75

REPORTS AND STUDIES

GESAMP

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

ESTIMATES OF OIL ENTERING THE MARINE ENVIRONMENT FROM SEA-BASED ACTIVITIES

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IMO FAO UNESCO-IOC WMO UNIDO IAEA UN UNEP

ESTIMATES OF OIL ENTERING THE MARINE ENVIRONMENT FROM SEA-BASED ACTIVITIES

INTERNATIONAL MARITIME ORGANIZATION
London, 2007

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Preface

Spilled oil from sea-based activities continues to be a marine pollutant in coastal and offshore waters. This is despite many successful regulatory initiatives at international and national levels, and the considerable efforts that are being made by the oil and shipping industries to reduce the number of accidents and to reuse, recycle and filter oily wastes aboard ships. This study develops a methodology and presents updated estimates of global inputs of oil, as defined under the MARPOL 73/78 Convention, that originate from shipping and other sea-based activites.

The report addresses the methods that can be used for making such estimates of input and the difficulties and uncertainties involved. Ship-based activities are the primary focus. These activities include ships, offshore oil and gas exploration and production, and the onshore facilities related to both operations, including refineries and all associated infrastructures. Estimation of operational ship inputs, both cargo and ship related, was a primary focal point of this study and required knowledge of vessel types and structures, operations, the oil trade, and MARPOL 73/78 regulations. Data on other inputs were obtained from many sources, published and unpublished. Considerable effort has been made to assemble data and conduct trend analysis of accidental spills from ships and other sea-based activities, from the late 1960s onwards.

Some other important input topics are briefly presented. These include volatile organic compounds (VOC) emissions from shipping, inputs from sunken vessels (casualties), inputs from recreational boating, and oil seeps. These help to supplement the picture of inputs from sea-based activities. Inputs from VOC emissions and recreational boating may be very substantial, but methods for making global estimates are very uncertain. Pelagic and littoral tar is discussed as tar is found on beaches worldwide and can be a monitor of shipping discharges.

The Working Group strived to identify all sources of oil from ships and sea-based activities, to reach reasonable estimates of current annual inputs to the oceans from these sources, and to point out areas of uncertainty. The input values are estimates, from both calculations and measurements. With the exception of data on accidental discharges, most estimates lack ranges or confidence limits, i.e. measures of variability. The greatest value of the presented input numbers, therefore, is that they give a picture of relative inputs from the different global ship and sea-based sources and they point to input sources requiring additional research, monitoring, assessment, regulatory and industry attention. The study presents recommendations for improving our ability to provide oil input estimates, a knowledge of which will ultimately contribute to global marine environmental protection related to sea-based activities.

Acknowledgments

This study was conducted by the GESAMP Oil Inputs Working Group, the members of which are listed below. The Group is very grateful to the many persons providing data and information for this study. Funding for this work came from IMO. Other agencies (IAITO, ITOPF, Environment Canada, and E&P Forum) supported some of the working group members. The Cutter Information Corp., USA, provided one of the primary data bases, but disclaims all warranties as to the accuracy, completeness or adequacy of the information provided to IMO, and has no liability for damages resulting in the use of this data. GESAMP members reviewed the report on several occasions from 1999-2003; they are thanked for these special efforts. The report was technically reviewed by J. N. Butler (USA), M. Fingas (Canada), T. Gunner (Norway), S. Hara (Japan), K. Kvenvolden (USA), R. Law (UK), J. Payne (Canada), J. Phinney (USA), R. Pond (USA), J. A. Sanchez Cabeza (Spain), K. Skjolsvik (Norway), D. Walker (USA), and F. Wiese (Canada), whom the Group thanks immensely for their special efforts

The Working Group received considerable support from Dr. Manfred Nauke, IMO (retired), and Mr. René Coenen, Marine Environment Division, IMO, who in their capacity as technical secretaries of GESAMP graciously and efficiently assisted the study. At IMO, Ms. Jennie Hallett assisted the working group at its early meetings, and Ms. Jennifer Francis greatly assisted with the co-ordination of the technical reviews and preparation of the final manuscript. The report was revised and edited through several drafts by Dr. P. G. Wells, Chair of the Working Group, who accepts responsibility for any errors or omissions that remain. The Group and IMO solicit comments from the reader on any aspect of this topic.

"There must be a beginning of any great matter, but the continuing unto the end until it be thoroughly finished yields the great glory."

Sir Francis Drake

Dedication

This report is dedicated to Dr. Manfred Nauke, recently retired from the Marine Environment Division, IMO, and the GESAMP Secretariat. Dr. Nauke provided leadership, inspiration, knowledge and support for many GESAMP working groups and their members over many years, and was instrumental at initiating the Oil Inputs Working Group. He symbolizes the excellence of individual marine professionals who, through extraordinary commitment and efforts throughout their careers, contribute substantially to the protection and conservation of the global seas and their living resources for present and future generations.

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EXECUTIVE SUMMARY

1 Introduction

ES-1 As part of the global effort to reduce oil inputs into the marine environment from ships and other sea-based activities, an independent detailed assessment of inputs from the various sources is periodically required. This has been conducted previously (GESAMP 1976, 1993; MEPC 1990; The National Research Council of USA, NRC 1975, 1985, 2003; amongst others). In the late 1990s, the Marine Environment Protection Committee (MEPC) of IMO requested GESAMP to evaluate carefully all available data sources on oil inputs into the marine environment from sea-based activities (i.e. maritime transportation, offshore exploration and production), and particularly to develop approaches that might be used for the provision of such input data. Hence, the terms of reference of the GESAMP Oil Input Working Group were to estimate current annual amounts of oil entering the marine environment from sea-based activities, and to focus particularly on improving the methodology of making such estimates. This report addresses both inputs and methodologies for making estimates, and places the various types of oil source inputs from ships and ship-related activities into perspective. The report covers four areas: approaches to making estimates of oil inputs, oil inputs from ships, oil inputs from offshore exploration and production, and other oil inputs and related topics.

2 Approaches to making estimates of oil inputs into the sea

ES-2 Obtaining reliable and up-to-date data on quantities of oil entering the marine environment from all of the different ship and other sea-based sources is not a simple task. Some inputs have to be calculated (i.e. operational inputs from ships). Few countries have reliable databases, thus this report relies heavily on spill and other input data available for the North Sea and for North American waters. Data on inputs are lacking or are inaccessible from key areas such as the Middle East, South America (e.g. Brazil), West Africa and South-East Asia. It is important that steps be taken to ensure that data on oil entering the marine environment in all of these geographic areas are routinely obtained, stored and transmitted to international databases. Further problems relating to operational oil input data relate to the fact that changes are taking place continually in shipping fleets, such as ship design and tonnage, and in volumes of crude oil transported. Newer ships are cleaner, and represent a growing percentage of various fleets. Volumes of oil originating from different countries are not constant. Such changes have to be taken into account when calculating inputs of oil to the sea from ship operations.

ES-3 The methodology was extensively revised and re-modelled to estimate operational inputs from ships, owing to extensive legislation and the specialization with regard to vessel type, function, performance and regulatory requirements. Hence, different methodologies from both the original 1990 Report (MEPC 1990) and between the various sources of oil discharge from ships have been used in the current report. Inputs of bilge oil and fuel oil sludge are the most extensively evaluated sources.

ES-4 Much of the data used in the analysis of spillage from all point sources, including vessels, pipelines, facilities, and offshore exploration and production activities, were derived from records in the International Oil Spill Database (IOSD) of Cutter Information Corp., and records in the databases of Environmental Research Consulting (ERC), USA. Each of the databases has extensive information on individual spill incidents. This includes information on spill date, location, source type, source name, and the amount and type of oil spilled. Data on spill incidents in the IOSD and ERC databases, as well as other compiled data on which these databases rely, are collected from a large number of reputable sources on an international basis e.g. the ITOPF Tanker spills database and personal contacts. Due to the nature of the data collection process, discrepancies and inaccuracies exist in these databases and original data sources. Since the IOSD contains no verified information on oil spills below 34 tonnes and the ERC databases contain incomplete information on oil spills in this smaller range, a "small spill estimation factor" was calculated for both the number of spills and the amount of oil spilled in incidents involving less than 34 tonnes.

ES-5 Estimates for oil inputs from produced water at offshore wells and from refineries near-shore were based on extrapolations from best available data and assumptions on compliance with existing regulations and guidelines.

ES-6 Sources of data and information on oil discharges from ships and boats are extensive in the published literature, but uneven in detail and quality. They were used where appropriate and reliable. An extensive source bibliography was compiled during the study.

3 Oil inputs from ships

ES-7 Operational oil discharges from ships were estimated. Operational discharges of oil into the marine environment from ships depend on several factors. These include: type and age of ship; level of maintenance of ship and engines; presence of oil-water separators and other equipment designed to curtail discharges of oil; practice of the LOT (load-on-top) principle; training and vigilance of the crew; level of shipping activity; and presence of adequate reception facilities. To estimate the fuel sludge discharge figures for all ships including tankers, it was necessary to estimate at the outset the bunker consumption for all ships, tankers and other ships. The bunker consumption per vessel was estimated, followed by estimates of sludge generation and compliance with the MARPOL discharge allowance of 15ppm. In summary, total operational discharges into the marine environment of bilge oil and fuel oil sludge from all ships are approximately ~188,000 tonnes/yr. Oily ballast (fuel tanks) discharges into the sea from ship operations was estimated to be ~900 tonnes/yr.

ES-8 Operational discharges associated with tanker cargoes, i.e. tank washing and oil in ballast water, were estimated. Due to the lack of complete data for movements of tankers, and owing to the potential for one cargo to be carried by a number of vessels, the numbers of tankers were used as the basis of the estimates of oil transportation and subsequent cargo- related operational discharges. Tanker construction, fleet size, and assumptions to an outflow model (taking into account tanker type, voyage length and frequency) were considered for the new estimates of oil inputs. The methodology and calculations are complex, but the approach is original and believed to give the best input estimates. The estimated discharge of oil into the marine environment from cargo-related tanker activities, which includes tank washing and oil in ballast, is 19,250 tonnes/yr., or ~ 19,000 tonnes/yr.

ES-9 Oil cargoes release VOCs during loading operations and transport, and the operation of ships results in the release of VOCs from the engines and funnels. VOCs go into the atmosphere and a fraction returns to the sea surface. The total discharge into the atmosphere of VOCs from the carriage at sea of crude oil by tankers would be 3,085,072 tonnes/yr., or ~3,000,000 tonnes/yr. VOCs from loading must also be added to this figure. Hence, the total emission of VOCs from tanker operations is: 3,085,075 tonnes (Carriage) + 3,712,961 tonnes (Loading) = 6,798,036 tonnes, or ~6,800,000 tonnes/yr. To establish the volume of this emission that enters the sea, it was necessary to establish which fractions within the VOCs would precipitate. Pentane contributes approximately 1% of VOC. As this is the main component with a boiling point above 0 deg. C (36 deg. C), this is the main fraction of VOCs that could enter the sea due to its solubility. Hence, 67,980 tonnes/yr. or ~68,000 tonnes/yr. of “oil” constituents from VOC emissions may enter the oceans.

ES-10 Accidental oil discharges from ships and other sea-based activities are thoroughly evaluated. The IOSD is described, especially in regard to units and conversions, data reporting and collection, and the definition of “accidental spillage”. A statistically-derived correction factor for spills smaller than 34 tonnes was generated and used throughout this evaluation in order to correct for the absence of small spills, those between 0.17 and 34 tonnes, in both spill number and spill amount estimates. Looking first at accidental spillage from all sources, after rising in the first decade between 1968 and 1977, spill numbers have dropped and levelled off in the last 15 years. Over the three 10-year periods evaluated in this study (1968-1997), spill amounts have dropped but there are unusual peaks in 1979 (associated with the *Ixtoc I* well blowout in the Gulf of Mexico, and 3 large tanker spills), 1983 and 1991. Vessels consistently constituted the largest source of accidental spillage over all time periods. The best estimates of annual oil inputs into the marine environment from accidental releases from all sources during the 3rd 10 year period, 1988-1997, are: vessels – 163,200 tonnes; coastal facilities – 2,400 tonnes; pipelines – 2,800 tonnes; exploration and production - 600 tonnes; other/unknown sources - 200 tonnes; and war related activities – 1,052,300 tonnes. The total input from accidental sea-based releases (without the war-related annual input) is ~169,000 tonnes/yr.

ES-11 The annual percentage of spills from all sources involving 5,000 tonnes or more has declined considerably since 1968, but it has remained steady at about 0.2 % of spills for the last 10 year period (1988-97), or 4.1 spills of this size annually on average, most of which (93%) involve vessels. Catastrophic exploration and production activity spills are much less frequent than large tanker spills e.g. *Ixtoc I* was a rare event. If one eliminates from consideration the spills over 5000 tonnes and the unique 1991 Gulf War spillages, the contributions from vessels and coastal facilities drop, resulting in a total accidental release input of 68,700 tonnes/yr. Smaller spills, particularly those under 34 tonnes (i.e. 10,000 US gal., an arbitrary division), make up nearly 97% of the number of annual spills, although together they contribute less than 16% of the amount of oil entering the sea annually from accidents. In general, over the last ten-year period evaluated (1988-97), the occurrence of accidental spills of all sizes has declined in most global regions compared to the previous two 10-year periods (exceptions being the Black Sea, portions of Africa, the Persian Gulf and Australia).

ES-12 Considering accidental discharges from ships alone, the number of spills over 0.17 tonnes (50 US gal. – a regulated volume in the USA) and amounts spilled both rose during the 1960s to a peak in 1979, then dropped and levelled off by the mid-1980s to a mean annual spillage of 163,200 tonnes from vessels during 1988-97. The amount of oil spilled annually from tankers has declined steadily since the late 1960s, to 157,900 tonnes per year from 1988-97. Spills from non-oil cargo vessels have increased significantly in number over the past 30 years (1968-97) – 53 spills, 740 spills and 1049 spills per year on average for the three 10-year periods that were considered. Correcting the data for small spills, the best estimate of oil inputs into the sea from accidental releases from vessels of all types (e.g. tankers, barges, non-oil cargo) during the years 1988-1997 is 163,200 tonnes annually (range of 46,000-256,000 tonnes).

ES-13 Analyses were conducted of accidental spillage in relation to oil production and tanker transport over the past 30 years (1968-1997) in order to correct the spill statistics for increases in oil production and transport. The mean annual number of spills (of at least 0.17 tonnes) rose from 0.60 spills per million tonnes produced in 1968-77, to a peak of 1.39 spills per million tonnes produced in 1978-87, then fell to 1.08 spills per million tonnes produced in 1988-97. The mean annual number of vessel spills per million tonnes transported followed a similar pattern - 1.54 (1968-77), 2.57 (1978-87) and 2.02 (1988-97). As well, the general trend is that the mean annual percentage of transported oil that is spilled has decreased over the last 30 years. Despite greater opportunities to spill more oil during the last period evaluated, fewer tanker spills have occurred and less oil has been spilled accidentally into the sea, compared with the previous two periods.

ES-14 The regional analysis of accidental spillage data, using 18 regions to cover the globe, shows that the large majority of spills, particularly from vessels, still occur in port areas or in vessel traffic lanes. All but 3 regions (Eastern Africa/Indian Ocean, Persian Gulf, Australia and New Zealand) showed decreases in the average annual amount spilled in accidental releases over the past 30 years (1968-97). The exceptional regions show either increases due to more shipping traffic and wars (East Africa, Persian Gulf) or no change in amount spilled (Australia and New Zealand).

ES-15 Statistics were also gathered for sunken vessels, both merchant and military. Between 1939 and 1997, a total of 21,486 vessels, i.e. ~21,500 vessels, were recorded as total losses. Many of these have been lost together with their remaining bunker, lubricating and hydraulic oils, and oil as cargo. Losses in the smaller gross tonnage ranges are probably underestimated, yet these vessels may contain significant quantities of oil. During this period, technology has improved for recovery of oil from casualties, and fuel types have changed to the modern bunker oils. It is not yet possible to derive accurate estimates for oil lost at sea globally by marine casualties and annual inputs from these sources. It is well known, however, that such inputs are occurring and may be significant in size and impact, especially at island states of the Western Pacific. Every effort should continue to map ship locations, describe the ships condition and the volumes of contained oil, estimate the risks of and from release, and organize an international effort to recover oil from casualties of highest risk.

ES-16 Oil enters the sea from dry-docked vessels. For tankers, based on the current fleet of 321.1 million dead-weight tonnes or DWT (circa 2000), the annual discharge of oil from tankers in dry docks is estimated to be 2569 tonnes. For other vessels such as drybulkers, the estimate of annual discharge due to dry-docking is 347 tonnes of oil, hence the total oil discharge during dry-docking is estimated at 2916 tonnes/yr. or ~2900 tonnes/yr.

ES-17 During recycling (previously called scrapping) of ships, most frequently occurring on beaches in countries of south-east Asia, oil can be released if the ships were not made "gas-free" and "slop-free" prior to demolition, or if the oil was released during the tank cleaning operations *en route* to the break-up locations. Two categories of oil can be established to calculate the quantities of oil discharged into the ocean during recycling operations: (1) fuels, hydraulic oils and lubricating oils (all ships); and (2) cargo residues and oil sludge (tankers). Estimates of oil inputs are 330 tonnes/yr. and 14,500 tonnes/yr., respectively, for a total of 14,830 tonnes/yr. from recycling of ships. A massive recycling of tankers is being anticipated during the period 2003-2007. INTERTANKO predicts that 25 tankers will be phased out in 2003, 97 in 2004, 142 in 2005, 134 in 2006 and 71 in 2007, a total of 469 tankers over this five-year period, and making this input source even more important for evaluation in future studies.

4 Oil inputs from exploration and production in the offshore

ES-18 Operational discharges of hydrocarbons occur from the 6000 oil and gas installations currently working in the marine environment, the greatest number (>4000) being in the Gulf of Mexico. Operational discharges of oil or oily water from offshore installations are numerous. There are machinery space discharges; no estimates are available but these are thought to be small. Drilling discharges contribute due to the use of oil-based drilling muds; these are now being phased out, but amounts ranged between 3,180-14,248 tonnes oil per year on cuttings for the North Sea, 1989-96. Produced water also contributes, with annual oil input from produced water for the Gulf of Mexico of 2900 tonnes, assuming 40 mg/l water; annual inputs for the North Sea range between 4119 to 8109 tonnes oil, 1989-97, with predictions of 12,000 tonnes by the year 2002. Finally, there are air emissions or VOCs. Using the average figures from the Gulf of Mexico (2900 tonnes/yr.), Australia (1450 tonnes/yr.), and the North Sea (12000 tonnes/yr.), the total estimated annual input of oil from offshore operations is estimated to be 16,350 tonnes/yr. This is a minimum value as data were not available for a number of active oil fields.

ES-19 Accidental discharges of oil from exploration and production activities include spills from platforms, wells and rigs but not pipelines, and are expressed as numbers of spills and amounts spilled. The largest spillages to date occurred in 1979 (*Ixtoc I*, Gulf of Mexico) and 1983 (*Nowruz*, Iran). While there have been no marine production and exploration spills over 2000 tonnes over the last decade, there have been 7 spills over 350 tonnes, all but one in the North Sea. The best estimate of oil input from accidental releases during 1988-97 is 600 tonnes/yr. While the probability of a catastrophic blow-out such as *Ixtoc* has been vastly reduced by current methodologies and technology, the possibility of such an event always exists.

