5	
	Medium										60		60	
	Deep				6		214				135		135	
	Total				**6**		**214**				**200**		**200**	92.0

Table B.5b
Chuckchi Sea High Case MidPoint Development Scenarios

Year	Water Depth	Exploration Wells	Delineation Wells	Production Platforms		Prod./Serv. Wells		Pipeline Length [miles]						Production MMbbl
								Sum<10"		Sum >=10"		Sum All		
				Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	Incr.	Cum.	
1998	Shallow													
	Medium													
	Deep	3	1											
	Total	**3**	**1**											0
1999	Shallow													
	Medium													
	Deep	2	1											
	Total	**2**	**1**											0
2000	Shallow									5	5	5	5	
	Medium									60	60	60	60	
	Deep	2		2	2					135	135	135	135	
	Total	**2**		**2**	**2**					**200**	**200**	**200**	**200**	0
2001	Shallow										5		5	
	Medium										60		60	
	Deep			6	8	50	50				135		135	
	Total			**6**	**8**	**50**	**50**				**200**		**200**	0
2002	Shallow										5		5	
	Medium										60		60	
	Deep			4	12	80	130				135		135	
	Total			**4**	**12**	**80**	**130**				**200**		**200**	0
2003	Shallow										5		5	
	Medium										60		60	
	Deep				12	140	270				135		135	
	Total				**12**	**140**	**270**				**200**		**200**	223.0
2004	Shallow										5		5	
	Medium										60		60	
	Deep				12	140	410				135		135	
	Total				**12**	**140**	**410**				**200**		**200**	297.0
2005	Shallow										5		5	
	Medium										60		60	
	Deep				12	72	482				135		135	
	Total				**12**	**72**	**482**				**200**		**200**	297.0
2006	Shallow										5		5	
	Medium										60		60	
	Deep				12		482				135		135	
	Total				**12**		**482**				**200**		**200**	297.0
2007	Shallow										5		5	
	Medium										60		60	
	Deep				12		482				135		135	
	Total				**12**		**482**				**200**		**200**	297.0
2008	Shallow										5		5	
	Medium										60		60	
	Deep				12		482				135		135	
	Total				**12**		**482**				**200**		**200**	297.0
2009	Shallow										5		5	
	Medium										60		60	
	Deep				12		482				135		135	
	Total				**12**		**482**				**200**		**200**	262.0
2010	Shallow										5		5	
	Medium										60		60	
	Deep				12		482				135		135	
	Total				**12**		**482**				**200**		**200**	227.0

APPENDIX C

MONTE CARLO CALCULATIONS AND RESULTS

TABLE OF CONTENTS

0 TOC
T.0 Appendix C Table of Contents
F.0 Flow Chart

1 Historical Data Analysis
T.1.1 Analysis of Historical Spills - Pipeline
T.1.2 Distribution And Frequency of Historical Spills - Pipeline
T.1.2A Historical Spills Data - Pipeline
T.1.3 Analysis of Historical Spills - Platforms
T.1.4 Distribution And Frequency of Historical Spills - Platforms
T.1.5 Frequency of Historical Spills - Wells
T.1.5A Historical Spills Data - Wells

2 Fault Tree Analysis
T.2.1 FTA Input Rationalization - Pipeline
T.2.1A Monte Carlo Input - Pipeline
T.2.2 FTA Input Rationalization - Platforms
T2.2A Monte Carlo Input - Platforms
T.2.3 Arctic Spill Distribution and Frequency - P/L - Small Spills
T.2.4 Arctic Spill Distribution and Frequency - P/L - Medium Spills
T.2.5 Arctic Spill Distribution and Frequency - P/L - Large Spills
T.2.6 Arctic Spill Distribution and Frequency - P/L - Huge Spills
T.2.7 Arctic Spill Distribution and Frequency - Platforms - Small and Medium Spills
T.2.8 Arctic Spill Distribution and Frequency - Platforms - Large and Huge Spills
T.2.9 Arctic Frequency - Wells
T.2.10 Average Spill Distribution

F.2.1 Fault Tree - Pipeline - Small Spills
F.2.2 Fault Tree - Pipeline - Medium Spills
F.2.3 Fault Tree - Pipeline - Large Spills
F.2.4 Fault Tree - Pipeline - Huge Spills
F.2.5 Fault Tree - Platform Spills

3 Hazard Scenarios
T.3.1 Beaufort Sea Sale 1 2004-2038
T.3.2 Beaufort Sea Sale 2 2004-2038
T.3.3 Beaufort Sea Sale 3 2004-2038
T.3.4 Beaufort Sea All Sales 2004-2038
T.3.5 Chukchi Sea Base Case 1998-2010
T.3.6 Chukchi Sea High Case 1998-2010

4 Spill Occurrence
4.1 Arctic Spill Occurrence - Beaufort Sea Sale 1
T.4.1.1 Arctic Spill Occurrence - Sale 1 - Pipeline
T.4.1.2 Arctic Spill Occurrence - Sale 1 - Pipeline - Summary
T.4.1.3 Arctic Spill Occurrence - Sale 1 - Platforms
T.4.1.4 Arctic Spill Occurrence - Sale 1 - Platforms - Summary
T.4.1.5 Arctic Spill Occurrence - Sale 1 - Production Wells
T.4.1.6 Arctic Spill Occurrence - Sale 1 - Production Wells - Summary

T.4.1.7 Arctic Spill Occurrence - Sale 1 - Exploration Wells
T.4.1.8 Arctic Spill Occurrence - Sale 1 - Exploration Wells - Summary
T.4.1.9 Arctic Spill Occurrence - Sale 1 - Development Wells
T.4.1.10 Arctic Spill Occurrence - Sale 1 - Development Wells - Summary
T.4.1.11 Arctic Spill Occurrence - Sale 1 - Summary
T.4.1.12 Arctic Spill Occurrence - Sale 1 - Annual Summary
T.4.1.13 Arctic Spill Occurrence - Sale 1 - Wells - Summary
T.4.1.14 Monte Carlo Results - Sale 1 - Year 2016

F.4.1.1 Beaufort Sea Sale 1 Spill Frequency
F.4.1.2 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced
F.4.1.3 Beaufort Sea Sale 1 Spill Index
F.4.1.4 Beaufort Sea Sale 1 Spill Frequency - P/L
F.4.1.5 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - P/L
F.4.1.6 Beaufort Sea Sale 1 Spill Index - P/L
F.4.1.7 Beaufort Sea Sale 1 Spill Frequency - Platforms
F.4.1.8 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.1.9 Beaufort Sea Sale 1 Spill Index - Platforms
F.4.1.10 Beaufort Sea Sale 1 Spill Frequency - Wells
F.4.1.11 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - Wells
F.4.1.12 Beaufort Sea Sale 1 Spill Index - Wells
F.4.1.13 CDF - Sale 1 - Year 2016

4.2 Arctic Spill Occurrence - Beaufort Sea Sale 2
T.4.2.1 Arctic Spill Occurrence - Sale 2 - Pipeline
T.4.2.2 Arctic Spill Occurrence - Sale 2 - Pipeline - Summary
T.4.2.3 Arctic Spill Occurrence - Sale 2 - Platforms
T.4.2.4 Arctic Spill Occurrence - Sale 2 - Platforms - Summary
T.4.2.5 Arctic Spill Occurrence - Sale 2 - Production Wells
T.4.2.6 Arctic Spill Occurrence - Sale 2 - Production Wells - Summary
T.4.2.7 Arctic Spill Occurrence - Sale 2 - Exploration Wells
T.4.2.8 Arctic Spill Occurrence - Sale 2 - Exploration Wells - Summary
T.4.2.9 Arctic Spill Occurrence - Sale 2 - Development Wells
T.4.2.10 Arctic Spill Occurrence - Sale 2 - Development Wells - Summary
T.4.2.11 Arctic Spill Occurrence - Sale 2 - Summary
T.4.2.12 Arctic Spill Occurrence - Sale 2 - Annual Summary
T.4.2.13 Arctic Spill Occurrence - Sale 2 - Wells - Summary
T.4.2.14 Monte Carlo Results - Sale 2 - Year 2019

F.4.2.1 Beaufort Sea Sale 2 Spill Frequency
F.4.2.2 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced
F.4.2.3 Beaufort Sea Sale 2 Spill Index
F.4.2.4 Beaufort Sea Sale 2 Spill Frequency - P/L
F.4.2.5 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - P/L
F.4.2.6 Beaufort Sea Sale 2 Spill Index - P/L
F.4.2.7 Beaufort Sea Sale 2 Spill Frequency - Platforms
F.4.2.8 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.2.9 Beaufort Sea Sale 2 Spill Index - Platforms
F.4.2.10 Beaufort Sea Sale 2 Spill Frequency - Wells
F.4.2.11 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - Wells
F.4.2.12 Beaufort Sea Sale 2 Spill Index - Wells
F.4.2.13 CDF - Sale 2 - Year 2019

4.3 Arctic Spill Occurrence - Beaufort Sea Sale 3
T.4.3.1 Arctic Spill Occurrence - Sale 3 - Pipeline
T.4.3.2 Arctic Spill Occurrence - Sale 3 - Pipeline - Summary
T.4.3.3 Arctic Spill Occurrence - Sale 3 - Platforms
T.4.3.4 Arctic Spill Occurrence - Sale 3 - Platforms - Summary