ES-20 Accidental releases from offshore or coastal pipelines occur. Numbers of spills over 0.17 tonnes have risen sharply, from an average of 47 per year (range 31-125) in 1968-77, to 188 (range 63-438) in 1978-87, to 228 (range 125-438) in 1988-97. This apparent upward trend may be due in part to increased reporting of moderate-sized spills. Large spills over 5,000 tonnes are rare events, being only 4.9% of all of the spills from this source. The best estimate of oil input from offshore or coastal pipelines during the years 1988-97 is 2,800 tonnes/yr. This spillage represents a slight increase in amount spilled from this source compared to the previous two periods.

5 Other oil inputs into the sea and related topics

ES-21 There are both operational oil inputs and accidental spillage from coastal facilities, i.e. coastal refineries. In the most developed nations, the effluents contain on average 5 ppm of oil, while for developing nations and nations with refineries that are not well maintained or operated, effluents may contain an average of 25 ppm oil. Estimates are based on the total crude refining capacities of coastal or estuarine refineries, and their operating conditions; hence the maximum total operational input of oil from refineries would be approximately 180,000 tonnes of oil per year (worst case) or 45,000-180,000 tonnes of oil per year if the less efficient refineries were discharging at less than 25 ppm or operating for shorter periods. A median value for oil inputs from refineries is 112,500 tonnes/yr.

ES-22 Accidental releases from coastal facilities also occur. Numbers of spills decreased during the 1988-97 period, while spill amounts stayed fairly constant over 30 years except for 3 years (1978, 1981, and 1991). Smaller spills (i.e. those under 34 tonnes) make up more than 97% of the annual number of accidental spills from coastal refineries and facilities. The best estimate of oil input from accidental releases from coastal facilities, including refineries, marine terminals and storage facilities during the years 1988-1997, is 2,400 tonnes/yr.

ES-23 Inputs from coastal oil reception facilities may be significant, based on qualitative information on what they receive and how they function. Inputs could not be estimated due to the unavailability of quantitative data.

ES-24 Inputs of oils in dredged materials are probably insignificant; this source is well known as it is regulated under the London Convention and Protocol but global data were unavailable to the Working Group.

ES-25 Inputs of oils from small, predominantly leisure craft were estimated, using mainly North American data and a methodology reported by NRC (2003). At 53,000 tonnes/yr., likely a very conservative value and much less than the GESAMP working group originally estimated, small craft are a significant source of oil and its components into coastal waters. The estimates require verification from field measurements, better data on numbers and types of recreational boats and engines in use worldwide, and consideration of future trends in engine efficiency.

ES-26 Other topics included aircraft fuel dumps, beach tar, and natural seeps, but were not dealt with comprehensively. There are oil inputs from fuel dumps from aircraft, rocket launches and unknown point sources. Although not sea-based activities directly, these occur over or near the sea. As well, the significance of tar amounts and distributions on beaches as a reflection of oil discharges from tankers and the efficacy of regulations under MARPOL 73/78 is discussed. Likewise, natural seeps are discussed briefly; at 600,000 tonnes/yr., conservatively, this is a natural but important source of crude oil to the sea.

6 Summary

ES-27 This study shows the wide range of types and quantities of oil inputs from ship and other sea-based activities, as well as the spatial and temporal variability of accidental spills globally. The reader should view the input figures in a relative sense, carefully noting the estimation methods employed and their limitations. The most recent published information was also used where appropriate.

ES-28 The estimated average annual inputs of oil entering the marine environment, in metric tonnes per year (tonnes/yr.), from ships and other sea-based activities, based on the most recent 10 year period of data available (1988-97), are:

Totals:

- Ships	**457,000**
- Offshore exploration and production	20,000
- Ships plus offshore	**477,000**
- Coastal facilities	115,000
- Ships plus offshore plus coastal facilities	**592,000**
- Small craft activity	53,000
- Natural seeps	600,000
- Unknown (unidentified) sources	200
- GRAND TOTAL	**1,245,200 tonnes/yr.**

ES-29 Operational discharges from ships make up 45% of the input of 457,000 tonnes/yr. (ships), followed by shipping accidents at 36% of the input. Fuel oil sludge from vessels is the major routine operational input (~186,000 tonnes/yr.), or 68% of ship operational inputs. There are important ecological reasons to try to reduce this input, especially in coastal waters and in particularly sensitive marine areas of international importance for the conservation of wildlife.

ES-30 Oil tankers, which are often identified as being major routine polluters, account for 4.2% (~4%) of ship inputs as oil in ballast waters, an operational input. However, tanker and barge accidents are a major input (158,000 tonnes/yr.), even with the decline in large spills from tankers in recent years. Accidents are a very variable input source, and bad years, i.e. a large spill such as the *Amoco Cadiz or Exxon Valdez*, can skew the statistics. Most accidents are coastal and many are damaging to marine ecosystems, sometimes for years, regardless of spill size.

ES-31 Coastal facilities contribute significantly to oil inputs, at 115,000 tonnes/yr. This is 25.2 % of the ship input, or 19.4 % of the total of input from ships, offshore and coastal facilities, combined. VOC emissions from tankers, conservatively estimated at 68,000 tonnes/yr., make up 14.9% of total ship inputs.

ES-32 The offshore oil inputs, often considered by the public as a major input, represent a minimum of 4.1% of the total input from both ships and the offshore exploration and production (EandP) combined, or 4.3% of ship inputs. More data is required to verify this estimated input as global data are limited.

ES-33 Small craft activity inputs are a serious concern, based on amount and location. They represent a significant input of oil-derived hydrocarbons, albeit with estimates based largely on North American data. Whether or not such inputs should be included in this study on sea-based activities is debatable, and the method used here to estimate global inputs from small craft is preliminary. They obviously, however, represent a large and chronic input source of hydrocarbons to the coastal marine environment, and deserve additional study.

ES-34 The study concludes with a series of recommendations for improving the oil input estimates from sea-based activities. Such estimates are important for assessing the efficacy of MARPOL 73/78 and relevant national legislation, and for estimating risks of oiling to coastal and offshore marine ecosystems and living resources, in the years ahead.

1 INTRODUCTION

1 Oil was the first of the recognized "marine pollutants" to be controlled and regulated. This started with the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, and many other specific international conventions, including The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) (GESAMP 1993; IMO 2002; Carlin 2002). National legislation has also been improved, as in the United Kingdom following the *Torrey Canyon* spill of 1967, and in the United States following the *Exxon Valdez* spill of 1989. As a result of cooperation between governments, industry and intergovernmental organizations, many positive changes have taken place in the oil and shipping industries to reduce oil inputs from routine operations, and to recover oil from small spills and large accidents.

2 However, oil continues to enter the world's oceans from shipping and ship-based activities, through accidental spills and intentional discharges, as well as from many land-based sources and natural oil seeps. In coastal areas, such inputs often cause ecological damage and harm to public amenities (NRC, 1975, 1985, 2003; Boesch and Rabalais 1987; GESAMP 1977, 1993; Wells *et al.* 1995; amongst others). The ecological harm can vary in degree, ranging from being catastrophic, largely acute lethal effects on invertebrates, fish and wildlife, to being longer term or chronic sub-lethal and cumulative effects. The latter remain a concern, especially in relation to continuous discharges of oil from ships onto water surfaces, with lethal and sub-lethal effects on long-lived, slow-breeding wildlife such as seabirds (e.g. Wiese 2001, Wiese *et al.* 2002, 2003). Some shipping incidents, particularly accidents causing large spills, cause widespread community, political and industry concern (NRC 1985; GESAMP 1993; Mitchell 1993; IMO 1998a) and are very costly. Recent examples include the *Erika* (off France, 1999) and the *Prestige* (off Spain, 2002), both of which caused costly cleanups and much damage to coastal resources.

3 Hence, there is a strong scientific, economic and public policy rationale for industry, governments and agencies to continue efforts to reduce inputs of oil into the marine environment from all ship-based sources. As part of the effort to bring attention to the oil pollution issue and to continue to reduce inputs, an independent and current assessment of inputs of oil into the sea from the various sources is required.

1.1 Scope of task

4 The National Research Council of the United States published reports in 1975, 1985 and 2003, estimating the amounts of oil entering the marine environment from a wide range of sources, e.g. as land-based effluent releases and run-off as well as from marine transportation and offshore activities, including accidental spillages (NRC 1975, 1985, 2003). In 1990, the United States Coast Guard requested the Marine Board of the National Research Council to produce an "Update of Inputs of Petroleum Hydrocarbons into the Oceans due to Marine Transportation Activities". The unpublished report, entitled "Petroleum in the Marine Environment", was distributed as IMO document MEPC 30/INF.13 of 19 September 1990 (MEPC 1990). The most recent NRC report focuses on North American oil inputs, and oil fates and effects (NRC 2003).

5 GESAMP[6], when preparing its report "Impact of Oil and Related Chemicals and Wastes on the Marine Environment" (GESAMP 1993), used the input data estimated by the National Research Council in the 1970s and 1980s, and in the 1990 report to MEPC, as well as current literature. GESAMP evaluated considerable data and information from the literature on tar or tar balls, i.e. weathered oil accumulations, primarily found on beaches and along coastlines. The occurrence of coastal tar appeared to be substantial, both in quantity and global distribution. This showed that considerable oil presumed to be largely from shipping or ship-based activities were still entering coastal waters, and that this input might not be fully accounted for in the input estimates reported by GESAMP (1993).

6 The Marine Environment Protection Committee (MEPC) of IMO, at its 35th session in 1994, noted that the estimates made by the National Research Council in 1990 were based on the assumption that ships flying the flag of, or registered in, a State party to the MARPOL 73/78 Convention would fully comply with its requirements, i.e. it would apply all provisions prescribed in that Convention. MEPC requested GESAMP to evaluate all available data sources on input(s) of oil into the marine environment from sea-based activities, i.e. those related to shipping and offshore activities, and to develop approaches that might in future be used for the provision of input data (GESAMP XXVIII). In light of the many efforts made by IMO to prevent, through a number of globally applicable conventions, the pollution of the sea by oil from ships, the Intergovernmental Conference to Adopt a Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities (Washington, D.C., 23 October - 3 November 1995) also recommended that IMO should, *inter alia*, evaluate the input into the sea of oil from all sources. After consideration by the Fourth Session of the Commission on Sustainable Development in early 1996, this recommendation was included in a draft resolution on institutional arrangements for our the

[6] GESAMP is described on the GESAMP website (www.gesamp.net) and by Wells et al. (2002).

implementation of the Global Programme of Action and submitted to the United Nations General Assembly at its fifty-first session in December 1996. The United Nations General Assembly adopted resolution 51/189 on "Institutional arrangements for the Global Programme of Action"regarding land-based activities.

7 The IMO Assembly at its twentieth session in November 1997 took note of the United Nations General Assembly resolution, indicating that the degradation of the marine environment from land-based activities was outside IMO's mandate and that without extra-budgetary financial resources, IMO was not in a position to carry out the tasks as set out in United Nations resolution 51/189. The Assembly welcomed, however, the information that GESAMP would, as requested by MEPC, start work in 1997 with regard to the input of oil from sea-based activities, i.e. maritime transportation and offshore exploration and production activities.

8 The first meeting of the GESAMP Working Group on Estimates of Oil Entering the Marine Environment from Sea-based Activities was in November 1997. In this regard, the Working Group used the term "sea-based activities". This referred to Agenda 21 of the 1992 United Nations Conference on Environment and Development (UNCED) which in Chapter 17 "Marine Environmental Protection" (Integrated management and sustainable development of coastal and marine areas, including exclusive economic zones) clearly differentiates land-based activities from sea-based activities. Sea-based activities comprise activities related to shipping, dumping, offshore exploration and production, and the operation of port reception facilities.

9 GESAMP at its twenty-eighth session (Geneva, April 1998) adopted terms of reference for the work on oil inputs as follows:

.1 to estimate current annual amounts of oil entering the marine environment from sea-based activities, taking into account that:

.1 "oil" would be defined as in MARPOL 73/78, Annex I (IMO 1997), i.e. oil means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals);

.2 sea-based activities would include all forms of shipping, especially in oil tankers and carriers, other commercial and non-commercial ships, as well as transportation through marine pipelines. They would further include offshore and coastal exploration and production, atmospheric emissions from such sea-based activities, coastal refineries and storage facilities, oil contaminated material disposed of at sea, and natural marine oil seeps;

.3 the annual input estimates would consider both historical and extant data, the methods for deriving those estimates, and associated uncertainties; and

.4 the annual input estimates would consider the amounts of oil entering the sea through operational discharges and accidental spills in relation to quantities transported by ships, through pipelines, etc., or in relation to offshore and coastal oil exploitation, and related industrial operations.

.2 to focus particularly on improving the estimates of oil entering the marine environment from transportation sources, as one test of the efficacy of the MARPOL 73/78 Convention, and other conventions where appropriate, pertaining to the prevention of marine pollution from oil, and the safety of life at sea.

10 Five meetings of the working group followed, in May 1998 (Meeting 2), January 1999 (Meeting 3), February 2000 (Meeting 4), February 2001 (Meeting 5), and February 2003 (working session/meeting 6). The report was then completed by correspondence, in Halifax and London.

11 A number of terms e.g. oil, oil discharge, accidental spills, spills, operational discharge, are used consistently throughout this report. Definitions are in the Glossary (Annex).

1.2 Overview of the report

12 The report has four major sections - approaches to making estimates of oil inputs (Part 2), oil inputs from ships (Part 3), oil inputs from offshore exploration and production (Part 4), and other oil inputs and related topics (Part 5). The report's emphasis is on Parts 2, 3 and 4. The data on oil inputs (Parts 3-5) are compiled and evaluated to produce a 'global annual estimate' for each type of ship and ship-based activity. The data are then summarized to produce a 'total global annual estimate' accounting for all oil inputs from ships and ship-based activities (Part 6).

13 The general approach and types of inputs are illustrated in Figure 1 - Framework for Evaluating Inputs of Oil in the Sea from Sea-Based Activities. All key sources of data and information are in the Bibliography.

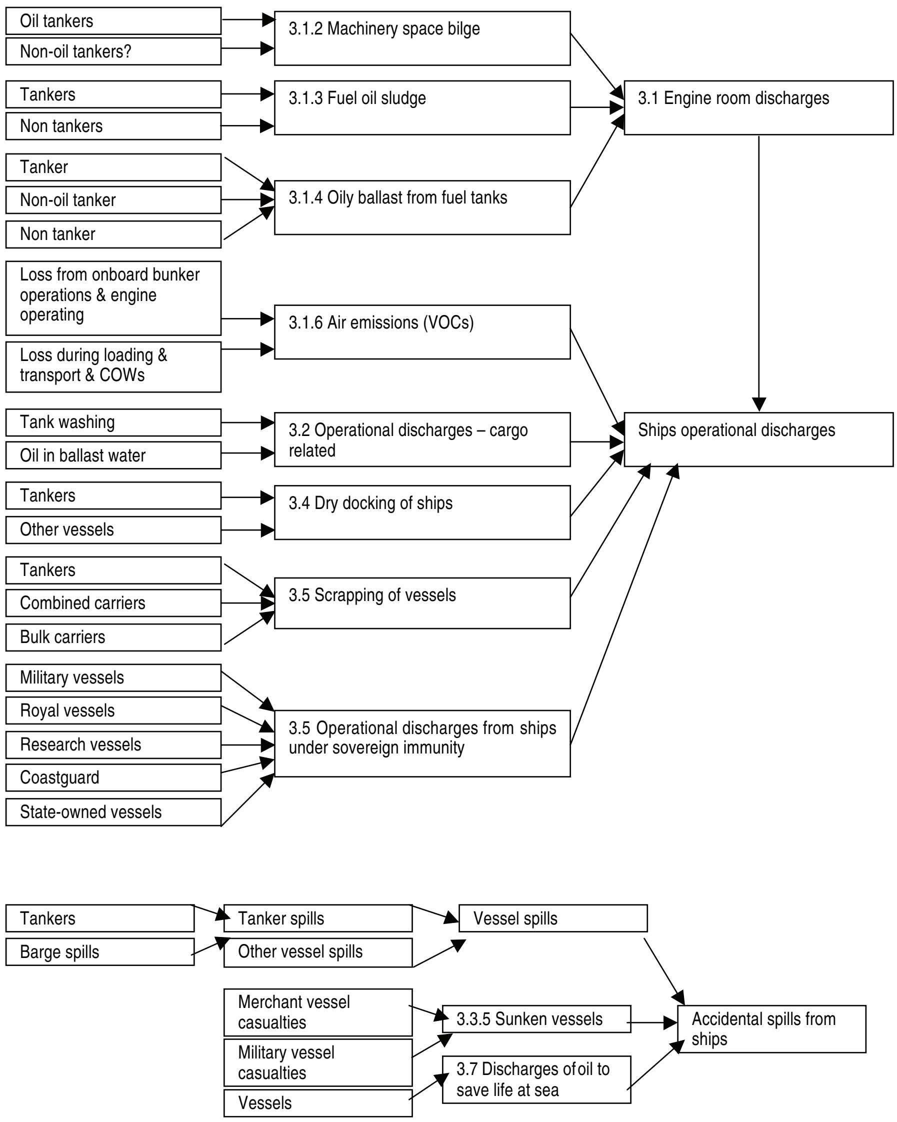
2 METHODS - MAKING ESTIMATES OF OIL ENTERING THE SEA FROM SHIPS AND OTHER SEA-BASED ACTIVITIES

2.1 The general approach

14 Obtaining reliable, up-to-date data on quantities of oil entering the marine environment, from all of the different ship and other sea-based sources world-wide, is not a simple task. Few countries and organizations have reliable databases, thus this report relies heavily on data available for the North Sea region and for North America. Data on inputs are lacking from key oil-producing areas such as the Middle East, South America (e.g. Brazil), West Africa and South East Asia. As well, there is a difference in the reporting of oil spilled from the different sources, which influences the accuracy of the amounts reported lost; for example, oil lost from shipping accidents generally includes the slick, oil in the wreck, and oil burnt, with prior knowledge of the total amounts in each ship, whereas for oil well accidents or blowouts it is more difficult to estimate what has been lost to the water and the air.

15 Further problems regarding input data relate to the fact that changes are taking place continually in shipping fleets, such as ship design and tonnage, and in volumes of crude oil transported. Newer ships are cleaner. Volumes of oil originating from different countries are not constant (e.g. note the effects of the Venezuelan political crisis in December, 2002 on reducing oil shipments from that country, and the effects of the Iraq war in Spring 2003 on reducing oil output from that country). Such changes and events have to be taken into account when calculating inputs of oil into the marine environment from ship operations, the predominant sea-based activity.