T.4.3.5 Arctic Spill Occurrence - Sale 3 - Production Wells
T.4.3.6 Arctic Spill Occurrence - Sale 3 - Production Wells - Summary
T.4.3.7 Arctic Spill Occurrence - Sale 3 - Exploration Wells
T.4.3.8 Arctic Spill Occurrence - Sale 3 - Exploration Wells - Summary
T.4.3.9 Arctic Spill Occurrence - Sale 3 - Development Wells
T.4.3.10 Arctic Spill Occurrence - Sale 3 - Development Wells - Summary
T.4.3.11 Arctic Spill Occurrence - Sale 3 - Summary
T.4.3.12 Arctic Spill Occurrence - Sale 3 - Annual Summary
T.4.3.13 Arctic Spill Occurrence - Sale 3 - Wells - Summary
T.4.3.14 Monte Carlo Results - Sale 3 - Year 2024

F.4.3.1 Beaufort Sea Sale 3 Spill Frequency
F.4.3.2 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced
F.4.3.3 Beaufort Sea Sale 3 Spill Index
F.4.3.4 Beaufort Sea Sale 3 Spill Frequency - P/L
F.4.3.5 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - P/L
F.4.3.6 Beaufort Sea Sale 3 Spill Index - P/L
F.4.3.7 Beaufort Sea Sale 3 Spill Frequency - Platforms
F.4.3.8 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.3.9 Beaufort Sea Sale 3 Spill Index - Platforms
F.4.3.10 Beaufort Sea Sale 3 Spill Frequency - Wells
F.4.3.11 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - Wells
F.4.3.12 Beaufort Sea Sale 3 Spill Index - Wells
F.4.3.13 CDF - Sale 3 - Year 2024

4.4 Arctic Spill Occurrence - Beaufort Sea All Sales
T.4.4.1 Arctic Spill Occurrence - All Sales - Pipeline
T.4.4.2 Arctic Spill Occurrence - All Sales - Pipeline - Summary
T.4.4.3 Arctic Spill Occurrence - All Sales - Platforms
T.4.4.4 Arctic Spill Occurrence - All Sales - Platforms - Summary
T.4.4.5 Arctic Spill Occurrence - All Sales - Production Wells
T.4.4.6 Arctic Spill Occurrence - All Sales - Production Wells - Summary
T.4.4.7 Arctic Spill Occurrence - All Sales - Exploration Wells
T.4.4.8 Arctic Spill Occurrence - All Sales - Exploration Wells - Summary
T.4.4.9 Arctic Spill Occurrence - All Sales - Development Wells
T.4.4.10 Arctic Spill Occurrence - All Sales - Development Wells - Summary
T.4.4.11 Arctic Spill Occurrence - All Sales - Summary
T.4.4.12 Arctic Spill Occurrence - All Sales - Annual Summary
T.4.4.13 Arctic Spill Occurrence - All Sales - Wells - Summary
T.4.4.14 Monte Carlo Results - All Sales - Year 2024

F.4.4.1 Beaufort Sea All Sales Spill Frequency
F.4.4.2 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced
F.4.4.3 Beaufort Sea All Sales Spill Index
F.4.4.4 Beaufort Sea All Sales Spill Frequency - P/L
F.4.4.5 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - P/L
F.4.4.6 Beaufort Sea All Sales Spill Index - P/L
F.4.4.7 Beaufort Sea All Sales Spill Frequency - Platforms
F.4.4.8 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Platforms
F.4.4.9 Beaufort Sea All Sales Spill Index - Platforms
F.4.4.10 Beaufort Sea All Sales Spill Frequency - Wells
F.4.4.11 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Wells
F.4.4.12 Beaufort Sea All Sales Spill Index - Wells
F.4.4.13 CDF - All Sales - Year 2024

4.4A Non Arctic Spill Occurrence - Beaufort Sea All Sales
T.4.4A.1 Non Arctic Spill Occurrence - All Sales - Pipeline
T.4.4A.2 Non Arctic Spill Occurrence - All Sales - Pipeline - Summary

T.4.4A.3 Non Arctic Spill Occurrence - All Sales - Platforms
T.4.4A.4 Non Arctic Spill Occurrence - All Sales - Platforms - Summary
T.4.4A.5 Non Arctic Spill Occurrence - All Sales - Production Wells
T.4.4A.6 Non Arctic Spill Occurrence - All Sales - Production Wells - Summary
T.4.4A.7 Non Arctic Spill Occurrence - All Sales - Exploration Wells
T.4.4A.8 Non Arctic Spill Occurrence - All Sales - Exploration Wells - Summary
T.4.4A.9 Non Arctic Spill Occurrence - All Sales - Development Wells
T.4.4A.10 Non Arctic Spill Occurrence - All Sales - Development Wells - Summary
T.4.4A.11 Non Arctic Spill Occurrence - All Sales - Summary
T.4.4A.12 Non Arctic Spill Occurrence - All Sales - Annual Summary
T.4.4A.13 Non Arctic Spill Occurrence - All Sales - Wells - Summary

F.4.4A.1 Beaufort Sea All Sales Spill Frequency
F.4.4A.2 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced
F.4.4A.3 Beaufort Sea All Sales Spill Index
F.4.4A.4 Beaufort Sea All Sales Spill Frequency - P/L
F.4.4A.5 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - P/L
F.4.4A.6 Beaufort Sea All Sales Spill Index - P/L
F.4.4A.7 Beaufort Sea All Sales Spill Frequency - Platforms
F.4.4A.8 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Platforms
F.4.4A.9 Beaufort Sea All Sales Spill Index - Platforms
F.4.4A.10 Beaufort Sea All Sales Spill Frequency - Wells
F.4.4A.11 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Wells
F.4.4A.12 Beaufort Sea All Sales Spill Index - Wells
F.4.4A.13 Beaufort Sea All Sales Spill Frequency Arctic and Non Arctic
F.4.4A.14 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced Arctic and Non Arctic
F.4.4A.15 Beaufort Sea All Sales Spill Index Arctic and Non Arctic

4.5 Arctic Spill Occurrence - Chukchi Sea Base Case
T.4.5.1 Arctic Spill Occurrence - Base Case - Pipeline
T.4.5.2 Arctic Spill Occurrence - Base Case - Pipeline - Summary
T.4.5.3 Arctic Spill Occurrence - Base Case - Platforms
T.4.5.4 Arctic Spill Occurrence - Base Case - Platforms - Summary
T.4.5.5 Arctic Spill Occurrence - Base Case - Production Wells
T.4.5.6 Arctic Spill Occurrence - Base Case - Production Wells - Summary
T.4.5.7 Arctic Spill Occurrence - Base Case - Exploration Wells
T.4.5.8 Arctic Spill Occurrence - Base Case - Exploration Wells - Summary
T.4.5.9 Arctic Spill Occurrence - Base Case - Development Wells
T.4.5.10 Arctic Spill Occurrence - Base Case - Development Wells - Summary
T.4.5.11 Arctic Spill Occurrence - Base Case - Summary
T.4.5.12 Arctic Spill Occurrence - Base Case - Annual Summary
T.4.5.13 Monte Carlo Results - Base Case - Year 2010

F.4.5.1 Chukchi Sea Base Case Spill Frequency
F.4.5.2 Chukchi Sea Base Case Spill Frequency per 10^9 bbl Produced
F.4.5.3 Chukchi Sea Base Case Spill Index
F.4.5.4 CDF - Base Case- Year 2010

4.6 Arctic Spill Occurrence - Chukchi Sea High Case
T.4.6.1 Arctic Spill Occurrence - High Case - Pipeline
T.4.6.2 Arctic Spill Occurrence - High Case - Pipeline - Summary
T.4.6.3 Arctic Spill Occurrence - High Case - Platforms
T.4.6.4 Arctic Spill Occurrence - High Case - Platforms - Summary
T.4.6.5 Arctic Spill Occurrence - High Case - Production Wells
T.4.6.6 Arctic Spill Occurrence - High Case - Production Wells - Summary
T.4.6.7 Arctic Spill Occurrence - High Case - Exploration Wells
T.4.6.8 Arctic Spill Occurrence - High Case - Exploration Wells - Summary
T.4.6.9 Arctic Spill Occurrence - High Case - Development Wells

T.4.6.10 Arctic Spill Occurrence - High Case - Development Wells - Summary
T.4.6.11 Arctic Spill Occurrence - High Case - Summary
T.4.6.12 Arctic Spill Occurrence - High Case - Annual Summary
T.4.6.13 Monte Carlo Results - High Case - Year 2010

F.4.6.1 Chukchi Sea High Case Spill Frequency
F.4.6.2 Chukchi Sea High Case Spill Frequency per 10^9 bbl Produced
F.4.6.3 Chukchi Sea High Case Spill Index
F.4.6.4 CDF - High Case- Year 2010

4.6A Non Arctic Spill Occurrence - Chukchi Sea High Case
T.4.6A.1 Non Arctic Spill Occurrence - High Case - Pipeline
T.4.6A.2 Non Arctic Spill Occurrence - High Case - Pipeline - Summary
T.4.6A.3 Non Arctic Spill Occurrence - High Case - Platforms
T.4.6A.4 Non Arctic Spill Occurrence - High Case - Platforms - Summary
T.4.6A.5 Non Arctic Spill Occurrence - High Case - Production Wells
T.4.6A.6 Non Arctic Spill Occurrence - High Case - Production Wells - Summary
T.4.6A.7 Non Arctic Spill Occurrence - High Case - Exploration Wells
T.4.6A.8 Non Arctic Spill Occurrence - High Case - Exploration Wells - Summary
T.4.6A.9 Non Arctic Spill Occurrence - High Case - Development Wells
T.4.6A.10 Non Arctic Spill Occurrence - High Case - Development Wells - Summary
T.4.6A.11 Non Arctic Spill Occurrence - High Case - Summary
T.4.6A.12 Non Arctic Spill Occurrence - High Case - Annual Summary