Figure 1. Framework for Evaluating Sources of Inouts of oil in the Sea from Sea-based Activities

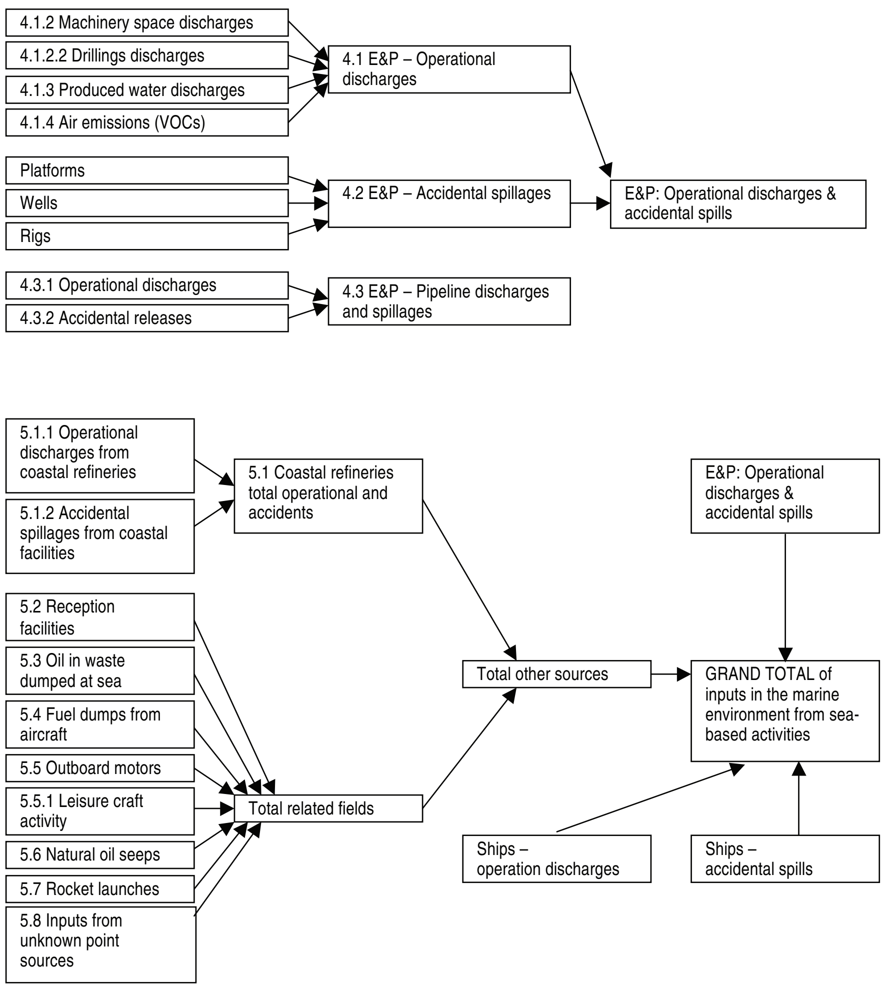


16 It should be noted again that "oil" is defined as in MARPOL 73/78, but many kinds of mineral oils are considered under this topic. In this study, we have quantified the oil inputs as "metric tonnes of oil", but in so doing, have added together the weights, or transformed the volumes to weights, of quite different oils and oily mixtures. The proportions of oil from different sources lost to the sea are also quite different, as shown in the report. There are far more small spills of different sorts than large accidental spills, which are largely crude and marine fuel oils[6] (such as bunkers). This distinction is quite important when considering how to use the information on oil inputs, as ecologically, a tonne of waste machinery space oils may not equate in potential impact to a tonne of a light crude or a marine fuel oil[7]. Likewise, we can obtain reasonable estimates of large spills or legal discharges, whereas illegal discharges are rarely quantified. The working group had many discussions on these points, but considered that taking the "total weight" approach for each source, normalizing for quantity but not type, was the only way to produce a summary input value.

17 Oil is a very complex mixture of substances and as a consequence, its measurement in environmental samples will be a function of the analytical method used. Although analytical methods are frequently standardized at a national and regional level, care needs to be exercised in cross comparison of data.

18 The physical state of oil in water also affects its accurate determination in the various environmental compartments. Current methodology extracts and quantifies hydrocarbons dispersed in the aqueous phase. The dissolved phase will typically contain low molecular weight aromatic compounds, carboxylic acids and phenols. Estimates of the concentrations of these groups of substances have been given in the Exploration and Production (E&P) Forum, 1994 (E&P Forum 1994). For the North Sea, concentrations of carboxylic acids have been measured in the range 100 to 1000 mg l^{-1} and phenols in the range 1-15 mg l^{-1}. Concentrations of low molecular weight PAHs are higher in discharges from gas installations (up to 300 µg l^{1}), while discharges

Figure 1. (cont'd)



[7] Reference should be made to the section on marine fuels found in Table 2 of ISO 8217:1996. Terms such as Bunker C, though commonly used in the marine environmental literature, have been replaced since 1980 by new categories of fuel types. (T.J. Gunner, pers. comm.).

from oil platforms are generally <10 µg l-1. Similar constraints on comparability occur in the estimate of oil based mud (OBM) where the analytical method used for estimating oil on cuttings will reflect to an extent the composition and physical partitioning of the mud components.

19 The challenges notwithstanding, this report describes the study methods and presents new estimates of annual average global oil inputs from sea-based activities, expressed as annual quantities of oil in metric tonnes (i.e. tonnes/yr.). This report complements the recent report of the United States National Research Council that largely considered North American oil inputs (NRC 2003).

2.2 Limitations and uncertainties of methodology – inputs from ships

20 Owing to extensive legislation and the fragmentation with regards to vessel type, function, performance and regulatory requirements, this section was extensively modelled. Different methodologies from both the original 1990 Report (MEPC 1990) and between the various sources of oil discharge from ships have been used in the current report. Given that cargo-related discharges, bilge oil and fuel oil sludge are the most extensively analysed, summary versions are given below.

2.2.1 Operational discharges – cargo-related

21 In the 1990 report (MEPC 1990), the statistics on oil movements by sea were used as a basis for the remaining estimates and assumptions. Furthermore, certain intra-area movements of oil at sea were estimated. On updating the figures for this report, the amount of oil moved and the tonnage type and voyage frequency gave a disproportionate ratio. In this case the total amount of oil moved was seen as an underestimate owing to the amount of tonnage in the world fleet. Due to the lack of complete data for intra-area movements[8] and owing to the potential for one cargo to be carried by a number of vessels, the numbers of tankers were used as the basis of the estimates of oil transportation and subsequent, cargo related, operational discharge.

22 Due to MARPOL 73/78, various regulatory requirements apply to varying sizes and types of tankers hence the quantity of oil discharged from the various types of tankers will differ. The data are, therefore, arranged within certain categories to take into account the various regulations and the current standard size categories used in the tanker market.

2.2.2 Operational discharges – ship-related (bilge oil and fuel oil sludge)

23 In estimating the fuel sludge discharge figures for all ships including tankers, it was necessary to estimate at the outset the bunker consumption for all ships. This total consumption was then divided by the sludge component based on fuel testing figures. In the 1990 Report (MEPC 1990), the ship categories were divided between tankers and all other ships. In order to be more specific in this study, further division of vessels was required as shown in section 3.1.2.

24 Given the average BHP (brake horse power) and calculating the number of days at sea for each category of ship, the total bunker consumption per vessel was estimated. This was further based on a bunker usage of 128 grams per BHP per hour (188 grams/kWhr).

25 Sludge generation is based on the sludge content in the fuel used by each ship. Fuel analysis companies, FOBAS and DNVPS, suggest that sludge percentage stands at 0.8%[9]. Some fuels are less likely to sludge, such as marine diesel oil (MDO), owing to emission regulations. This sludge may also be incinerated, or delivered ashore, hence its constituent hydrocarbons would not be entering the sea directly.

26 The sludge production figure of 0.8% was derived from the bunker consumption figures. An adjustment was then made to the compliance figure derived from IMO Port State Control (PSC) detention statistics, the variability of which was unknown to the working group.

2.2.3 Air pollution from ships

27 The amount of volatile organic compounds (VOCs) emitted from oil and chemical tankers, and returning to the sea surface and water column, has been very difficult to estimate until recently, because the phenomena have not been sufficiently studied. The loss of VOCs from engine/bunkering operations in all ships has also been impossible to estimate due to lack of data.

2.3 Accidental spillage methodology

2.3.1 International Oil Spill Database (IOSD)

28 Much of the data used in the analysis of spillages from all point sources, including vessels, pipelines, facilities, and offshore exploration and production activities, are derived from records of 7,400 documented oil spill incidents involving more than 10,000 US gallons (an arbitrary volume used in the US to denote a major spill, and equivalent to 34 tonnes) in the International Oil Spill Database (IOSD) of Cutter Information Corporation, and approximate-

[8] Another way of accessing accurate ship intra-area movement data would be through shipbrokers, such as Fearnleys.

[9] This figure and approach can vary. In recent Norwegian reports (Skjolsvik, pers. comm. July 2003.), evaluating the production of oily waste in three ships (one bulk carrier, one tanker, one car carrier), "all vessels either burned sludge in the incinerators or delivered this ashore. For two of the vessels, the sludge amounted to approximately 0.5% of fuel consumption, for one vessel 1.4% of fuel consumption". The figure used in our study of O.8% is between these values, and it was assumed that what was generated was discharged to the sea.

ly 250,000 records of spills of all sizes in the Environmental Research Consulting (ERC) databases[10]. The spill data on spills of 34 tonnes and larger in the IOSD are derived from weekly reports in the *Oil Spill Intelligence Report* and information obtained from sources worldwide representing governmental agencies, international authorities, non-governmental organizations, and industry. The data in the ERC databases are obtained from published reports (e.g. DeCola 2001; Etkin 1996 a,b, 1997 a,b; 1998 a,b; 1999 a-j; Welch 1990, 1991, 1993, 1994, 1995), Lloyd's Casualty Archive, reports of spills in periodicals and journals (e.g. *Oil Spill Intelligence Report*, *Oil Pollution Bulletin, Marine Pollution Bulletin*, and *Proceedings of the International Oil Spill Conference*), reviews of large numbers of additional published lists of spills, regional spill reports, individual spill case studies, data obtained from existing databases developed by a number of national, regional, state and provincial authorities, and industry sources, and information obtained from government and industry contacts by a large number of national fora.

29 Each of the databases contains as much information as is known and available on individual spill incidents[11]. This includes information on spill date, location, source type, source name, and the amount and type of oil spilled. This data used for this study was up to date to the late 1990s.

30 The data involving spills less than 10 tonnes are considerably less complete and reliable than for larger spills. The most reliable data for all sources with the exception of tankers and tank barges involve spills of at least 34-50 tonnes. Data on all tanker spills and barge spills, particularly those due to accidents (groundings, collisions, and allisions) are better documented and more comprehensive, due largely to the efforts of the International Tanker Owners Pollution Federation (ITOPF).

31 Much of the data in the US-based IOSD and ERC databases was originally recorded in or converted to units of US gallons. Since most international authorities and non-US national authorities rely on the metric tonne for oil measurement, the metric tonne (referred to in this study as the tonne) was used in this analysis and all volume measurements have been converted to tonnes for simplicity of comparison.

32 The conversion of US gallons to tonnes involves the conversion of a volumetric measure (gallon) to a mass measure (tonne). The measure of the volume of oil can itself present inaccuracies since oil has different volumes depending on its temperature. For truly precise conversions from gallons to tonnes, it is also important to take into account that different oils have different relative densities. For this reason it is necessary to use relative density (the density in relation to pure water) in making conversions such that:

US gallons = (921.5 x tonnes)/(3.785 l/gal x relative density).

Eqn. 1.

33 Relative densities of petroleum products generally range from approx. 0.74 for gasoline, to approx. 0.90 for a heavy crude, and to 0.95 for a heavy marine fuel (formerly known as a Bunker C or No. 6 fuel oil) (Clark and Brown 1977; NRC 1985; Etkin 1999i). Some heavy blends of marine fuels are even heavier than seawater, having relative densities over 1.0. In all analyses of accidental spills, the conversion of volumes of oil to tonnes of oil is based on an average relative density of 0.83, an average measure of a number of different oils including various crude and fuel oils (Etkin, pers. comm.). This results in 294 US gallons per tonne of oil[12].

34 Data on spill incidents in the IOSD and ERC databases, as well as other compiled data on which these databases rely, are collected from a large number of credible sources on an international basis. Due to the nature of the data collection process, discrepancies and inaccuracies exist in these databases and original data sources. For example, incident information can be inaccurate regardless of its source; one recent spill in Korea was reported by a reputable news agency as >20,000 tonnes, whereas it was actually 2-5 tonnes (ITOPF, pers. comm.). As well, there are undoubtedly omissions of spills, especially those in smaller size ranges and from areas in which spill recording and reporting are not rigorously pursued; the percent error for the various input categories due to omissions is unknown. Hence, spill input figures are smaller than the "true" values.

35 Prior to the 1970s, reporting of oil spills to authorities and record keeping on oil pollution was not legally required in many countries, including the US. Although major spills during this earlier period (1950s and 1960s) have been logged, input data prior to the 1970s should be viewed with caution and the values taken as underestimates. The data prior to the 1980s in the IOSD and ERC databases are particularly incomplete with regard to spills from non-vessel sources; these spills tended to escape the notice of media and the public unless they were in highly visible or high profile locations, such as in the vicinity of amenity beaches (e.g. cities or resorts). Even in recent years, reporting of oil spills and sharing of information on spill events from some countries and regions have been unreliable for both political and logistical reasons. In some countries, record keeping and reporting requirements have been less rigorous in the past and spillage records

[10] The IOSD and ERC databases are not in the public domain. However, this study and that of the recent NRC Committee (NRC 2003) relied on their data. The databases are acknowledged to be the best available, due to the specialty of the firms and their experts. The proprietary nature of the two databases precludes other independent analysis of the input data.

[11] The ITOPF database on tanker spills is also very extensive but was only selectively utilized for this study.

[12] GESAMP (1993) reported 308 US Gal. or 1,165.78 litres, per metric tonne for typical crude oils, a higher conversion factor than used in this study due to it being derived solely from crude oils.

often have been incomplete. In general, however, reporting of spill incidents has improved worldwide.

36 The analyses of accidental spillages are subject to these inherent deficiencies in the data, and all input estimates for accidental spills should generally be viewed as underestimates.

2.3.2 Estimation factor for smaller spills

37 In any one year and in any one location, many more small spills occur than very large spills, i.e. small spills contribute a large percentage of the total number of spills annually. At the same time, even added together, the smaller spills contribute a much smaller amount of oil spilled than one much larger incident.

38 The spillage represented by these smaller spills could be merely accepted as a weakness of the data. However, for calculating the amount of oil spilled annually in the marine environment from these spills, it is important to include as much information as possible in the estimation attempts. Likewise, for the purposes of analysing the efficacy of prevention measures and the risks for ecological effects, it is important to consider the total number of incidents, including these smaller spills.

39 The IOSD contains no verified information on oil spills below 34 tonnes and the ERC databases contain incomplete information on oil spills in this smaller size range. Hence, a “small spill estimation factor” was calculated by D. Etkin (ERC) for both the number of spills and the amount of oil spilled in incidents involving less than 34 tonnes. The two estimation factors (for number of spills, and amount spilled) were based on an analysis of over 95,000 spills of at least one US gallon (0.003 tonnes) that occurred in US marine waters during 1985-1999. The data are in the ERC database based on comprehensive data of spills of at least one US gallon (0.003 tonnes) from the US Coast Guard, the US Minerals Management Service, Environmental Protection Agency, the US Office of Pipeline Safety, and several State databases; they were compiled, cross-checked and verified. The ERC data set was selected since it was the most complete set of data available to the working group and lent itself to rigorous statistical testing.

40 A frequency distribution analysis was conducted on over 60,000 vessel spills and nearly 35,000 pipeline and facility spills in US marine waters to derive correction factors for vessels and for coastal and offshore pipelines and facilities.

41 The application of the small spill estimation factors derived solely from US data to correct the missing of representation of small spills introduces inherent errors. The pattern of spillage in different regions of the world may not follow the frequency distribution of spill sizes in the US data, although it would be expected that small spills are generally more common than larger spills in all areas. Even within the US data set, the frequency distribution of spill size varied from year to year.

42 The frequency distribution analyses of the US data are shown in Figures 2 and 3. Final small spill estimation factors for both vessels and pipelines/facilities were calculated by taking the percentage of the number of oil spills under 34 tonnes and the total amount of oil spilled in spills involving less than 34 tonnes but at least 0.003 tonnes (the equivalent of one US gallon). Thus, an average of 23.3% of the total amount of spilled oil from vessels is spilled in incidents of less than 34 tonnes, although this represents 99.99% of the number of incidents. For pipelines and facilities, 17.4% of the total amount of oil spilled comes from incidents involving 0.003-34 tonnes. The smaller spills comprise 99.6% of the total number of pipeline and facility spills.

43 To project from the international data on spills of over 34 tonnes to the larger range of spills involving at least 0.003 tonnes, the small spill estimation factor for spill number was applied in the following manner for vessels:

$V_{nl} = 0.001 \times V_{ne}$
or
$V_{nl}/0.001 = V_{ne}$

where V_{nl} = number of vessel spills ≥ 34 tonnes; V_{ne} = estimated number of vessel spills ≥ 0.003 tonnes.

This estimation assumes that if there are x vessel spills of at least 34 tonnes, then there are an estimated 1,000 *x* spills of at least 0.003 tonnes. It should be noted that this estimation applies to all vessels and for all types of spill causes.

Figure 2.
Cumulative Percentage of Total Oil Spillage From Facilities and Pipelines Into US Marine Waters (Numbers of Spills and Amounts) By Size Class US Vessel Spills (1985-1999) (Environmental Research Consulting Database)

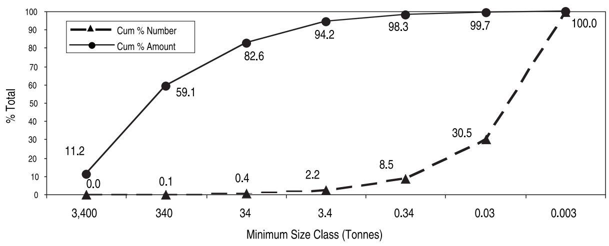
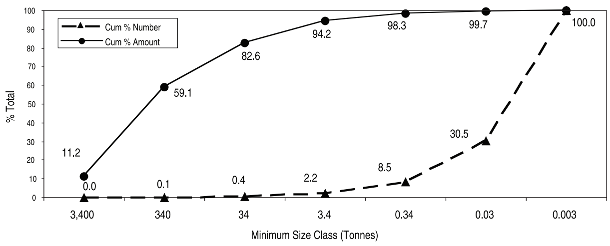


Figure 3.
Cumulative Percentage of Total Oil Spillage From Facilities and Pipelines Into US Marine Waters (Numbers and Amounts Spilled) By Spill Size Class (1985-1999) (Environmental Research Consulting Database)



44 Likewise, to estimate the amount of oil spilled from vessels in all size classes based on verified data of spills of at least 34 tonnes, the following estimation factor was applied:

$V_{al} = 0.767 \times V_{ae}$
or
$V_{al}/0.767 \times V_{ae}$,

where V_{al} = amount spilled from vessels in spills ≥ 34 tonnes; V_{ae} = estimated amount spilled from vessels in spills ≥ 0.003 tonne.

This estimation states that, if there are x tonnes of annual spillage from vessels attributable to spills involving at least 34 tonnes, there are an estimated 1.3*x* tonnes of oil spilled in incidents involving at least 0.003 tonnes.

45 For coastal pipelines and facilities (including offshore exploration and production facilities), a second estimation factor for spill numbers was derived as follows:

$PF_{nl} = 0.004 \times PF_{ne}$
or
$PF_{nl}/0.004 \times PF_{ne}$,

where PF_{nl} = amount spilled from pipelines and facilities in spills ≥ 34 tonnes; PF_{ne} = estimated amount spilled from pipelines and facilities in spills ≥ 0.003 tonne.