F.4.6A.1 Chukchi Sea High Case Spill Frequency
F.4.6A.2 Chukchi Sea High Case Spill Frequency per 10^9 bbl Produced
F.4.6A.3 Chukchi Sea High Case Spill Index
F.4.6A.4 Chukchi Sea All Sales Spill Frequency Arctic and Non Arctic
F.4.6A.5 Chukchi Sea All Sales Spill Frequency per 10^9 bbl Produced Arctic and Non Arctic
F.4.6A.6 Chukchi Sea All Sales Spill Index Arctic and Non Arctic

5 Conclusions
T.5.1 Summary of Spill Indicators for All Scenarios
T.5.2 Composition of Spill Indicators

F.5.1 Beaufort Sea Sale All Year 2024 Spill Indicators
F.5.2 Beaufort Sea Sale All Year 2024 Spill Indicators for Spill Size
F.5.3 Chukchi Sea High Case Year 2010 Spill Indicators
F.5.4 Chukchi Sea High Case Year 2010 Spill Indicators for Spill Size

APPENDIX D

EXPECTED VALUE CALCULATIONS AND RESULTS

TABLE OF CONTENTS

0 TOC
T.0 Appendix D Table of Contents
F.0 Flow Chart

1 Historical Data Analysis
T.1.1 Analysis of Historical Spills - Pipeline
T.1.2 Distribution And Frequency of Historical Spills - Pipeline
T.1.2A Historical Spills Data - Pipeline
T.1.3 Analysis of Historical Spills - Platforms
T.1.4 Distribution And Frequency of Historical Spills - Platforms
T.1.5 Frequency of Historical Spills - Wells
T.1.5A Historical Spills Data - Wells

2 Fault Tree Analysis
T.2.1 FTA Input Rationalization - Pipeline
T.2.1A Monte Carlo Input - Pipeline
T.2.2 FTA Input Rationalization - Platforms
T2.2A Monte Carlo Input - Platforms
T.2.3 Arctic Spill Distribution and Frequency - P/L - Small Spills
T.2.4 Arctic Spill Distribution and Frequency - P/L - Medium Spills
T.2.5 Arctic Spill Distribution and Frequency - P/L - Large Spills
T.2.6 Arctic Spill Distribution and Frequency - P/L - Huge Spills
T.2.7 Arctic Spill Distribution and Frequency - Platforms - Small and Medium Spills
T.2.8 Arctic Spill Distribution and Frequency - Platforms - Large and Huge Spills
T.2.9 Arctic Frequency - Wells
T.2.10 Average Spill Distribution

F.2.1 Fault Tree - Pipeline - Small Spills
F.2.2 Fault Tree - Pipeline - Medium Spills
F.2.3 Fault Tree - Pipeline - Large Spills
F.2.4 Fault Tree - Pipeline - Huge Spills
F.2.5 Fault Tree - Platform Spills

3 Hazard Scenarios
T.3.1 Beaufort Sea Sale 1 2004-2038
T.3.2 Beaufort Sea Sale 2 2004-2038
T.3.3 Beaufort Sea Sale 3 2004-2038
T.3.4 Beaufort Sea All Sales 2004-2038
T.3.5 Chukchi Sea Base Case 1998-2010
T.3.6 Chukchi Sea High Case 1998-2010

4 Spill Occurrence
4.1 Arctic Spill Occurrence - Beaufort Sea Sale 1
T.4.1.1 Arctic Spill Occurrence - Sale 1 - Pipeline
T.4.1.2 Arctic Spill Occurrence - Sale 1 - Pipeline - Summary
T.4.1.3 Arctic Spill Occurrence - Sale 1 - Platforms
T.4.1.4 Arctic Spill Occurrence - Sale 1 - Platforms - Summary
T.4.1.5 Arctic Spill Occurrence - Sale 1 - Production Wells
T.4.1.6 Arctic Spill Occurrence - Sale 1 - Production Wells - Summary

T.4.1.7 Arctic Spill Occurrence - Sale 1 - Exploration Wells
T.4.1.8 Arctic Spill Occurrence - Sale 1 - Exploration Wells - Summary
T.4.1.9 Arctic Spill Occurrence - Sale 1 - Development Wells
T.4.1.10 Arctic Spill Occurrence - Sale 1 - Development Wells - Summary
T.4.1.11 Arctic Spill Occurrence - Sale 1 - Summary
T.4.1.12 Arctic Spill Occurrence - Sale 1 - Annual Summary
T.4.1.13 Arctic Spill Occurrence - Sale 1 - Wells - Summary