This estimation states that, if there are x number of pipeline and facility spills of at least 34 tonnes, there are an estimated 250*x* spills of at least 0.003 tonnes. It should be noted that this estimation applies to all pipelines and facilities and for all types of spill causes.

46 Another estimation factor for spill amount was derived for application to pipeline and facility spill input estimates, as follows:

$PF_{al} = 0.826 \times PF_{ae}$
or
$PF_{al}/0.826 = PF_{ae}$,

where PF_{al} = amount spilled from facilities/pipelines in spills ≥ 34 tonnes; PF_{ae} = estimated amount spilled from facilities/pipelines in spills ≥ 0.003 tonne.

This estimation states that, if there are known to be *x* tonnes of annual spillage from pipelines and facilities attributable to spills involving at least 34 tonnes, there are an estimated 1.21*x* tonnes of oil spilled in incidents involving at least 0.003 tonnes.

2.3.3 Application of the small spill estimation factors to the IOSD

47 To project from the IOSD data of spills over 34 tonnes to the larger range of spills involving at least 0.17 tonnes, the small spill estimation factor for spill number was applied in the following manner:

IOSD spill number = 0.03203 x estimated number of spills ≥ 0.17 tonnes
or
IOSD spill number/0.03203 = estimated number of spills ≥ 0.17 tonnes

48 Likewise, to project from the IOSD data of spills over 34 tonnes to the larger range of spills involving at least 0.17 tonnes, the small spill estimation factor for spill amount was applied in the following manner:

IOSD spill amount = 0.84408 x estimated amount from spills ≥ 0.17 tonnes
or
IOSD spill amount/0.84408 = estimated amount from spills ≥ 0.17 tonnes

2.3.4 Average annual input estimation

49 Preliminary estimates of average annual input for the time period 1988-1997 were made for all source categories of accidental spills by taking the mean estimated annual spill amount based on the amount spilled in incidents involving at least 34 tonnes adjusted upwards to account for the estimated amount of spillage that would be attributable to spills of at least 0.003 tonnes to just under 34 tonnes. These figures were compared to estimates for the two previous ten-year time periods (1968-1977 and 1978-1987) that were made using the same methodology and data sets.

50 Deriving an average annual input figure for a ten-year period presents a statistical problem in that there is considerable variability from one year to the next in terms of the amount of oil spilled from the various sources. In any year, one or more very large (over 5,000-tonnes, arbitrarily set by US) spills can completely dominate the annual input for that year (see Figure 4). The estimated annual input figures, therefore, need to be put into perspective by adjusting for these very large inputs.

51 The annual percentage of vessel spills involving 5,000 tonnes or more has declined considerably since 1968 (see Figure 5 and regression equation), but has remained steady at about 0.2% of spills for the last decade. Thus, on average in any one year, 0.2% of accidental vessel spills involve at least 5,000 tonnes of oil (e.g. *Khark V* in 1989, *ABT Summer* in 1991, see Table 21). With the exception of 1995, which experienced no spills in this size category, all years in the last decade have involved at least two spills of this magnitude. In fact, over the last decade the average number of spills involving over 5,000 tonnes is 4.1 spills annually.

52 Another approach to estimating average annual input from accidental releases would be to look at average annual spillage *without* these larger spills and then to add the larger spills as an error or uncertainty factor. This would give a more accurate perspective on the current state of affairs with respect to accidental spillage. The variability from

year to year of total spill amount attributable only to spills *below* 5,000 tonnes has varied relatively little over the last decade (see Figure 4). Applying a separate factor of spill amount over 5,000 tonnes is most appropriate for vessel spills of all the source categories since, historically, the great majority of spill incidents in this size category have involved vessels. During the time period of 1988-1997, 93% of incidents over 5,000 tonnes involved tankers and barges; the remaining 7% were pipeline incidents.

53 Extremely large exploration and production activity spills such as the *Ixtoc I* well blowout spill of 1979-1980, which involved the spillage of in excess of 476,000 tonnes of oil, are even rarer than very large tanker spills. The *Ixtoc I* spill, though a rare event, represented the largest total amount of oil released from a single, man-made point source in recorded history. While the probability of another extremely large blowout has been vastly reduced by current methodologies and technology, the possibility still exists and should be borne in mind in making any kind of predictive analyses. There were no exploration and production spills over 5,000 tonnes during the 1988-1997 period designated for the input analysis of this report.

54 Spills attributable to war-related events can also be extremely large. The spillage into the Gulf during the 1991 Gulf War of an estimated 986,000 tonnes due to attacks on eight tankers and 13 facilities is such an epochal event. This could be repeated, though speculation on the probability of this type of war-related occurrence is beyond the scope of this study. Any individual *Ixtoc I*- or Gulf War-type event or series of such events would greatly skew the input data and resulting analyses for any decade or individual year. Due to the unique circumstances surrounding spills related to war attacks, these spill events were removed from the accidental spill data and are presented separately.

55 Estimates of accidental spillage from the various sources were calculated as the average annual amount attributable to spills of less than 5,000 tonnes and the average annual amount spilled in incidents involving 5,000 tonnes or more. The average annual input estimate for each accidental spill source type was then calculated using the amount spilled in incidents involving less than 5,000 tonnes plus the average annual amount attributed to spills in the larger spill size category.

2.3.5 Definition of accidental spillage

56 In the context of this study and in all ensuing analyses of "accidental" spillages, the term "accidental" does not necessarily imply that there is no fault or possible intent involved in all of the included incidents. The "accidents" should be viewed as "incidents" involving the release of oil from point sources over a relatively limited amount of time (i.e. hours or days), rather than from slow leakages of relatively small amounts of oil over months or years. An exception to the criterion of a time limit would be the inclusion of the 1979 *Ixtoc I* well blowout in the Gulf of Mexico that caused the discharge of large amounts of oil over a period of ten months.

Figure 4.
Accidental Oil Spills from All Source Types into the Marine Environment (1988-1997) (ERC Database and OSIR International Oil Spill Database)

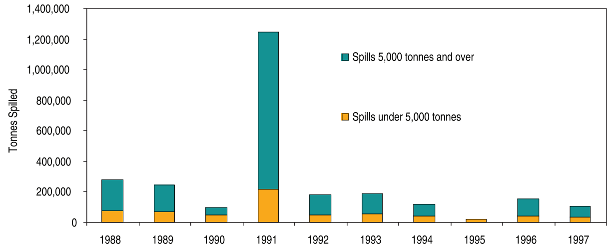
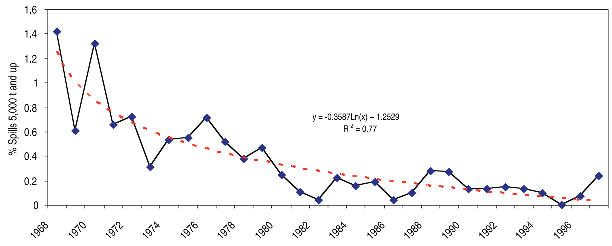


Figure 5.
Percent of Vessel Spill Numbers Involving at Least 5,000 Tonnes of Oil (Based on Etkin 1999h)



57 Most accidents are unintentional (see glossary). However, the "accidents" that are used in this analysis include spills that may have been intentional. These include the 149 incidents over 34 tonnes which involved the intentional release of oil, the case of illegal discharges of amounts of oil in excess of that which can be expected from vessels in operational discharges of not more than 15 ppm in the manner described in MARPOL 73/78, and the jettisoning of oil to prevent loss of life at sea. Legal operational discharges are covered in section 3.1 of this report. An additional 77 incidents involved war acts resulting in the spillage of oil from vessels, and 50 incidents involved war acts resulting in spillage from exploration and production (E&P) facilities, coastal facilities, and pipelines. "Accidental" spillage, then, is defined as the release of oil, whether intentional or unintentional, from a point source in one incident over a limited period of time other than what could normally be expected as operational or MARPOL-regulated discharges.

2.3.6 Regional analysis of accidental spillage data

58 The data on accidental oil spills derived from the International Oil Spill Database (IOSD), with the small spill estimation factors for spills under 34 tonnes, were analysed on a regional basis for 18 regions (See Figs. 5 and 6, also Etkin 1999g).

59 The 18 regions (Figure 6) selected for analysis were based on approximate boundaries of marine areas defined by the UNEP Regional Seas

Programme as well as special areas described under MARPOL 73/78, within the geographic selection limitations of software programmes based on 10-degree Marsden squares. The areas not covered by either of these descriptions were based on arbitrary subdivisions of remaining marine areas. The boundaries of the regions used in these analyses are shown in Table 1. The boundaries to these regions are not based on any national boundaries or territorial waters and no implications were made with regard to any particular countries with respect to oil spillage. Indeed, several countries are represented in two areas since the regions selected were based on seas or ocean regions rather than on national boundaries. Data on individual regions should be viewed very carefully with this in mind.

60 Each region was analysed for spillage over the course of the last three decades (1970s to 1990s) for both numbers of spills and total amount of oil spilled. As with all the data analyses based on the databases with the small spill estimation factors applied, there are inherent inaccuracies in the estimation techniques used to derive these figures.

61 The estimates for average annual input of oil are based on data of actual spills recorded with adjustment factors for vessels and pipelines/facilities for the absence of data on smaller spills. The small spill estimation factors have been used to increase accuracy of the data by taking into account the lack of data on small spills of under 34 tonnes. There may, however, be unavoidable gaps in records on spills of over 34 tonnes that might create underestimates in accidental spillage figures even after the adjustment factors are applied to both spill number and spill amount. In addition, some regions have less reliable spill data reporting facilities than others, which may also lead to underestimation of inputs in those regions.

62 In addition, the use of the small spill estimation factors (derived from an analysis of United States data) might create some inaccuracies, especially with regard to spill numbers, if the pattern of spillage worldwide does not closely resemble the size frequency distribution of spill sizes in the United States. In general, however, it can be expected that spill size frequency would follow a pattern of many smaller spills and fewer large spills.

Figure 6. Regional oil spill analysis showing the 18 geographic regions (Etkin, 1999g)

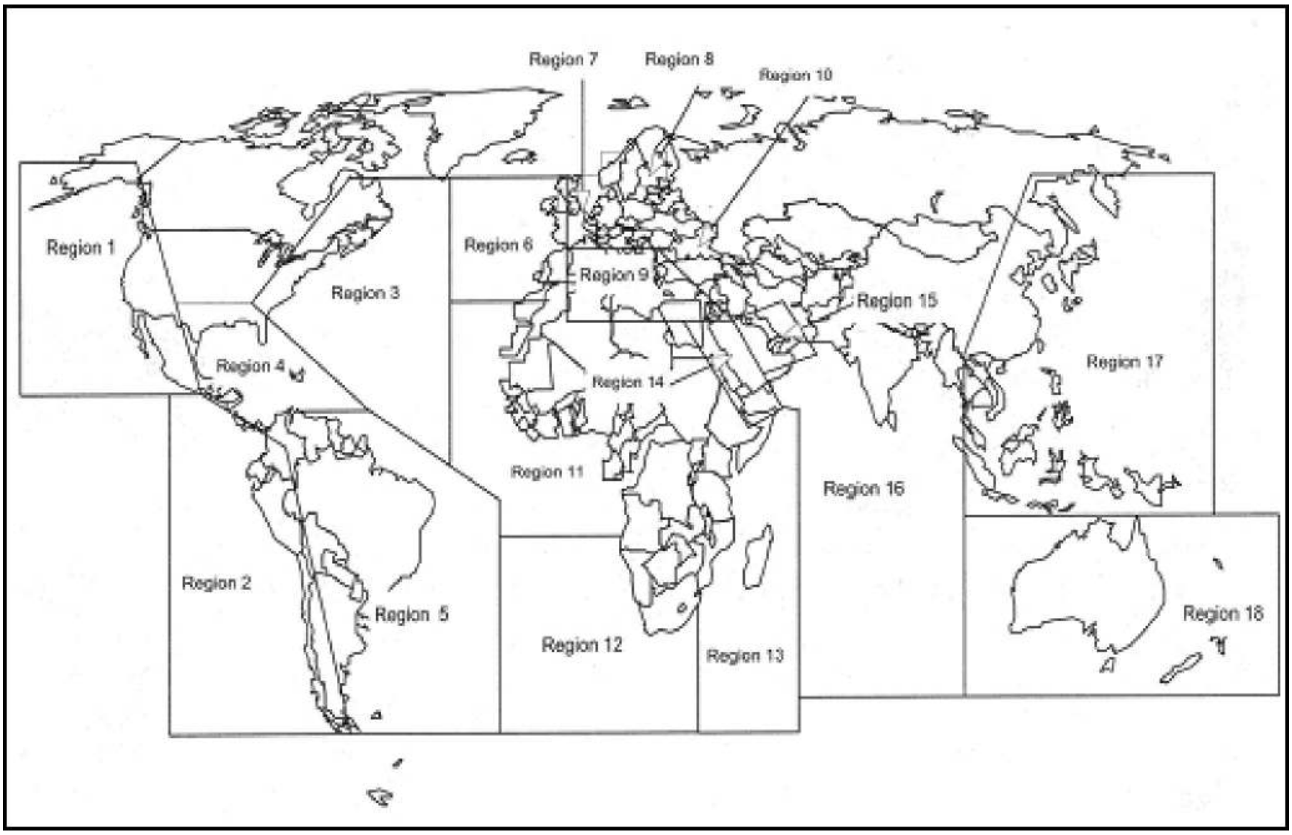


Table 1. Regional descriptions for regional data analysis (adapted from Etkin 1999g)

Region number[1]	Region name	Region boundaries[2]
1	Northeast Pacific Ocean	East of 170°W, north of 10°N, east to coastal and estuarine areas of USA, Canada, Mexico, Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica to 10°N
2	Southeast Pacific Ocean	East of 170°W, south of 10°N to 60°S, east to coastal and estuarine areas of Costa Rica, Panama, Columbia, Ecuador, Peru, and Chile east to 70°W
3	North Atlantic Ocean	West of 40°W to coastal and estuarine areas of Canada and USA to east coast of Florida, USA
4	Gulf of Mexico/ Caribbean Sea	Gulf of Mexico and Caribbean Sea to coastal and estuarine areas of USA (western and souther coast of Florida west to Texas), island nations and territories in Caribbean Sea east of 60°W, eastern coastal and estuarine areas of Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama, and northern coastal and estuarine areas of Colombia; not including Lake Maracaibo area of Venezuela
5	Southwest Atlantic Ocean	West of 20°W to coastal and estuarine areas of Argentina, Uruguay, Brazil, Fr. Guinea, Suriname, Guyana, Venezuela (including Lake Maracaibo), and Magellan Strait east of 70°W
6	Northeast Atlantic Ocean	East of 40°W, north of 30°N to 60°N, east to coastal and estuarine areas of Ireland, United Kingdom, not including east of 5°W north of Scotland, United Kingdom, or north of 52°N on eastern coast of United Kingdom or coast of Belgium; including France, Portugal, Spain, and Morocco, west of Gibraltar
7	North Sea	North of 52°N at eastern coast of United Kingdom and coast of Belgium north to 65°N east to 5°W to Scotland, United Kingdom, coast, and east to 10°E, including coastal and estuarine areas of western United Kingdom, Belgium, Netherlands, Germany, Denmark, and Norway
8	Baltic Sea	Baltic Sea, Kattegat, Gulf of Bothnia, Gulf of Finland, and Gulf of Riga, east of 10°E to 30°E; incluing coastal and estuarine areas of Denmark, Sweden, Norway, Germany, Poland, Lithuania, Latvia, Russian Federation, and Finland
9	Mediterranean Sea	East of Strait of Gibraltar, including Mediterranean Sea, Tyrrhenian Sea, Adriatic Sea, Ionian Sea, Aegean Sea, up to, but not including Bosporus Strait, Turkey; including coastal and estuarine areas of France, Spain, Italy, Monaco, Greece, Turkey, Syria, Lebanon, Israel, Egypt, Libya, Tunisia, Algeria, Slovenia, Croatia, Bosnia-Herzogovnia, Yugoslavia, Albania, and Morocco
10	Black Sea	Black Sea including Bosporus Strait; including coastal and estuarine areas of Turkey, Bulgaria, Romania, Georgia, and Russian Federation
11	West/Central African Atlantic Ocean	South of 30°N, east of 40°W to 0°, east of 20°W, north of 10°S, east towards western African coast; including coastal and estuarine areas of Morocco, W. Sahara, Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra-Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo, Zaire, and Angola north of 10°S
12	Southern Africa	South of 10°S, east of 20°W to African coastal and estuarine areas east to 30°E; including Angola south of 10°S, Namibia, and South America to 30°N on Indian Ocean coast
13	Eastern Africa Indian Ocean	East of 30°E to 60°E north as 10°N; including coastal and estuarine areas of South Africa north of 30°N, Mozambique, Madagascar, Tanzania, Kenya, and Somalia north to 10°N
14	Red Sea/ Gulf of Aden	Red Sea, including Suez Canal, and Gulf of Aden and Gulf of Aqaba, north of 10°N, east to 60°E; including coastal and estuarine areas of Somalia, Djibouti, Eritrea, Egypt, Yemen, Saudi Arabia, Oman, and Jordan
15	Gulf	Gulf area and associated coastal and estuarine areas in Saudi Arabia, Qatar, United Arab Emirates, Bahrain, Kuwait, Iraq, and Iran, to Strait of Hormuz
16	Arabian Sea/ Indian Ocean	East of 60°E, and Gulf of Hormuz, east to 100°E; including coastal and estuarine areas of Iran, Oman, Pakistan, India, Bangladesh, Burma, Sri Lanka, Thailand, and Indonesia
17	East Asia/ Southeast Asia	East of 100°E, north of 10°S, east to 170°W; including coastal and estuarine areas of Thailand, Indonesia, Malaysia, Japan, North Korea, South Korea, Vietnam, Philippines, China, Russia, Papua New Guinea, and Brunei
18	Australia/ New Zealand	East of 100°E to 170°W, south of 100°S; including coastal and estuarine areas of New Zealand and Australia

[1] Refers to regions depicted in regional map
[2] Boundaries were determined on the basis of approximate marine areas rather than on national boundaries.

2.4 Produced water discharges

63 Water occurs naturally in geological oil reservoirs and is extracted from formations along with the hydrocarbons. Production water and hydrocarbons are separated at the site of production by physical and chemical techniques. The water phase may be re-injected into the reservoir to maintain pressure and thereby to enhance exploitation. At some locations, where the subterranean geology permits, produced water can be re-injected as a means of disposal. However, for geological and other reasons, this option is not widely available, thus treated produced water containing amounts of dispersed oil is most often discharged at sea.

64 In the initial stages of exploiting a hydrocarbon deposit, production water volumes may be low. As the field matures, however, volumes of production water rise and in mature areas water amounts of more than 90% are typical.

65 In many producing areas, local and/or regional regulatory authorities have imposed a quality standard for oil in produced water. Numerical standards range from around 30 mg oil per litre of produced water to 100 mg l^{-1}. In others, discharge targets or standards have not been established. In all cases, it is clearly in the operators' interests to maximize the separation of oil (product) from water, if only from an economic perspective. Care must be taken, however, in making direct comparisons between the numerical standards defined in different geographic regions. As stated above, since oil is a complex mixture of organic components, analysis of oil in water is non-specific and results of determinations will be dependent upon the analytical method used. Thus, numerical differences in standards do not necessarily reflect different regional views on environmental protection. Consequently, for this and other reasons, care must be taken comparing and combining input estimates from different producing regions.