F.4.1.1 Beaufort Sea Sale 1 Spill Frequency
F.4.1.2 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced
F.4.1.3 Beaufort Sea Sale 1 Spill Index
F.4.1.4 Beaufort Sea Sale 1 Spill Frequency - P/L
F.4.1.5 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - P/L
F.4.1.6 Beaufort Sea Sale 1 Spill Index - P/L
F.4.1.7 Beaufort Sea Sale 1 Spill Frequency - Platforms
F.4.1.8 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.1.9 Beaufort Sea Sale 1 Spill Index - Platforms
F.4.1.10 Beaufort Sea Sale 1 Spill Frequency - Wells
F.4.1.11 Beaufort Sea Sale 1 Spill Frequency per 10^9 bbl Produced - Wells
F.4.1.12 Beaufort Sea Sale 1 Spill Index - Wells

4.2 Arctic Spill Occurrence - Beaufort Sea Sale 2
T.4.2.1 Arctic Spill Occurrence - Sale 2 - Pipeline
T.4.2.2 Arctic Spill Occurrence - Sale 2 - Pipeline - Summary
T.4.2.3 Arctic Spill Occurrence - Sale 2 - Platforms
T.4.2.4 Arctic Spill Occurrence - Sale 2 - Platforms - Summary
T.4.2.5 Arctic Spill Occurrence - Sale 2 - Production Wells
T.4.2.6 Arctic Spill Occurrence - Sale 2 - Production Wells - Summary
T.4.2.7 Arctic Spill Occurrence - Sale 2 - Exploration Wells
T.4.2.8 Arctic Spill Occurrence - Sale 2 - Exploration Wells - Summary
T.4.2.9 Arctic Spill Occurrence - Sale 2 - Development Wells
T.4.2.10 Arctic Spill Occurrence - Sale 2 - Development Wells - Summary
T.4.2.11 Arctic Spill Occurrence - Sale 2 - Summary
T.4.2.12 Arctic Spill Occurrence - Sale 2 - Annual Summary
T.4.2.13 Arctic Spill Occurrence - Sale 2 - Wells - Summary

F.4.2.1 Beaufort Sea Sale 2 Spill Frequency
F.4.2.2 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced
F.4.2.3 Beaufort Sea Sale 2 Spill Index
F.4.2.4 Beaufort Sea Sale 2 Spill Frequency - P/L
F.4.2.5 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - P/L
F.4.2.6 Beaufort Sea Sale 2 Spill Index - P/L
F.4.2.7 Beaufort Sea Sale 2 Spill Frequency - Platforms
F.4.2.8 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.2.9 Beaufort Sea Sale 2 Spill Index - Platforms
F.4.2.10 Beaufort Sea Sale 2 Spill Frequency - Wells
F.4.2.11 Beaufort Sea Sale 2 Spill Frequency per 10^9 bbl Produced - Wells
F.4.2.12 Beaufort Sea Sale 2 Spill Index - Wells

4.3 Arctic Spill Occurrence - Beaufort Sea Sale 3
T.4.3.1 Arctic Spill Occurrence - Sale 3 - Pipeline
T.4.3.2 Arctic Spill Occurrence - Sale 3 - Pipeline - Summary
T.4.3.3 Arctic Spill Occurrence - Sale 3 - Platforms
T.4.3.4 Arctic Spill Occurrence - Sale 3 - Platforms - Summary
T.4.3.5 Arctic Spill Occurrence - Sale 3 - Production Wells
T.4.3.6 Arctic Spill Occurrence - Sale 3 - Production Wells - Summary
T.4.3.7 Arctic Spill Occurrence - Sale 3 - Exploration Wells
T.4.3.8 Arctic Spill Occurrence - Sale 3 - Exploration Wells - Summary

T.4.3.9 Arctic Spill Occurrence - Sale 3 - Development Wells
T.4.3.10 Arctic Spill Occurrence - Sale 3 - Development Wells - Summary
T.4.3.11 Arctic Spill Occurrence - Sale 3 - Summary
T.4.3.12 Arctic Spill Occurrence - Sale 3 - Annual Summary
T.4.3.13 Arctic Spill Occurrence - Sale 3 - Wells - Summary

F.4.3.1 Beaufort Sea Sale 3 Spill Frequency
F.4.3.2 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced
F.4.3.3 Beaufort Sea Sale 3 Spill Index
F.4.3.4 Beaufort Sea Sale 3 Spill Frequency - P/L
F.4.3.5 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - P/L
F.4.3.6 Beaufort Sea Sale 3 Spill Index - P/L
F.4.3.7 Beaufort Sea Sale 3 Spill Frequency - Platforms
F.4.3.8 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - Platforms
F.4.3.9 Beaufort Sea Sale 3 Spill Index - Platforms
F.4.3.10 Beaufort Sea Sale 3 Spill Frequency - Wells
F.4.3.11 Beaufort Sea Sale 3 Spill Frequency per 10^9 bbl Produced - Wells
F.4.3.12 Beaufort Sea Sale 3 Spill Index - Wells

4.4 Arctic Spill Occurrence - Beaufort Sea All Sales
T.4.4.1 Arctic Spill Occurrence - All Sales - Pipeline
T.4.4.2 Arctic Spill Occurrence - All Sales - Pipeline - Summary
T.4.4.3 Arctic Spill Occurrence - All Sales - Platforms
T.4.4.4 Arctic Spill Occurrence - All Sales - Platforms - Summary
T.4.4.5 Arctic Spill Occurrence - All Sales - Production Wells
T.4.4.6 Arctic Spill Occurrence - All Sales - Production Wells - Summary
T.4.4.7 Arctic Spill Occurrence - All Sales - Exploration Wells
T.4.4.8 Arctic Spill Occurrence - All Sales - Exploration Wells - Summary
T.4.4.9 Arctic Spill Occurrence - All Sales - Development Wells
T.4.4.10 Arctic Spill Occurrence - All Sales - Development Wells - Summary
T.4.4.11 Arctic Spill Occurrence - All Sales - Summary
T.4.4.12 Arctic Spill Occurrence - All Sales - Annual Summary
T.4.4.13 Arctic Spill Occurrence - All Sales - Wells - Summary

F.4.4.1 Beaufort Sea All Sales Spill Frequency
F.4.4.2 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced
F.4.4.3 Beaufort Sea All Sales Spill Index
F.4.4.4 Beaufort Sea All Sales Spill Frequency - P/L
F.4.4.5 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - P/L
F.4.4.6 Beaufort Sea All Sales Spill Index - P/L
F.4.4.7 Beaufort Sea All Sales Spill Frequency - Platforms
F.4.4.8 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Platforms
F.4.4.9 Beaufort Sea All Sales Spill Index - Platforms
F.4.4.10 Beaufort Sea All Sales Spill Frequency - Wells
F.4.4.11 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Wells
F.4.4.12 Beaufort Sea All Sales Spill Index - Wells

4.4A Non Arctic Spill Occurrence - Beaufort Sea All Sales
T.4.4A.1 Non Arctic Spill Occurrence - All Sales - Pipeline
T.4.4A.2 Non Arctic Spill Occurrence - All Sales - Pipeline - Summary
T.4.4A.3 Non Arctic Spill Occurrence - All Sales - Platforms
T.4.4A.4 Non Arctic Spill Occurrence - All Sales - Platforms - Summary
T.4.4A.5 Non Arctic Spill Occurrence - All Sales - Production Wells
T.4.4A.6 Non Arctic Spill Occurrence - All Sales - Production Wells - Summary
T.4.4A.7 Non Arctic Spill Occurrence - All Sales - Exploration Wells
T.4.4A.8 Non Arctic Spill Occurrence - All Sales - Exploration Wells - Summary
T.4.4A.9 Non Arctic Spill Occurrence - All Sales - Development Wells
T.4.4A.10 Non Arctic Spill Occurrence - All Sales - Development Wells - Summary

T.4.4A.11 Non Arctic Spill Occurrence - All Sales - Summary
T.4.4A.12 Non Arctic Spill Occurrence - All Sales - Annual Summary
T.4.4A.13 Non Arctic Spill Occurrence - All Sales - Wells - Summary

F.4.4A.1 Beaufort Sea All Sales Spill Frequency
F.4.4A.2 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced
F.4.4A.3 Beaufort Sea All Sales Spill Index
F.4.4A.4 Beaufort Sea All Sales Spill Frequency - P/L
F.4.4A.5 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - P/L
F.4.4A.6 Beaufort Sea All Sales Spill Index - P/L
F.4.4A.7 Beaufort Sea All Sales Spill Frequency - Platforms
F.4.4A.8 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Platforms
F.4.4A.9 Beaufort Sea All Sales Spill Index - Platforms
F.4.4A.10 Beaufort Sea All Sales Spill Frequency - Wells
F.4.4A.11 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced - Wells
F.4.4A.12 Beaufort Sea All Sales Spill Index - Wells
F.4.4A.13 Beaufort Sea All Sales Spill Frequency Arctic and Non Arctic
F.4.4A.14 Beaufort Sea All Sales Spill Frequency per 10^9 bbl Produced Arctic and Non Arctic
F.4.4A.15 Beaufort Sea All Sales Spill Index Arctic and Non Arctic