2.5 Operational discharges from coastal refineries

66 The estimates for operational discharges from coastal oil refineries due to oily effluents are based on the total crude refining capacities of coastal or estuarine refineries as reported by PennWell Oil Directories (Tippee 2001). The total worldwide crude oil refining capacity is currently about 7,800,000 tonnes per day (circa Feb 2001), but increasing due to demand.

67 Four assumptions were made in assessing the maximum estimate of input:

.1 that refineries produce, on average, 4.5 units of wastewater per unit of refining capacity (shown by CONCAWE and EDF studies);

.2 that refinery effluents contain 5 ppm to 25 ppm of oil, depending on the condition and operation practices of the refineries;

.3 that refineries operate year-round; and

.4 that refineries discharge the maximum amount of oil permitted into their effluents.

There is also an implicit assumption that any effluent discharge that contains more than the permissible oil content should conceptually be considered a *spill event* rather than a permissible operational discharge.

68 The fact that higher oil levels may consistently be discharged in effluents is recognized. Such long-term discharges are unlikely to have been captured in spill event data which tracks discrete spill events rather than long-term small leaks. At the same time, it is known that many refineries in such countries as the United States discharge below the 5 ppm threshold (EDF 1995). This over- and underestimation of effluent oil content is a source of error in the overall input estimates. At the same time, the assumptions above do not always hold true. All refineries do not operate year-round at full capacity (D. Etkin, unpubl. data). The actual number could be as low as one quarter to one half of this amount if the less efficient refineries were actually releasing less than 25 ppm of oil in their effluents and were operating on a less than full-time schedule. The estimated input numbers for refinery operational discharges are put into a range to reflect this uncertainty.

3 OIL INPUTS FROM SHIPS

3.1 Operational discharges – ship-related

3.1.1 Introduction

69 Operational discharges of oil into the marine environment by ships depend on several factors. These include: type and age of ship; level of maintenance of ship and engines; presence of oil-water separators and other equipment designed to curtail discharges of oil; practice of the LOT (load-on-top) principle; training and vigilance of the crew; level of shipping activity, which was lower in the 1990s than in previous decades[13]; and presence of adequate reception facilities. Under the MARPOL 73/78 Convention, Annex 1 (IMO 1997a), discharges of oil are strictly regulated. As from 1997, the maximum legal operational discharge of oil was reduced from 100 parts of oil per million parts of water (i.e. ppm) to 15 ppm per nautical mile (nm), beyond 50 nm off a coastline.

3.1.2 Operational engine room wastes and discharges (Fuel oil sludge and bilge oil)

70 Tankers generally do not have a storage problem for excess sludge generated from purification of bunker fuels. The excess sludge and bilge oil (i.e. oily bilge waters, or oily waters, originating from engine room) that cannot be stored in the engine room sludge tank may be transferred to the vessel's main slop tanks for subsequent LOT or load on top, i.e. addition to the oil cargo, or it may be incinerated. However, such a procedure is not available to those tankers trading with clean products, that is, 9.4% of the total tanker tonnage (see section 3.2); therefore, the estimations have been corrected accordingly for these vessels for non-compliance.

71 Sludge and bilge oils are collected in the engine room sludge tanks and are taken to be the same source of oil for the estimations in this section. Due to the high cost of lubricating oil and the increasing refinement of marine engines, the numbers used in the 1990 report (MEPC 1990) are over-estimates based on today's practices (circa 2002). For an estimate of the bilge oil fraction, it has been assumed by Intertanko experts that this would be 1% of the total amount contained in the sludge tanks. It is further noted under MARPOL 73/78, Annex VI, that most of the fuel oil sludge produced goes to the ship's incinerator, and any remaining fuel oil sludge would be stored separately and discharged to port reception facilities.

[13] "Shipping has been through a recession in the 1990s, hence the annual fuel consumption is not significantly higher now than in 1990. The discharge regulation is stricter and the fleet partly renewed. Hence, one would expect a significant reduction (of oil input) compared to 1990 figures in oil input from bilge oil discharge." (K.O. Skjolsvik, pers.comm.).

72 On estimating the fuel sludge discharge numbers for all ships including tankers, it was necessary at the outset to estimate the bunker consumption for all ships. In the 1990 report (MEPC 1990), the ship categories were divided between tankers and all other ships. In order to be more specific, a further division of vessels was required. Table 2 illustrates the division of vessels together with the number of ships and their average brake horsepower (BHP) taken from the Fairplay database (Fairplay Database 2000).

73 Given the average BHP and estimating the number of days at sea for each category of ship (see Table 2), the total bunker consumption per vessel was estimated. As stated earlier, this was further based on the bunker usage of 128 grams per BHP per hour (see Table 3 below). The calculations gave a total consumption for all ships of 224,119,523 tonnes/yr. or ~224,000,000 tonnes/yr.[14]

74 Sludge generation is based on the sludge content in the fuel used by each ship. Fuel analysis companies, FOBAS (Fuel Oil Bunker Analysis and Advisory Service, Lloyd's Register, London, United Kingdom) and DNVPS (DNV Petroleum Services, London, United Kingdom), suggest that sludge percentage stands at 0.8% (Also note footnote 9). A number of vessels now run on fuels that are less likely to sludge, such as marine diesel oil (MDO), owing to new emission regulations. This sludge may also be incinerated, together with the bilge oil waste, hence, is not directly entering the marine environment.

75 The sludge production number of 0.8% is applied to the bunker consumption numbers, with the outflow numbers being estimated using the MARPOL 73/78 Annex I discharge allowance of 15 ppm. Table 4 illustrates discharge of fuel oil sludge, calculated on the assumption of 100% compliance. Based on this total compliance, the annual discharge into the marine environment of fuel and bilge oil from all of the ships combined is estimated at 13,453 tonnes/yr, or ~13,500 tonnes/yr.

76 However, IMO estimates on compliance numbers taken from submissions from States that are party to MARPOL 73/78 have shown a range of compliance under Port State Control (PSC) inspections of between 72% worst case and 100% (IMO FSI 9/8, 2001). On the basis of the median of 86%, compliance was used as an estimate of compliance in the shipping section of this report. Table 5 gives the outflow numbers adjusted for this compliance percentage.

[14] Other studies of total ship fuel consumption globally per year give other values. "Total world consumption from ships has been estimated in the range of 200,000,000-270,000,000 tonnes/yr., the number varying with amount of domestic shipping included in the calculation" (K.O. Skjolsvik, pers. comm.). Our numbers are in this range.

Table 2. Ship types, numbers and average brake horsepower (BHP)

Ship Type	Number of Ships	Avg. BHP*
Bulk Carriers	8,680	8,232
Combination Carriers	212	14,423
Container Vessels	2,574	20,504
Dry Cargo Vessels	7,446	4,374
Miscellaneous	5,570	4,168
Offshore Vessels	2,903	6,652
Ferries/Passenger Vessels	2,756	10,836
Reefer Vessels	1,838	6,772
RoRo Vessels	1,939	10,275
Tankers - All cats.	8,156	8,857
Total	42,074	

*Avg. BHP – average or mean brake horsepower.

Table 3. Estimation of total bunker consumption (cons.) per vessel

Ship Type	Number of Ships	Avg. BHP	Daily Bunker Consumed*	Number of Days at Sea	Yearly Bunker Cons./Vessel	Total Cons. for Vessel Type
Bulk Carriers	8,680	8,232	25.289	200	5,058	43,901,183
Combination Carriers	212	14,423	44.307	200	8,861	1,878,610
Container Vessels	2,574	20,504	62.990	180	11,338	29,184,295
Dry Cargo Vessels	7,446	4,374	13.438	150	2,015	15,009,051
Miscellaneous	5,570	4,168	12.803	200	2,560	14,263,099
Offshore Vessels	2,903	6,652	20.434	200	4,086	11,864,184
Ferries/Passenger Vessels	2,756	10,836	33.288	250	8,321	22,935,349
Reefer Vessels	1,838	6,772	20.803	200	4,160	7,647,164
RoRo Vessels	1,939	10,275	31.564	250	7,891	15,300,591
Tankers - All cats.	8,156	8,857	27.209	280	7,618	62,135,997
Total	42,074					224,119,523

* Bunker consumed (cons.) in tonnes.

Table 4. Discharge of fuel oil sludge from vessels, in tonnes, on assumption of 100% compliance with MARPOL Annex I

Ship Type	Total Oil Consumed for Vessel Type	Sludge Generation	Legal Discharge 15 ppm	100% compliance, tonnes discharged
Bulk Carriers	43,901,183	351,210	5.27	3,517
Combination Carriers	1,878,610	15,029	0.23	151
Container Vessels	29,184,295	233,474	3.50	2,338
Dry Cargo Vessels	15,009,051	120,073	1.80	1,203
Miscellaneous	14,263,099	114,105	1.71	1,143
Offshore Vessels	11,864,184	94,913	1.42	951
Ferries/Passenger Vls	22,935,349	183,483	2.75	1,838
Reefer Vessels	7,647,164	61,177	0.92	613
RoRo Vessels	15,300,591	122,405	1.84	1,226
Tankers - All cat.	62,135,997	497,088	7.46	475
Total	224,119,523	1,792,956	26.89	13,453

77 In summary, the estimated total operational discharge into the marine environment of fuel oil sludge and bilge oil from all ships = **187,990 tonnes/yr. or 188,000 tonnes/yr**. Given the assumption that 1% of this figure would be bilge oil, the following components can be derived:

Fuel Oil Sludge into the marine environment	=	**186,120 tonnes/yr.**
Bilge Oil into the marine environment	=	**1,880 tonnes/yr.**
Total operational engine room discharges	=	**188,000 tonnes/yr.**

3.1.3 Oily ballast from fuel tanks

78 The use of fuel tanks for ballasting a ship is now seen as an option, though it is limited in use and high in risk. It was noted by MEPC (1990) that certain non-tankers such as fishing vessels may still continue to use this practice of ballasting. Information from industry sources states that this practice is more cumbersome and includes the risk of mechanical/engine problems due to fuel contamination. As a consequence, this practice is seen as rare, however, an attempt has been made to take this into account and update the figures from those in the 1990 MEPC report.

79 In the 1990 MEPC report, 2% of non-tankers were estimated as carrying out this procedure. This has been revised down to 1% based on indicators stressing the limited use of the procedure. The clingage factor had already been revised by the 1990 report and due regard for the use of marine diesel fuel was given. In this regard, the factor of 0.4% in the 1990 report has been maintained.

80 Vessels have two options on the discharge of oily water produced under MARPOL 73/78. Firstly, in the absence of oily water filtering or separating equipment, the waste oil should be delivered to shore facilities and, secondly, discharge is permitted with the correct equipment at a maximum of 15 ppm. In view of this requirement, the 1990 report estimated that 25% of the oil waste would be discharged into the sea. This number can be corrected using the compliance number derived in section 3.1 and revised to 14% of the oil waste being discharged. The following equation takes into account the fuel consumption numbers developed in section 3.1.1 and gives the estimated discharge into the sea from ballast in fuel tanks procedure as:

Total tonnage (based on Fairplay Database 2000) x % non-tankers carrying out this procedure x the clingage factor (%) x quantity discharged based on 14% (non-compliance).

161,983,545.2 x 0.01 x 0.004 x 0.14 = **907 tonnes**.

Oily ballast (fuel tanks) into the marine environment = **907 tonnes/yr**.

3.1.4 Total operational discharges – ship-related: total amount of oil discharged from engine rooms (all ships)

81 The estimated total amount of oil entering the sea annually from the engine rooms and fuel tanks of all ships, based on the above, would be:

Fuel Oil Sludge:	186,120 tonnes
Bilge Oil:	1,880 tonnes
Oily Ballast from Fuel Tanks:	907 tonnes
Total:	**188,897 tonnes/yr.**
	or 189,000 tonnes/yr.

3.1.5 Air emissions - VOCs from tankers - "Volatile Organic Compounds"

82 Oil and certain volatile organic cargoes release VOCs during loading and unloading operations and transport, and the operation of the ships themselves results in the release of VOCs from the engines and funnels (Ostermark and Petersson 1993; Christensen 1994; APARG 1995; Anon. 1998 d). VOCs go into the atmosphere and a fraction returns to the sea surface.

Table 5. Operational oil outflow estimates, in tonnes based on 86% compliance with MARPOL legal limits

Ship Type	Total Oil Consumed for Vessel Type	Sludge Generation	Legal Discharge 15 ppm	86% compliance
Bulk Carriers	43,901,183	351,210	5.27	49,175
Combination Carriers	1,878,610	15,029	0.23	2,104
Container Vessels	29,184,295	233,474	3.50	32,690
Dry Cargo Vessels	15,009,051	120,073	1.80	16,812
Miscellaneous	14,263,099	114,105	1.71	15,976
Offshore Vessels	11,864,184	94,913	1.42	13,289
Ferries/Passenger Vessels	22,935,349	183,483	2.75	25,690
Reefer Vessels	7,647,164	61,177	0.92	8,566
RoRo Vessels	15,300,591	122,405	1.84	17,138
Tankers - All cats.	62,135,997	497,088	7.46	6,549
Total	224,119,523	1,792,956	26.89	187,990

83 The CRUCOGSA Research Programme (CRUCOGSA 1999; T.J. Gunner, pers. comm.) studied emissions of VOCs from loaded tankers through *in situ* studies. A total of 2,024 samples from 361 voyages were taken and an estimate of VOC emissions from transport of crude oil was made:

VOC emissions = Loss percent (Mass) per week per Vessel + 0.01 x TVP (psi) x (average density of HC Vapour/average density of crude oil)

Where HC - hydrocarbons
TVP - total vapour pressure in psi
VOCs - volatile organic compounds

84 The total VOC loss figure for transport of oil is given as 7.2 million tonnes VOCs per year (based on Fairplay statistics for 2000). Under section 3.2.3 of this study, it is noted that tankers are not always fully loaded; therefore, an average loaded figure for all tankers is given as 85%. Given this and taking into account the following variables:

The equation:

Loss percent (Mass) per week per vessel=0.01 *TVP (psi)*(average density of HC Vapour/average density of crude oil)

Variables for Calculation:
- Average Density of HC Vapour = 0.54 kg/litre
- Average Density of Crude Oil = 0.84 kg/litre
- Average TVP = 14 psi (98% loaded); 6 psi (85% loaded)
- Average size of Crude Oil Tanker = 163,335 dwt
- Average voyage length loaded = 1.56 weeks
- Average Number of Voyages per annum = 20
- Total number of Crude Oil Tankers (circa 2002) = 1574

The calculation is as follows, given 85% loaded:

Loss percent
= 0.01*6*(0.54/0.84) = 0.038% per week
= 0.038%*1.56 weeks = 0.06% per average voyage
= 0.06%*163,335 dwt = 98 tonnes per vessel per voyage
= 98*20 voyages/yr = 1960 tonnes per vessel/yr.
= 1960*1574 crude oil tankers = 3,085, 072 tonnes/yr.

Hence, the total discharge into the atmosphere of VOC from the carriage at sea of crude oil by tankers, assuming they are 85% loaded, is estimated at 3,085,075 tonnes/yr., or 3,085,000 tonnes/yr.

85 VOCs from loading must also be added to this number. Furthermore, a certain amount of VOCs would be produced during crude oil washing (COW). This, however, would only be displaced on loading and can be calculated alongside the loading number. For this estimate it was assumed that approximately 0.1% of the cargo would be emitted as VOCs. Given the total cargo transported numbers developed in section 3.2, the following is an estimation of VOCs emission during loading:

Total cargo loaded to Crude Oil Tankers
(3,712,961,000) x 0.001 = 3,712,961 tonnes

Combining this figure with the transportation figure, the total emission of VOC from tanker operations is:

VOCs from carriage + VOCs from loading = total VOC emission from tankers
or
3,085,075 tonnes + 3,712,961 tonnes = 6,798,036 tonnes (approx. 6,800,000 tonnes)

86 To establish the volume of this emission that enters the ocean, it is essential to establish which fractions within the VOCs would precipitate to the sea. Pentane contributes approximately 1% of VOCs, according to recent USA research. As this is the main component with a boiling point above 0 deg C (36 deg C), it represents the fraction of VOCs that could enter seawater. Based on the following calculation:

6.798 million tonnes x 0.01 = **67,980 tonnes/yr. or 68,000 tonnes/yr. VOCs**

Thus, a total of 68,000 tonnes of oil/yr. could enter the ocean from VOC emissions.

In contrast to this estimate, recent Norwegian studies based on measurements on several shuttle tankers have estimated the average density of HC vapours at 0.002 kg/l (K.O. Skjolsvik. pers. comm., July 2003). This is a 270-fold decrease from the value (0.54 kg/l) used in the above calculations. If that value is applied as above, the estimate of oil from VOC emissions from both carriage and loading losses that could enter the marine environment becomes:

[11,426 tonnes (from carriage) + 13,752 tonnes (from loading)] x 0.01= 252 tonnes/yr. or ~ **250 tonnes/yr**.

The difference in the two estimates shows the large uncertainty around calculating an input figure for VOCs from tankers. In addition, losses of VOCs that occur in ports may not impact the sea but rather the land, depending upon wind directions and velocities. It has been assumed in this study that all losses of VOCs will enter the sea. Hence, given the uncertainty of the estimation approach and to be conservative, the initial figure of 68,000 tonnes/yr. is adopted for this study's estimates of total inputs. Clearly, estimation of this input source requires more consideration.

3.1.6 VOCs from onboard bunkering and engine operations

87 VOCs are also emitted from engine operations and from the bunkering of all ship types. Due to lower volatility of marine fuels, the situation is not

comparable to that described above for tankers. However, there is no data available to estimate losses and, therefore, no input figure estimated. More information about this source is required.

3.2 Operational discharges - cargo-related

3.2.1 Introduction

88 In the 1990 report (MEPC 1990), the statistics on oil movements by sea were used as a basis for the remaining estimates and assumptions. Furthermore, certain intra-area movements of oil at sea were estimated. On updating the figures for this report, the amount of oil moved and the tonnage type and voyage frequency data did not match up. In this case, the total amount of oil moved was seen as an underestimate, owing to the tonnage of the world fleet. Due to the lack of complete data for intra-area movements and owing to the potential for a specific oil cargo to be carried to its destination by a number of vessels, i.e. transhipped in different hulls, the total numbers of tankers were used as the basis of the estimates of oil transportation and subsequent, cargo-related, operational discharge.

89 By way of explanation for this deviation from the 1990 model, two examples are given below:

.1 A Very Large Crude Carrier (VLCC, e.g. 300,000 dwt) loads a full cargo in the Arabian Gulf for discharge at Ain Sukhna in the Red Sea (potentially an intra- area movement). The cargo is discharged at Ain Sukhna and is pumped up the Sumed Pipeline to Sidi Kerir for loading onto four 100,000 dwt (Aframax) tankers for final discharge in southern European ports for onward pipeline movement to the end refinery. Within this total movement of 300,000 tons of cargo, five ships have been used with a combined dwt capacity of 700,000 dwt but each ship is capable of creating an operational discharge.

.2 40,000 tons of heavy fuel oil is delivered to Rotterdam storage from Russia on a long haul Dirty Petroleum Product (DPP) vessel (42,000 dwt). In Rotterdam, the product is cut/blended with gas-oil and prepared for delivery by bunker vessels (6,000 dwt) to ocean going vessels as bunkers. Earlier figures may have only recorded the fuel oil movement from Russia to Rotterdam but the onward movement of a greater combined tonnage by eight smaller bunker vessels (intra-area movement) is not recorded. This further movement of the blended material (Gas-oil), which was locally produced by a refinery, will have an additional operational discharge potential (which is estimated) associated with the eight bunker vessels.

90 Although having supplied two possible examples to account for the different estimates, creating an apparent increase in the total tonnage moved by sea, greater problems will occur in the United States with offshore lightering of VLCC's in the United States Gulf, Stapleton (New York) and the Bigstone anchorage (Delaware). The newly-generated numbers will also take into account, to a greater extent, further examples such as the crude oil movements between Valdez and the West Coast of the United States, and the subsequent lightering and onward movements through Panama to the East Coast.

3.2.2 Tanker construction and legislation

91 This section provides an overview of the general features of tanker construction and capability to mitigate operational discharges of oil. As stated in the 1990 report (MEPC 1990), oil tankers during normal operations discharge a certain amount of oil contained in the ballast and tank-washing water into the sea. The values of oily discharges were based on tankers having met MARPOL 73/78 construction, equipment and discharge requirements.

92 Under Regulation 13 of MARPOL 73/78, tankers over 20,000 tons deadweight that carry persistent oils are required to have segregated ballast tanks (SBT) and/or a crude oil washing system (COW), depending upon when they were built and their size. Segregated ballast tanks are tanks that are completely separated from the oil cargo and fuel systems and are permanently allocated to the sole carriage of water ballast. Dedicated clean ballast tanks are certain cargo tanks that are cleaned and then dedicated to the carriage of water ballast. It must also be noted that, although stated as an alternative under Regulation 13, dedicated clean ballast tanks (CBTs) on crude oil tankers are an obsolete provision being replaced by SBT requirements. However, CBT arrangements may still be found on certain product tankers such that, like SBT, the tank, pump and piping systems for CBT will be isolated from the cargo oil and piping system for the specific voyage when the CBT arrangement is in use.

93 A crude oil washing (COW) system is a cargo tank cleaning system that uses crude oil as the washing medium. Crude oil, under high pressure, is pumped through fixed but potentially programmable washing machines positioned in a tank so that oil impingement on the tank bulkheads and internal structures cleans off oil residues and sludge remaining in the tank after cargo discharge. The measures are specifically aimed at reducing operational pollution from tankers due to subsequent ballasting and tank washing. Crude oil washing (COW) of SBT/DH (segregated ballast tank/double hulled) tankers is limited by the lack of necessity to wash cargo tanks for the receipt of departure ballast. COW can be limited to 25% of the tanks for sludge control only.

94 For a COW system's efficiency to be certified under MARPOL, the extent of the total volume of oil found floating on top of the total volume of departure ballast after a COW operation within the cargo tanks can not exceed 0.00085 of the total volume of each tank containing the ballast water that has been in

contact with oil cargo residues. In practice, this very small volume of oil will never be discharged overboard as it will adhere to the tanker structures during a ballast decant and will be stripped to the vessel's slop tank for further treatment and decanting.

95 Regulation 15 of MARPOL 73/78 requires that all tankers have slop tanks (3% of their carrying capacity) in order to undertake load-on-top (LOT) procedures for recovered oil residues, and an oil discharge monitoring and control system (ODME) to monitor the amount of oily water from the cargo system that may be discharged to the sea. Regulation 9 of MARPOL 73/78 limits the quantity that may be discharged at 1/30,000 of the total carrying capacity for new tankers, and to 1/15,000 for existing tankers. In addition, this regulation also limits the engine room oily water discharge concentration to 15 ppm, which is monitored by the Engine Room 15 ppm alarm system. Regulation 9 ensures the limitation of oily water discharges to within permissible limits. Excess oil residues from the cargo are stored in the vessel's slop tanks, where the next crude oil cargoes may then be loaded on top (LOT) of these remaining oily residues in slop tanks.

96 MEPC (1990) found a lack of adequate reception facilities worldwide to handle the necessary tanker capacity. This situation has not changed (circa 2001). However, approximately 64% of the tanker fleet now operates with segregated ballast tanks, which obviates the need to dispose of ballast. An amount of tank washing may still need to be disposed of, in compliance with MARPOL. This will continue to pose serious problems for tankers on short haul voyages and for vessels operating within designated "Special Areas" (such as the Black Sea or Mediterranean Sea, see IMO 1997a, 2002).

3.2.3 Tanker fleet size

97 Due to MARPOL 73/78, various pollution prevention requirements apply to varying sizes and types of vessels, hence the quantity of oil discharged annually from the various types of ships will differ. The data are, therefore, arranged within the following categories in order to take into account the various regulations and also the current standard size categories used in the tanker market:

.1 Less than 10,000 dwt
.2 10 - 20,000 dwt
.3 20 - 40,000 dwt
.4 40 - 70,000 dwt
.5 70 - 110,000 dwt, e.g. Aframax/Shuttle/lightering tanker
.6 110 – 175,000 dwt, e.g. Suezmax tanker
.7 Greater than 175,000 dwt, e.g. VLCC (Very Large Crude Carrier)

Data from the Fairplay Database (Fairplay Database 2000) were used to produce numbers for tanker type and tonnage distribution greater than 5,000 dwt, up to the year 2000, for delivery/delivered tonnage (Table 6).

Table 6.
Tanker types and tonnage distribution (circa 2000)

	Size Category	Number of Vessels	Tonnage (dwt)
1	Less than 10,000 dwt	285	2,029,347
2	10 - 20,000 dwt	344	5,300,048
3	20 - 40,000 dwt	683	21,540,848
4	40 - 70,000 dwt	609	31,630,838
5	70 - 110,000 dwt	618	57,069,211
6	110 - 175,000 dwt	366	54,465,230
7	Greater than 175,000 dwt	516	149,087,730
	Total	3,421	321,123,252

98 The average Annex I (MARPOL 73/78) tanker tonnage is 93,868 dwt, with the average crude oil tanker tonnage being 163,335 dwt. The vessel size categories and numbers from the Fairplay database, as shown, are carried forward and used together with further estimates in the section below, which focuses on further subdivision of the tanker types with the estimates on voyage frequencies.

3.2.4 Assumptions to the outflow model

99 In order to comply with MARPOL 73/78 requirements, 60% (25% for sludge control, combined with sufficient washing for departure ballast) of a vessel's cargo tanks for pre-MARPOL tankers (single hull/non-SBT), and 25% for the MARPOL (SBT/DH) crude oil carriers may be crude oil washed (COWed). Some tanker terminals only require a minimum COW to be performed, i.e. 25% sludge control for SBT vessels.

100Industry sources provided a practical viewpoint to couple with the regulatory limits. The frequency that vessels washed their tanks with water was obtained. The estimates of oil inputs were derived, as shown below, and are believed to be a fair indication of industry practice.

3.2.4.1 Crude oil tankers

101 *MARPOL (double hull/separated ballast tank (SBT)) tankers:* These tankers do not, as a matter of course, have to wash their cargo tanks with water during the ballast voyage. However, an industry estimate is that they water wash 3 to 4 cargo tanks, twice a year, for in-tank inspection purposes. For this purpose, they use about 3,000 m^3 of water which is discharged with an oil content not more than 15 ppm. Thus, per annum, a tanker of this type discharges 6,000 m^3 of water containing 15 ppm of oil, or a discharge of 90 litres of oil for an oil-transported quantity of approximately 2,400,000,000 litres. Thus, approximately 100 litres oil is discharged; this oil outflow factor would be 1/24,000,000, or 0.04 $x10^{-6}$.

102 *Pre-MARPOL (hydrostatic balance loading (HBL)) tankers:* In an operator's study (Intertanko, unpubl.), an evaluation of the extent of

oil discharge for the ships of this type derived a value of 350 litres per voyage for a 300,000 m^3 cargo. As these vessels undertake 8 voyages per annum (see voyage frequency figures, Section 3.2.6), the total oil outflow is 2,800 litres or 2.8 m^3 against a total cargo carried of 2,400,000 m^3. Thus, the total outflow for one ship is approximately 3.0 m^3, a factor of 1/800,000, or 1.25 x 10^{-6}.

103 The average size of a crude oil tanker as calculated from the figures quoted in this model is 163,333 tonnes dwt. Assuming such a vessel discharges 30% of her deadweight as arrival ballast water with an oil content of 15 ppm (worst-case scenario), the tonnage of ballast water discharged would be 49,000 tonnes with an oil content of 735 litres. Thus, the oil outflow factor is 1/222,222, rounded to 1/223,000, or 4.5 x 10^{-6}; this takes into consideration a proportion of the ballast tonnage discharged as being segregated ballast which is not contained in designated crude oil cargo tanks as clean arrival ballast. Compared with the foregoing operator's study, this derived oil outflow factor supplies a worst-case scenario.

3.2.4.2 Product and chemical tankers

104 Although the prime categories for product tankers are shown falling into two types, namely Clean Petroleum Products (CPP) and Dirty Petroleum Products (DPP), the hull design affecting the operation of the vessel is taken into account within the final calculations to determine the extent of operational pollution from these types of vessels. The categories of SBT (not having ballast in cargo tanks) and the single hull product vessels, therefore, which need to practice Load on Top (LOT), have created a secondary division of category for the purposes of this study.

105 Clean Petroleum Product (CPP): A CPP vessel has between 16 and 20 cargo tanks with 2 slop tanks. It is estimated that the cargo tanks contain about 100 litres oil after discharge, giving a total cargo content remaining onboard of roughly 2 m^3. The cargo tanks are washed after discharge in readiness for the next cargo and the washings are returned to one of the slop tanks for primary settling. This type of cargo is light (density wise) and will readily separate from its associated wash water. The wash water is then decanted to the second slop tank for further separation and then discharged (from the bottom) over the side via the oil discharge monitor (ODME). On these ships, the inherent problems of the ODME operation are not as common as with DPP cargoes, as the optical systems do not get obstructed with black sludge, and, therefore, they tend to operate more efficiently. After decanting the majority of the wash water in the slop tanks, the balance of the oily water residue is discharged to lighters or slop facilities. This can be accepted, given that the loading of CPP will take place normally at a refinery where such slops can be easily treated alongside refinery water (wash water, etc.). This will result in a zero discharge by CPP tankers to the sea but in the most improbable and worst-case scenario - a maximum of 2 m^3 oil per voyage from 45,000 dwt, or a factor of 1/22,500 for non-conformity. This oil outflow factor lies between the two required factors and would allow compliance for older vessels. (Note: MARPOL 73/78 requirements, Regulation 9, also allow a maximum instantaneous outflow of 30 litres of oil content per nautical mile; thus, 2 m^3 can be discharged over a distance of 67 or approximately 70 nautical miles, outside of designated special areas).

106 Dirty Petroleum Product (DPP): Estimates of the amount of cargo remaining in the tanks after discharge have been around 300 litres per tank, with ships having between 16 and 20 tanks. Thus the maximum discharge would be 6 m^3 from a total cargo of about 42,000 m^3 - i.e. 1/7000 or 0.014% of cargo. This is in excess of the Regulation 9 limits of 1/15,000 ratio (the maximum allowed for these types of vessels together with their age). In the example used, the operator estimated an average of 450 m^3 slop tank size on these ships. If 450 m3 is, therefore, discharged with an oil content of 15 ppm (similar to the engine room outflow criteria for similar oils), then the quantity would be roughly 67.5 litres discharged with the wash water – rounded up to 100 litres of oil. Thus, 100 litres from a cargo of 42,000 m^3 would give a factor of 1/420,000. This has been rounded down to 1/400,000 or 2.5 x 10^{-6}, owing to the initial rounding up to 100 litres.

107 On the above basis, the following operational outflow factors were:

Operational Outflow Factors:

Crude Oil (Double Hull/SBT)	4x10^{-8}
Crude Oil (Pre MARPOL/HBL)	4.5x10^{-6}
Products (Double Hull/SBT (CPP & DPP))	Negligible
Products (Single Hull (CPP & DPP))	2.5x10^{-6}
Chemical	Treated as per Product tankers

108 The outflow factors were derived from estimates gained from a number of industry operators. The guiding factor in these estimates was the limit on the Oil Discharge Monitor (ODME) before it operates a shut down or valve closure. This limit is now 15 ppm (Regulations 9 and 16), except in MARPOL Special Areas where the limit is zero. It must be noted that 15 ppm oil in water is the maximum legal discharge limit and that a number of vessels will operate at levels well within this concentration. For this study, the worst-case scenario of 15 ppm is used.

3.2.5 Distinction between short haul and long haul voyages

109 Based on estimates from the industry (tanker operators and individual experts), the following distinctions were made for short haul and long haul voyages for the main three tanker types. The definitions of short haul and long haul voyages are consistent with MEPC (1990), i.e. a tanker on a short haul voyage is considered to be:

.1 on a voyage of less than 72 hours or 1,200 nautical miles;
.2 operating within a Special Area under Regulation 10 of MARPOL 73/78;
.3 operating under a specific trade exemption under regulation 13C of MARPOL 73/78; or
.4 carrying asphalt or other products which have physical properties that inhibit effective oil/water separation and monitoring.

110 Chemical/oil tankers have been corrected for the period of time when these vessels are carrying Annex 1 cargoes. Thus, factors of between 0.175 (17.5%) and 0.3 (30%) have been applied to the tonnage divisions for short haul and long haul voyages, respectively.

111 The distribution of tonnage for short haul and long haul voyages for the Product and Chemical/Oil tankers relies upon the following standard divisions:

Less than 10,000 dwt	100% Short Haul
10 - 20,000 dwt	50 / 50 Short/Long Haul
20 - 40,000 dwt	30 / 70 Short/Long Haul
40 –70,000 dwtq	10 / 90 Short/Long Haul
Greater than 70,000 dwt	100% Long Haul

112 The distribution of tonnage for long and short haul voyages for Crude Oil tankers relies upon the following standard divisions:

Less than 40,000 dwt	100% Short Haul
40 –70,000 dwt	50 / 50 Short/Long Haul
70 – 110,000 dwt	20 / 80 Short/Long Haul
110 – 175,000 dwt	15 / 85 Short/Long Haul
Above 175,000 dwt	100% Long Haul

113 For each tanker type category, data from the Fairplay Database (2000) (www.fairplay.co.uk/databases) were used to produce the tonnage figures in Tables 7 to 9.

Table 7.
Tonnage distributions, in tons dwt, of chemical/ oil tankers for long- and short-haul voyages, after correction for proportions used in Annex I cargoes

Ship size, dwt	Long Haul	Short Haul
LT 10,000	0	159,491
10 – 20,000	166,721	166,721
20 – 40,000	240,138	102,917
40 – 70,000	772,250	85,805
70 – 110,000	0	0
110 – 175,000	0	0
GT 175,000	0	0
Total	1,179,109	514,934

Table 8. Tonnage distributions, in tons dwt, of product tankers for long- and short-haul voyages

Ship size, dwt	Long Haul		Short Haul	
	DPP[1]	CPP[2]	DPP	CPP
LT 10,000	0	0	468,355	763,539
10 – 20,000	895,609	740,790	895,609	740,790
20 – 40,000	9,019,500	4,165,508	3,865,502	1,785,218
40 – 70,000	7,757,123	10,479,614	831,662	1,143,044
70 – 110,000	1,253,586	5,841,945	0	0
110 – 175,000	2,040,701	2,942,262	0	0
GT 175,000	880,336	0	0	0
Total	21,846,855	24,170,119	6,061,128	4,432,591

[1] DPP – dirty petroleum product [2] CPP – clean petroleum product

Table 9. Tonnage distributions, in tons dwt, of crude tankers for long- and short-haul voyages

Ship size, dwt	Long Haul		Short Haul	
	Double	Single	Double	Single
Lt 10,000	0	0	0	0
10-20,000	0	0	65,830	56,042
20-40,000	0	0	97,086	647,722
40-70,000	1,316,731	2,962,876	1,316,730	2,962,875
70-110,000	15,000,000	24,256,560	9,717,120	1,000,000
110-175,000	17,253,082	24,681,065	7,548,120	0
Gt 175,000	49,190,415	99,016,975	0	0
Total	82,760,228	150,917,476	18,744,886	4,666,639

(**Note:** Single - means that vessel is not registered as having a double form (hull, bottom or sides) of construction. This does not mean that the vessel is not operating with SBT. Double - means that the vessel is registered either with a double hull, double bottom or double sides. Thus, the vessel will probably have sufficient double hull capacity for ballast.)

3.2.6 *Voyage frequency*

114 Voyage factors for each size category of vessel were estimated using information taken from the shipping industry. These were estimated based on the size of the respective vessel categories and the description as supplied above for the definition of a short voyage. The following numbers of voyages per annum have been used in the matrix below and in Table 10:

Lt 10,000 dwt	40 voyages per annum
10-20,000 dwt	40 voyages per annum
20-40,000 dwt	32.5 voyages per annum
40-70,000 dwt	30 voyages per annum
70-110,000 dwt	30 voyages per annum – e.g. Aframax/Shuttle/lightering tanker
110-175,000 dwt	15 voyages per annum – e.g. Suezmax tanker
Gt 175,000 dwt	8 voyages per annum – e.g. VLCC

115 Values in Table 10 have been multiplied with the tonnage figures given earlier for the respective tanker types and sizes to give the matrix (Table 11) illustrating the total tonnage of oil (Annex 1 cargoes) shipped (100% dwt) by the world's tanker tonnage (million tonnes).

116 Further consideration was then given to the sub-categories as explained earlier, i.e. LOT, SBT and COW tankers. Table 12 subdivides the above matrix categories onto the defined subcategories. Table 12 shows the total oil shipped by the world's tanker fleet, assuming 100% dwt capacity is used.

117 Using data from the CRUCOGSA database and estimates from industry sources, it is assumed that

.1 70% of all tankers carry a full cargo – average 98% loaded;
.2 30% of all tankers are partially loaded, at 60% (this percentage includes an allowance for product part cargoes);
.3 the average correction applicable given .1 and .2 above is, therefore, 0.845 (84.5%).

118 Using the foregoing matrix of total oil cargo tonnage carried, the final oil outflow matrix (Table 14) was developed, using the outflow factors developed in Paragraph 3.2.4 above, assuming 100% compliance with MARPOL 73/78.