4.5 Arctic Spill Occurrence - Chukchi Sea Base Case
T.4.5.1 Arctic Spill Occurrence - Base Case - Pipeline
T.4.5.2 Arctic Spill Occurrence - Base Case - Pipeline - Summary
T.4.5.3 Arctic Spill Occurrence - Base Case - Platforms
T.4.5.4 Arctic Spill Occurrence - Base Case - Platforms - Summary
T.4.5.5 Arctic Spill Occurrence - Base Case - Production Wells
T.4.5.6 Arctic Spill Occurrence - Base Case - Production Wells - Summary
T.4.5.7 Arctic Spill Occurrence - Base Case - Exploration Wells
T.4.5.8 Arctic Spill Occurrence - Base Case - Exploration Wells - Summary
T.4.5.9 Arctic Spill Occurrence - Base Case - Development Wells
T.4.5.10 Arctic Spill Occurrence - Base Case - Development Wells - Summary
T.4.5.11 Arctic Spill Occurrence - Base Case - Summary
T.4.5.12 Arctic Spill Occurrence - Base Case - Annual Summary

F.4.5.1 Chukchi Sea Base Case Spill Frequency
F.4.5.2 Chukchi Sea Base Case Spill Frequency per 10^9 bbl Produced
F.4.5.3 Chukchi Sea Base Case Spill Index

4.6 Arctic Spill Occurrence - Chukchi Sea High Case
T.4.6.1 Arctic Spill Occurrence - High Case - Pipeline
T.4.6.2 Arctic Spill Occurrence - High Case - Pipeline - Summary
T.4.6.3 Arctic Spill Occurrence - High Case - Platforms
T.4.6.4 Arctic Spill Occurrence - High Case - Platforms - Summary
T.4.6.5 Arctic Spill Occurrence - High Case - Production Wells
T.4.6.6 Arctic Spill Occurrence - High Case - Production Wells - Summary
T.4.6.7 Arctic Spill Occurrence - High Case - Exploration Wells
T.4.6.8 Arctic Spill Occurrence - High Case - Exploration Wells - Summary
T.4.6.9 Arctic Spill Occurrence - High Case - Development Wells
T.4.6.10 Arctic Spill Occurrence - High Case - Development Wells - Summary
T.4.6.11 Arctic Spill Occurrence - High Case - Summary
T.4.6.12 Arctic Spill Occurrence - High Case - Annual Summary

F.4.6.1 Chukchi Sea High Case Spill Frequency
F.4.6.2 Chukchi Sea High Case Spill Frequency per 10^9 bbl Produced
F.4.6.3 Chukchi Sea High Case Spill Index

4.6A Non Arctic Spill Occurrence - Chukchi Sea High Case
T.4.6A.1 Non Arctic Spill Occurrence - High Case - Pipeline
T.4.6A.2 Non Arctic Spill Occurrence - High Case - Pipeline - Summary

T.4.6A.3 Non Arctic Spill Occurrence - High Case - Platforms
T.4.6A.4 Non Arctic Spill Occurrence - High Case - Platforms - Summary
T.4.6A.5 Non Arctic Spill Occurrence - High Case - Production Wells
T.4.6A.6 Non Arctic Spill Occurrence - High Case - Production Wells - Summary
T.4.6A.7 Non Arctic Spill Occurrence - High Case - Exploration Wells
T.4.6A.8 Non Arctic Spill Occurrence - High Case - Exploration Wells - Summary
T.4.6A.9 Non Arctic Spill Occurrence - High Case - Development Wells
T.4.6A.10 Non Arctic Spill Occurrence - High Case - Development Wells - Summary
T.4.6A.11 Non Arctic Spill Occurrence - High Case - Summary
T.4.6A.12 Non Arctic Spill Occurrence - High Case - Annual Summary

F.4.6A.1 Chukchi Sea High Case Spill Frequency
F.4.6A.2 Chukchi Sea High Case Spill Frequency per 10^9 bbl Produced
F.4.6A.3 Chukchi Sea High Case Spill Index
F.4.6A.4 Chukchi Sea All Sales Spill Frequency Arctic and Non Arctic
F.4.6A.5 Chukchi Sea All Sales Spill Frequency per 10^9 bbl Produced Arctic and Non Arctic
F.4.6A.6 Chukchi Sea All Sales Spill Index Arctic and Non Arctic

5 Conclusions
T.5.1 Summary of Spill Indicators for All Scenarios
T.5.2 Composition of Spill Indicators

F.5.1 Beaufort Sea Sale All Year 2024 Spill Indicators
F.5.2 Beaufort Sea Sale All Year 2024 Spill Indicators for Spill Size
F.5.3 Chukchi Sea High Case Year 2010 Spill Indicators
F.5.4 Chukchi Sea High Case Year 2010 Spill Indicators for Spill Size