119 In developing the final figure of **5728 tonnes or ~5700 tonnes** of oily waste discharge from

Table 10. Matrix of voyage frequency (laden voyages per annum) for vessel type and size

Dwt Size	Crude Oil				Products				Chemical/Oil	
	Long Haul		Short Haul		Long Haul		Short Haul			
	Double	Single	Double	Single	DPP	CPP	DPP	CPP	Long Haul	Short Haul
Lt 10,000	40	40	40	40	40	40	40	40	40	40
10-20,000	40	40	40	40	40	40	40	40	40	40
20-40,000	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
40-70,000	30	30	30	30	30	30	30	30	30	30
70-110,000	30	30	30	30	30	30	30	30	30	30
110-175,000	15	15	15	15	15	15	15	15	15	15
Gt 175,000	8	8	8	8	8	8	8	8	8	8

Table 11. Total tonnage of oil (Annex 1 cargoes) shipped by the world's tanker fleet (100% dwt, in million tons)

Dwt Size	Crude Oil				Products				Chemical/Oil	
	Long Haul		Short Haul		Long Haul		Short Haul			
	Double	Single	Double	Single	DPP	CPP	DPP	CPP	Long Haul	Short Haul
Lt 10,000	0	0	0	0	0	0	18.734	30.542	0	6.380
10-20,000	0	0	2.633	2.242	35.824	29.632	35.824	29.632	6.669	6.669
20-40,000	0	0	3.155	21.051	293.134	135.379	125.629	58.020	7.804	3.345
40-70,000	39.502	88.886	39.502	88.886	232.714	314.388	24.950	34.291	23.167	2.574
70-110,000	450.000	727.697	291.514	30.000	37.608	175.258	0	0	0	0
110-175,000	258.796	370.216	113.222	0	30.611	44.134	0	0	0	0
Gt 175,000	393.523	792.136	0	0	7.043	0	0	0	0	0
Totals	1,141.81	1,978.95	450.026	142.179	636.934	698.791	205.137	152.485	37.640	18.968
Grand Total	3,712.961				1,749.955					

Table 12. Outflow matrix for calculations of oily waste discharge from tanker cargo operations assuming 100% loading

Dwt Size	Crude Oil				Products				Chemical/Oil	
	Long Haul		Short Haul		Long Haul		Short Haul		CPP - See (2)	
	Double	Single	Double	Single	DPP	CPP	DPP	CPP	Long Haul	Short Haul
	0	0	0	0	0	0	18.734	30.542	0	6.380
With SBT	0	0	0	0	0	0	2.955	10.780	0	2.730
With LOT	0	0	0	0	0	0	15.779	19.762	0	3.650
10– 20000	0	0	2.633	2.242	35.824	29.632	35.824	29.632	6.669	6.669
With SBT	0	0	2.633	1.975	12.330	26.840	12.330	26.840	4.720	4.720
With LOT	0	0	0	0.267	23.494	2.792	23.494	2.792	1.949	1.949
20- 40000	0	0	3.155	21.051	293.134	135.379	125.629	58.020	7.804	3.345
With SBT	0	0	3.155	14.780	45.980	43.940	19.705	18.830	4.945	2.120
With LOT	0	0	0	6.271	247.154	91.349	105.924	39.190	2.859	1.225
40-70000	39.502	88.886	39.502	88.886	232.714	314.388	24.950	34.291	23.167	2.574
With SBT	39.502	67.005	39.502	67.005	61.645	162.700	6.610	17.745	19.160	2.130
With COW/LOT	0	21.881	0	21.881	171.069	151.688	18.340	16.546	4.007	0.444
70-110000	450.000	727.697	291.514	30.000	37.608	175.258	0	0	0	0
With SBT	450.000	424.180	291.514	17.490	4.795	130.470	0	0	0	0
With COW	0	303.517	0	12.510	32.813	44.788	0	0	0	0
110-175000	258.796	370.216	113.222	0	30.611	44.134	0	0	0	0
With SBT	258.796	182.000	113.222	0	0	41.415	0	0	0	0
With COW	0	188.216	0	0	30.611	2.719	0	0	0	0
	393.523	792.136	0	0	7.043	0	0	0	0	0
With SBT	393.523	427.815	0	0	0	0	0	0	0	0
With COW	0	364.321	0	0	7.043	0	0	0	0	0
Totals	1,141.821	1,978.935	450.026	142.179	636.933	698.791	205.137	152.484	37.641	18.967
Grand Total	SBT = 3,480.532				LOT/COW = 1,982.382					

(**Note:** All Crude Oil tankers built before 1975 have been retrofitted for SBT. All Crude/Oil tankers built between 1975 and 1980 are still operating with COW. All Crude Oil tankers with a Double Bottom, Double side or Double Hull have sufficient ballast space to be classified as SBT. All Chemical/Oil Tankers are operating with CPP only.)

Table 13. Outflow matrix for calculations of oily waste discharge from tanker cargo operations assuming 100% loading

Dwt Size	Crude Oil				Products				Chemical/Oil	
	Double	Single	Double	Single	DPP	CPP	DPP	CPP	Long Haul	Short Haul
	0	0	0	0	0	0	15.830	25.808	0	5.391
With SBT	0	0	0	0	0	0	2.497	9.109	0	2.307
With LOT	0	0	0	0	0	0	13.333	16.699	0	3.084
10– 20000	0	0	2.225	1.894	30.272	25.039	30.272	25.039	5.635	5.635
With SBT	0	0	2.225	1.669	10.419	22.680	10.419	22.680	3.988	3.988
With LOT	0	0	0	0.225	19.853	2.359	19.853	2.359	1.647	1.647
20-40000	0	0	2.666	17.788	247.698	114.395	106.156	49.027	6.595	2.826
With SBT	0	0	2.666	12.489	38.853	37.129	16.651	15.911	4.179	1.791
With LOT	0	0	0	5.299	208.845	77.266	89.506	33.115	2.416	1.035
40-70000	33.379	75.109	33.379	75.109	196.643	265.658	21.083	28.976	19.577	2.175
With SBT	33.379	56.619	33.379	56.619	52.090	137.482	5.585	14.995	16.190	1.800
With COW/LOT	0	18.490	0	18.490	144.553	128.177	15.497	13.982	3.386	0.375
70-110000	380.250	614.904	246.329	25.350	31.778	148.093	0	0	0	0
With SBT	380.250	358.432	246.329	14.779	4.052	110.247	0	0	0	0
With COW	0	256.466	0	10.571	27.726	37.846	0	0	0	0
110-175000	218.683	312.832	95.672	0	25.866	37.293	0	0	0	0
With SBT	218.683	153.790	95.672	0	0	34.996	0	0	0	0
With COW	0	159.042	0	0	25.866	2.297	0	0	0	0
	332.527	669.355	0	0	5.951	0	0	0	0	0
With SBT	332.527	361.504	0	0	0	0	0	0	0	0
With COW	0	307.850	0	0	5.953	0	0	0	0	0
Totals	964.839	1,672.200	380.272	120.141	538.208	590.479	173.341	128.849	31.806	16.027
Grand Total	SBT = 2,941/05				LOT/COW = 1,675,113					

tanker cargo operations, the following assumptions were used in the final oil outflow matrix (Table 14):

.1 All Annex 1 tankers comply with MARPOL Regulations – 94% of States are Parties to MARPOL 73/78 – All Charterers require compliance as a specific term in every Charter Party.

.2 Operational Outflow Factors (as explained in section 3.2.4.2):

Crude Oil (Double Hull/SBT) 4 x 10-8
Crude Oil (Pre MARPOL/HBL) 4.5 x 10-6
Products (Double Hull/SBT
(CPP & DPP)) ZERO
Products (Single Hull
(CPP & DPP)) 2.5x10-6
Chemical Treated as per product tankers

120 In section 3.1, it was stated that, based on IMO figures for PSC (IMO, FSI 9/8, 2001) detentions, an average of 86% compliance was used. In order to estimate the actual outflow, this compliance figure was used, coupled with an estimate of 1/50,000 discharge as a non-compliant, outflow factor.

3.2.7 Summary of operational discharges – cargo-related

121 Based on the above calculations, the estimated discharge of oil into the marine environment from cargo-related, tanker activities, which includes tank washing and oil in ballast, is **19, 250 tonnes/yr, or ~19,000 tonnes/yr.**

Table 14. The final oil outflow matrix for calculations of oil discharge from tanker cargo operations, in tonnes

Dwt Size	Crude Oil				Products				Chemical/Oil	
	Long Haul		Short Haul		Long Haul		Short Haul			
	Double	Single	Double	Single	DPP	CPP	DPP	CPP	Long Haul	Short Haul
	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With LOT	0	0	0	0	0	0	33.334	41.746	0	7.710
10– 20000	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With LOT	0	0	0	1.011	49.632	5.897	49.632	5.897	4.117	4.117
20- 40000	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With LOT	0	0	0	23.762	522.112	193.165	223.764	82.788	6.041	2.587
40-70000	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With COW/LOT	0	82.913	0	82.913	361.383	320.442	38.743	34.954	8.466	0.938
70-110000	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With COW	0	1,150.097	0	47.403	69.317	94.615	0	0	0	0
110-175000	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With COW	0	713.195	0	0	64.665	5.744	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
With SBT	0	0	0	0	0	0	0	0	0	0
With COW	0	1,380.498	0	0	14.878	0	0	0	0	0
Totals	0	3,326.704	0	155.089	1,081.986	619.863	345.472	165.386	18.623	15.352
Grand Total	SBT = 0				LOT/COW = 5,728.476 tonnes					

Table 15. Summary matrix of operational discharges – cargo-related (values in tonnes/yr.)

	Crude Oil				Products					Chemical /Oil	Totals
		LH		SH		LH		SH			
Dwt	DH	SgH	DH	SgH	DPP	CPP	DPP	CPP	LH	SH	
Totals	964.839	1,672,200	380.272	120.141	538.208	590.479	173.341	128.849	31.806	16.027	461,616.268
86% Com	829.762	1,438.092	327.034	103.321	462.859	507.812	149.073	110.810	27.354	13.784	39,698.999
Non Com	135.077	234.108	53.238	16.820	75.349	82.667	24.268	18.039	4.453	2.244	646,262.775
Out Flow	0.000	11,131.003	0.000	799.720	2,664.130	2,922.869	858.038	637.803	157.442	79.336	19,250.340

3.3 Accidental discharges of oil

122 This section first considers accidental inputs from all sea-based activity sources and then focuses exclusively on ships (tankers, other vessels or non-tankers).

3.3.1 Accidental spillage from all sea-based activity sources[15]

123 The recorded annual numbers of accidental oil spills into the marine environment of at least 34 tonnes that occurred during 1968-1999 from all point sources, including vessels, pipelines, offshore exploration and production activities, shoreline facilities, and unknown sources, are shown in Table 16. The annual amounts spilled are shown in Table 17. Total numbers of spills and amounts spilled annually are shown graphically in Figure 7. War-related incidents are separated out from accidental spills in Figure 8. The relatively enormous amount of oil spillage associated with the 1991 Gulf War is also illustrated here.

124 After rising in the first decade between 1968 and 1977, spill numbers have dropped and levelled off in the following 15 years. Part of the apparent initial increase in spillage may in part be due to reduced spill reporting during the earlier time period. In the same three decades, the amount spilled

Table 16. Annual number of accidental, sea-based oil spills of 34 tonnes and over (based on ERC database)

Year	Tankers	Tankers Military	Barges	Non-Tankers	Pipelines	Pipelines Military	E&P	E&P Military	Facilities	Facilities Military	Unknown/ Other	TOTAL
1968	15	0	0	0	0		0		0		0	15
1969	13	0	0	0	0		0		0		0	13
1970	17	0	1	1	1		0		0		0	20
1971	10	0	0	1	0		1		0		0	12
1972	19	0	0	1	0		0		0		0	20
1973	21	0	0	3	1		1		2		1	29
1974	46	0	0	0	0		1		2		0	49
1975	38	0	3	3	0		0		0		0	44
1976	37	0	4	2	0		0		0		0	43
1977	37	0	0	1	0		1		4		0	43
1978	44	0	6	8	1		2		13		0	74
1979	66	0	3	16	1		7		16		2	111
1980	38	0	1	15	0		7		4		3	68
1981	30	0	2	20	0		0		9		1	62
1982	28	1	3	21	7		4		4		0	68
1983	31	0	2	25	2		10		5		0	75
1984	22	2	4	15	1		2		3		0	49
1985	30	3	5	5	2		3		2		0	50
1986	22	29	4	8	4		6		18		1	92
1987	23	24	0	16	3		6		5		0	77
1988	18	1	0	11	2		6		11		1	50
1989	42	1	2	13	0		3		7		0	68
1990	26	1	4	14	0		4		4		3	56
1991	18	8	1	16	4	1	2	1	5	10	1	67
1992	19		3	18	0		1		2		4	47
1993	27		3	15	2		1		3		1	52
1994	27		1	21	1		0		3		4	57
1995	21		0	22	3		1		0		4	51
1996	18		1	20	0		0		3		0	42
1997	22		4	19	4		4		1		2	56
1998	17		3	23	14		3		7		2	69
1999	11		4	10	5		0		7		2	39
Total	853	70	64	363	58	1	76	1	140	10	32	1,668

(**Note:** Blanks denote no data; 0's denote no spillages.)

[15] This section does not include leisure craft, which are treated in a separate section and for which only very approximate estimates are derived.

Table 17. Annual oil spillage, in tonnes, from spills of 34 tonnes and over (based on ERC database)

Year	Tankers	Tankers Military	Barges	Non-Tankers	Pipelines	Pipelines Military	E&P	E&P Military	Facilities	Facilities Military	Unknown/ Other	TOTAL
1968	156,497		0	0	0		0		0		0	156,497
1969	142,272		0	0	0		0		0		0	142,272
1970	219,675		1,129	85	14,286		0		0		0	235,175
1971	203,786		0	520	0		14,286		0		0	218,592
1972	253,417		0	88	0		0		0		0	253,505
1973	86,901		0	255	952		0		0		0	88,108
1974	208,888		0	0	0		150		40,008		34	249,080
1975	263,134		3,119	2,000	0		0		0		0	268,253
1976	331,895		4,187	218	0		0		0		0	336,300
1977	281,211		350	0	0		28,912		315		0	310,788
1978	484,248		0	1,969	34		3,432		79,915		0	569,598
1979	697,959		11,551	2,863	116		477,807		25,437		68	1,215,801
1980	261,213		143	2,732	4,401		44,184		11,259		5,643	329,575
1981	63,142		252	6,704	0		0		106,847		588	177,533
1982	47,523	340	1,047	7,810	6,983		3,007		1,779		0	68,489
1983	437,139		224	4,218	265		280,599		12,097		0	734,542
1984	27,017	8,507	721	8,507	357		1,180		752		0	47,041
1985	101,069	13,606	2,306	2,310	1,622		578		85		0	121,576
1986	28,118	19,388	898	4,024	3,099		38,092		46,133		170	139,922
1987	33,334	23,980	0	3,136	629		8,969		578		0	70,626
1988	207,114	680	0	1,729	310		2,054		2,918		34	214,839
1989	153,431	1,429	2,932	2,939	0		180		619		0	161,530
1990	51,311	255	432	4,757	51		626		1,348		374	59,154
1991	218,440	608,565	2,000	4,315	1,374	83,897	136	14,286	2,160	9,814,020	88	10,749,281
1992	146,683		867	2,454	10,085		827		204		306	161,426
1993	139,153		1,518	3,269	8,262		61		2,493		34	154,790
1994	125,884		129	6,220	157		0		3,848		165	136,403
1995	16,218		0	4,358	384		500		0		187	21,647
1996	81,172		323	7,358	0		0		4,973		0	93,826
1997	74,675		7,262	3,344	1,980		885		34		163	88,343
1998	13,405		13,344	3,839	13,853		440		1,536		782	47,199
1999	22,783		180	2,976	3,902		0		7,083		234	37,158
Total	5,578,707	676,750	54,914	94,997	73,102	83,897	906,905	14,286	352,421	9,814,020	8,870	17,658,869

Figure 7.
Total Non-Military-Related Oil Spills From All Sources (Spills of at Least 34 Tonnes) (Based on Environmental Research Consulting Database)

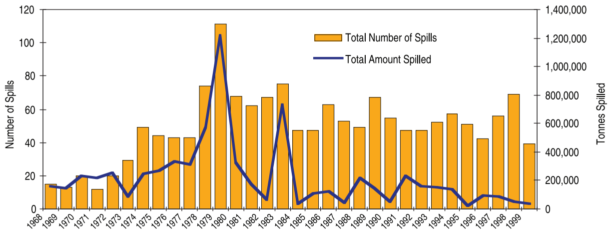
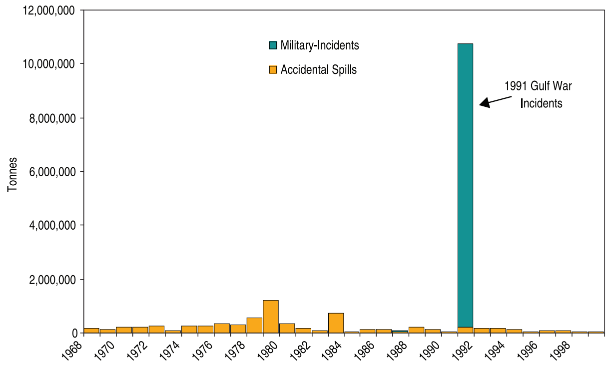


Figure 8.
Total Oil Spillage From All Sources (Spills of 34 Tonnes and Over) (Based on Environmental Research Consulting Database)



dropped, although there were unusually high peaks in 1979 (associated with the *Ixtoc I* well blowout, and three very large tanker spills), and in 1983 (with the *Nowruz* well blowout and the *Castillo de Bellver* tanker spill, the largest tanker spill to date).

125 Table 18 and Figure 9 give estimates of source-specific annual spill inputs for the ten-year periods 1968-1977, 1978-1987, and 1988-1997. These estimates are based on the small spill, factor estimation methodology. Vessels consistently constitute the largest source of accidental spillage over all time periods, except for the large Gulf War-related incidents of 1991. However, the largest exploration and production spills of 1979 and 1983 significantly increased the percentage contribution of these source types with a corresponding reduction in the vessel spill amount percentages for these years and the time periods incorporating these years. Figures 11 to 13 show the relative percentages of accidental oil spillage by source type for the three ten-year time periods.

126 The estimates of oil input into the marine environment from accidental releases from all sources during the years 1988-1997, based solely on ten-year averages, are:

Tankers: 157,900 tonnes/yr.
Non-Tankers: 5,300 tonnes/yr.
Facilities: 2,400 tonnes/yr.
Pipelines: 2,800 tonnes/yr.
Exploration and Production: 600 tonnes/yr.
Other and Unknown Sources: 200 tonnes/yr.
War-related activities: 1,052,200 tonnes/yr.

Total accidental spill input: 169,200 tonnes/yr. or 169,000 tonnes/yr
(without war-related spillage; note, Figs 10-13 do not include this source)

Total accidental input (including war-related spillage): 1,221,500 tonnes/yr. or 1,220,000 tonnes/yr.

Table 18. Estimated average annual oil input from ships and other sea-based activities, in tonnes, for three, ten-year time periods (based on ERC database)

Source	Time Period		
	1968-1977	1978-1987	1988-1997
Tankers	281,155	286,558	157,895
Tankers (Military Incidents)	No data	6,650	61,025
NonTankers	413	5,772	5,312
Pipelines	1,845	2,120	2,736
Pipelines (Military Incidents)	No data	No data	8,390
E&P	5,248	103,856	638
E&P (Military Incidents)	No data	No data	1,429
Facilities	52,572	37,142	2,425
Facilities (Military Incidents)	No data	No data	981,402
Unknown	No data	647	135
Total Average Non-Military Input	341,233 or 341,000	436,095 or 436,000	171,551 or 172,000
Total Average Military Input	No data	6,650	1,052,246
Total Input (incl. Military Incidents)	341,233 or 341,000	442,745 or 443,000	1,223,797 or 1,220,000

(**Note:** Estimates were based on use estimation factors for small spills.)

Figure 9.
Estimated Annual Oil Spill Input For Ten-Year Periods By Source Type Excluding Military Incidents (Based on Environmental Research Consulting Database)

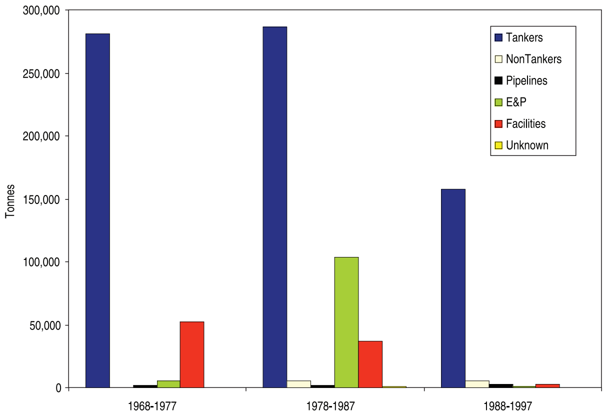
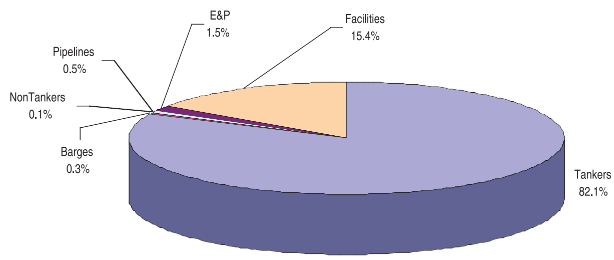


Figure 10.
Total Oil Input into Marine Environment By Source Type 1968-1977 (Based on Environmental Research Consulting Database)



127 The estimates for average annual oil input for the last decade are based on data of actual spills recorded, with an adjustment for the absence of data on spills under 34 tonnes, which were not recorded in the database used. The small spill estimation factors have been used to increase the accuracy of the data, taking into account the lack of data on small spills of under 34 tonnes. Hence, there may be unavoidable gaps in records on spills of over 34 tonnes; this might create underestimates in accidental spillage figures even after the small spill estimation factors are applied both to spill number and spill amount. The estimates for average annual oil input should, therefore, be viewed in this context as underestimates.

128 The same methodology was used to estimate accidental and war-related spill input from the previous two ten-year time periods, 1968-1977 and 1978-1987. The estimates are shown in Table 19.

129 When the input estimates from the different source types are further broken down into spills of less than and more than 5,000 tonnes, the influence of the very large spills on overall amounts is very clear. Figure 13 shows estimated average annual inputs by source types for 1988-1997 with respect to spill size. Table 20 gives annual input estimates, from small and large spills, by source types and spill size for the three time periods. There were 35 tanker/barge spills of greater than 5,000 tonnes and two spills of this magnitude from marine pipelines during 1988-1997. There were no other spills greater than 5,000 tonnes in any other source category during this time period.

130 The estimates for average annual oil input into the marine environment, from accidental releases from all point source types of ships and shipping activity, for the period of 1988-1997, are:

Tankers:
16,300 tonnes/yr. in <5,000-tonne spills
plus an average of 144,000 tonnes/yr. in spills >5,000 tonnes
with an overall average input of 160,300 tonnes/yr.

Non-tankers:
5,300 tonnes/yr. in spills of >5,000 tonnes

Facilities: 2,400 tonnes/yr. in spills of <5,000 tonnes

Pipelines:
900 tonnes/yr. in <5,000-tonne spills
plus an average of 1,900 tonnes/yr. in spills >5,000 tonnes
with an overall average input of 2,800 tonnes/yr.

Exploration and production: 600 tonnes/yr. in spills of <5,000 tonnes

Other/unknown sources: 200 tonnes/yr. in spills of <5,000 tonnes

Total accidental release input:
20,400 tonnes/yr. in spills < 5,000 tonnes
plus **151,200** tonnes/yr. in tankers, non-tankers and pipeline spills of > 5,000 tonnes for an overall average spill input from all sources of **171,600** tonnes/yr.

War-related incident input: **1,052,300** tonnes/yr. in spills of all sizes.

3.3.2 Accidental discharges from ships

3.3.2.1 Accidental discharges from tankers

131 The estimated annual number of oil spills over 0.003 tonnes (1 US Gal.) and the estimated amount of oil spilled annually by tankers (including barges and all types of tank vessels carrying oil as cargo) are shown in Figure 14. The number of spills

Figure 11.
Total Estimated Oil Spill Input By Source Type 1978-1988 (Based on Environmental Research Consulting Database)

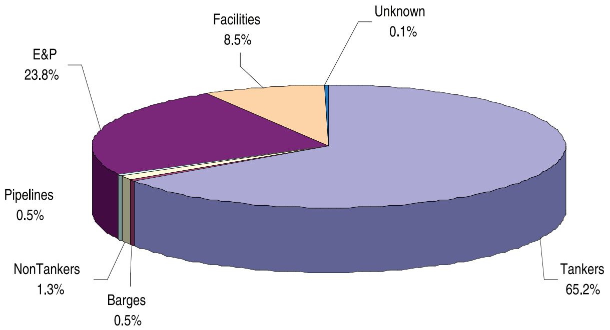


Figure 12.
Estimated Total Oil Spillage By Source Type 1988-1997 (Based on Environmental Research Consulting Database)

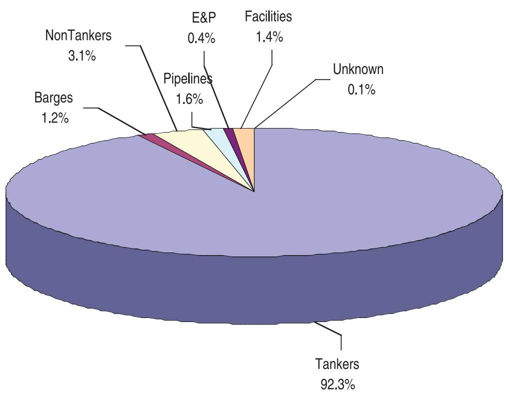


Table 19. Estimated average annual oil input, in tonnes, for three, ten-year time periods – a summary (based on ERC database)

Source	Time Period		
	1968-1977	1978-1987	1988-1997
Tankers	281,200	286,600	160,300
Non-Tankers	400	5,800	5,300
Pipelines	1,800	2,100	2,800
E&P	5,200	103,900	600
Facilities	52,600	37,100	2,400
Unknown	No data	600	200
Total Average Non-Military Input	341,200	436,100	171,600
Total Average Military Input	No data	6,600	1,052,300 or 1,052,000
Total Input (incl. Military Incidents)	341,200 or 341,000	442,700 or 443,000	1,223,900 or 1,224,000

(**Note:** Estimates are based on use of estimation factors for small spills.)

Table 20. Estimated annual average input, in tonnes, from smaller and large spills by source type (based on ERC database)

Source	1968-1977	1978-1987	1988-1997
Tankers/Barges (>5,000-tonne spills)	260,300	258,000	144,000
Tankers/Barges (<5,000-tonne spills)	18,600	38,000	16,300
Non-Tankers (>5,000-tonne spills)	0	0	0
Non-Tankers (<5,000-tonne spills)	500	600	5,300
Facilities (>5,000-tonne spills)	4,600	30,300	0
Facilities (<5,000-tonne spills)	100	2,700	2,400
Pipelines (>5,000-tonne spills)	1,700	700	1,900
Pipelines (<5,000-tonne spills)	100	1,300	900
E&P (>5,000-tonne spills)	5,600	96,900	0
E&P (<5,000-tonne spills)	17	2,600	600
Unknown (>5,000-tonne spills)	0	0	0
Unknown (<5,000-tonne spills)	4	900	200
Total	291,400	432,200	171,600

(**Note:** Estimates are based on small spill estimation factors and rounding.)

Figure 13.
Average Annual Oil Spill Input by Source Type 1988-1997 (Based on Environmental Research Consulting Database)

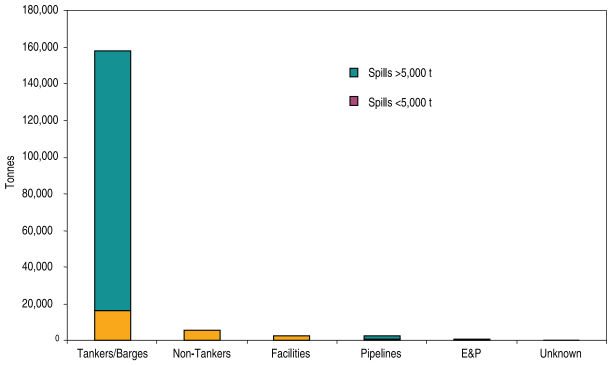
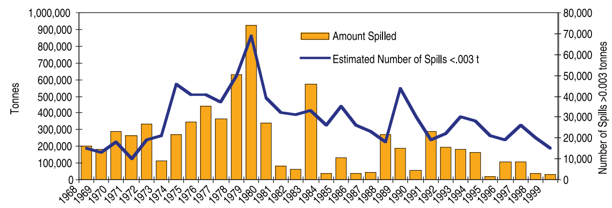


Figure 14.
Estimated Annual Oil Spills From Tankers 1968-1999 – Amounts Spilled and Estimated Number of Spills (Based on Environmental Research Consulting Database)



and amount spilled both increased during the 1960s, reaching a peak in 1979, subsequently decreasing before levelling off in the mid-1980s. Since the mid-1990s, there has been an additional drop in spill numbers. The estimates do not include tanker spills related to acts of war. The estimates also exclude recent, important large spills 1999-2002 (e.g. *Erika*, off France; *Prestige*, off Spain). There has also been better reporting since the 1970s, increasing confidence in any trend analysis as time proceeds.

132 The amount of oil released into the marine environment from tanker spills varies considerably from one year to the next and it is highly dependent on the number of very large spills that occur, as explained in Section 2.3.5. A list of the non-war-related tanker spill incidents, each involving at least 50,000 tonnes, is shown in Table 21. Figure 15 shows the influence of these large spills on overall tanker oil spillage for the years 1968-1999.

133 The estimates for average annual oil input into the sea from accidental spills from all tankers, based on 1988-1997 data, are:

Tankers:
16,300 tonnes/yr. in <5,000-tonne spills
plus an average of 144,000 tonnes/yr. in spills >5,000 tonnes
with an overall average input of **160,300 tonnes/yr. or ~160,000 tonnes/yr**.

3.3.2.2. Accidental discharges from non-tankers

134 The estimated annual number of oil spills over 0.003 tonnes (1 US gal.) and the estimated amount of oil spilled annually by non-tankers (all other vessels carrying oil as fuel, but not cargo, including, but not limited to cargo vessels, bulk carriers, passenger vessels, and fishing vessels) are shown in Figure 16. The number of spills as well as the amount spilled rose dramatically in the late 1970s. This apparent increase of spillages from these vessels is most likely due to the increased reporting and recording of data on these incidents.

135 The variability of spill amounts from non-tankers from year to year is similar to that of tankers. However, the overall amounts of oil spilled are about

Table 21. Worldwide Tanker Spills since 1960, Over 50,000 Tonnes[1]. Recent, well-publicized, European spills such as Erika *(1999) and* Prestige *(2002) are not shown, nor is the well-known Exxon Valdez spill which was only 37-38,000 tonnes.*

YEAR	TANKER NAME	LOCATION	TONNES SPILLED (as reported)
1983	*Castillo de Bellver*	South Africa	267,007
1978	*Amoco Cadiz*	France	233,565
1988	*Odyssey*	North Atlantic Canada	146,599
1979	*Atlantic Empress*[2]	Trinidad and Tobago	145,252
1991	*Haven*	Italy	144,000
1979	*Atlantic Empress*[2]	Barbados	141,102
1967	*Torrey Canyon*	United Kingdom	129,857
1972	*Sea Star*	Oman	128,891
1980	*Irenes Serenade*	Greece	124,490
1971	*Texaco Denmark*	Belgium	107,143
1979	*Independentza*	Turkey	98,255
1969	*Julius Schindler*	Portugal	96,429
1976	*Urquiola*	Spain	95,714
1993	*Braer*	United Kingdom	85,034
1975	*Jakob Maersk*	Portugal	82,503
1992	*Aegean Sea*	Spain	74,490
1985	*Nova*	Iran	72,626
1996	*Sea Empress*	United Kingdom	72,361
1989	*Khark 5*	Morocco	70,068
1971	*Wafra*	South Africa	68,571
1960	*Sinclair Petrolore*	Brazil	60,000
1983	*Assimi*	Oman	53,741
1974	*Yuyo Maru No. 10*	Japan	53,571
1991	*ABT Summer*	Angola	51,020
1992	*Katina P.*	South Africa	51,020
1965	*Heimvard*	Japan	50,000

[1] Not including military-related tanker incidents.
[2] The Atlantic Empress was involved in a collision which resulted in a spill in Trinidad and Tobago and then broke up while under tow resulting in another spill nearly two weeks later nearly 1,000 km from the location of the first spill. Some records report these two incidents as one spill involving 286,354 tonnes, making it the largest recorded tanker spill. The incidents are reported separately here due to the time period between the two incidents and the fact that the two spills occurred in different locations creating oil inputs and environmental impacts in different locations. For records maintained on the histories of individual vessels, these incidents may more logically be considered as a single incident.

two orders of magnitude smaller from non-tankers since they carry much less oil (fuel rather than cargo). Reduced reporting of non-tanker incidents and incomplete records may also be involved to some extent since non-tankers have been subject to less regulation than tankers.

136 The estimated of average annual oil input from non-tankers is **5,300 tonnes/yr**. Since all spills were less than 5,000 tonnes, no separation for amounts spilled from larger incidents has been conducted.

3.3.3 Accidental spillage in relation to sea-borne oil trade

137 In an analysis based largely on Etkin (1999d), the accidental tanker oil spill data in the IOSD (with modifications based on ERC data) were specified with regard to changes in oil transport over the years 1968-1997. The data were adjusted with small spill estimation factors using methods described in Section 2.3.5 and by Etkin (pers. comm.). Estimation factors derived from a smaller set of United States Coast Guard spill data were used to adjust for spills of 0.17 to 34 tonnes. This analysis was performed to shed more light on the significance of apparent overall reductions in spillage despite the fact that, concurrently, there has been more oil transport in recent years. Presumably, more oil transport activity would lead to more opportunities for accidental spills from tankers.

138 Figure 17 shows oil movement by tankers since 1974, according to data from British Petroleum (BP), 1997. Petroleum tanker transport on a worldwide basis dipped in the 1980s and rose again in the 1990s. Inter-area tanker movements for 1997 are also shown in Table 22 and in the map in Figure 18. Tanker movement is much dependent upon world events; for example, the oil embargo during the 1990s and the 2003 war in Iraq greatly reduced tanker movement from that country through the Persian Gulf and beyond (also see section 3.2.1). It should also be noted that BP's estimate of crude oil transported in the different areas in 1997 (Table 22, totalling ~1,980 million tonnes) is lower than the Lloyd's Register, Fairplay Database estimate of oil transported in 2000 (Table 11, ~3,713 million tonnes), the latter used to make estimates of operational discharges from tankers; this points out another difficulty of making global estimates of inputs from all sources, as the data sets available for or calculated for each input source may not be directly comparable unless they are based on the same raw data for the same period of time.

Figure 15.
Estimated Annual Oil Spills From Tankers 1968-1999 – Amounts spilled with >50,000 Tonne-Tanker Spills Identified (Based on Environmental Research Consulting Database)

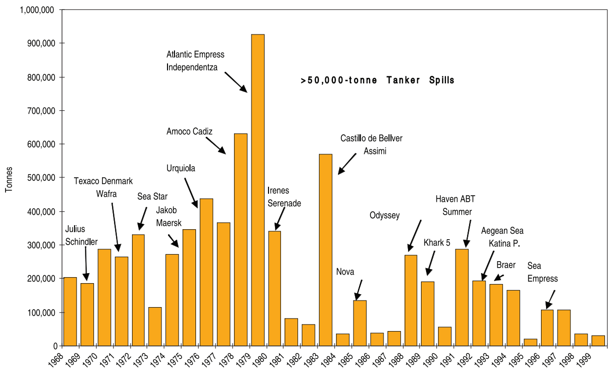


Figure 16.
Estimated Annual Oil Spills From Tankers 1968-1999 – Amounts Spilled and Number of Spills (Based on Environmental Research Consulting Database)

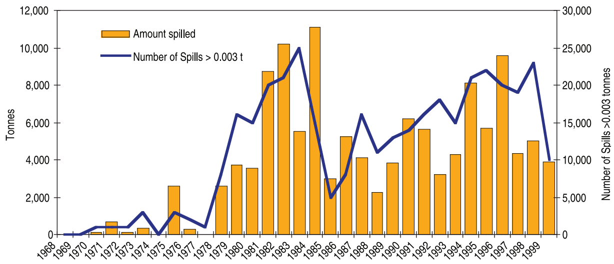


Figure 17.
Oil Movement By Tankers Worldwide (Millions of Tonnes) (Brtish Petroleum Data)

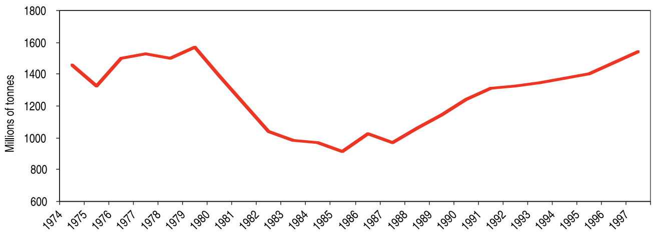


Table 22. Inter-area oil movements 1997 (million tonnes)

Inter-Area Oil Movements 1997 (Million Tonnes)														
From	To													
	USA	Canada	Mexico	South & Central America	Western Europe	Central Europe	Africa	Australasia	China	Japan	Other Asia Pacific	Rest of World	Un-identi-fied	TOTAL
USA	-	7.7	10.7	9.2	9.9	-	0.5	0.8	1.1	2.0	4.1	0.9	-	46.9
Canada	72.7	-	-	-	0.8	-	0.1	-	-	-	-	-	-	73.6
Mexico	68.0	1.7	-	5.9	7.9	-	0.8	-	-	3.3	-	0.3	-	87.9
South & Central America	132.1	6.1	2.2	-	11.6	-	1.3	-	1.1	0.2	3.8	-	-	158.4
Western Europe	32.9	19.1	19.1	1.8	-	10.1	7.4	-	1.0	0.1	4.3	3.0	-	80.0
Former Soviet Union	0.6	0.2	-	2.2	90.8	31.8	0.5	-	4.0	0.4	4.8	2.3	30.0	167.6
Central Europe	0.4	-	-	-	5.0	-	-	-	-	-	-	1.4	-	6.8
Middle East	86.9	5.4	5.4	27.8	187.9	19.3	32.0	9.8	16.7	218.1	294.4	1.4	-	900.7
North Africa	15.6	3.0	3.0	1.5	97.9	4.0	4.3	-	-	1.2	4.4	3.2	-	135.2
West Africa	68.3	1.2	1.2	14.2	40.1	0.1	0.9	-	5.2	1.4	23.0	-	-	154.4
East & Southern Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Australasia	2.4	-	-	-	-	-	-	-	0.3	3.1	7.9	-	2.0	15.7
China	2.2	-	-	0.2	-	-	-	0.2	-	11.5	10.8	0.1	-	25.0
Japan	0.1	-	-	-	-	-	-	-	2.5	-	3.2	0.2	-	6.0
Other Asia Pacific	5.1	-	-	-	1.6	-	-	13.8	25.3	42.2	5.0	0.2	-	93.2
Un-identified	2.3	1.8	-	-	12.1	-	0.8	2.0	2.1	-	6.4	-	-	27.5
TOTAL	489.6	46.2	14.3	62.8	465.6	65.3	48.6	26.6	59.3	283.5	372.1	13.0	32.0	1,978.9

Data from British Petroleum

Figure 18. Major oil trade movements 1997

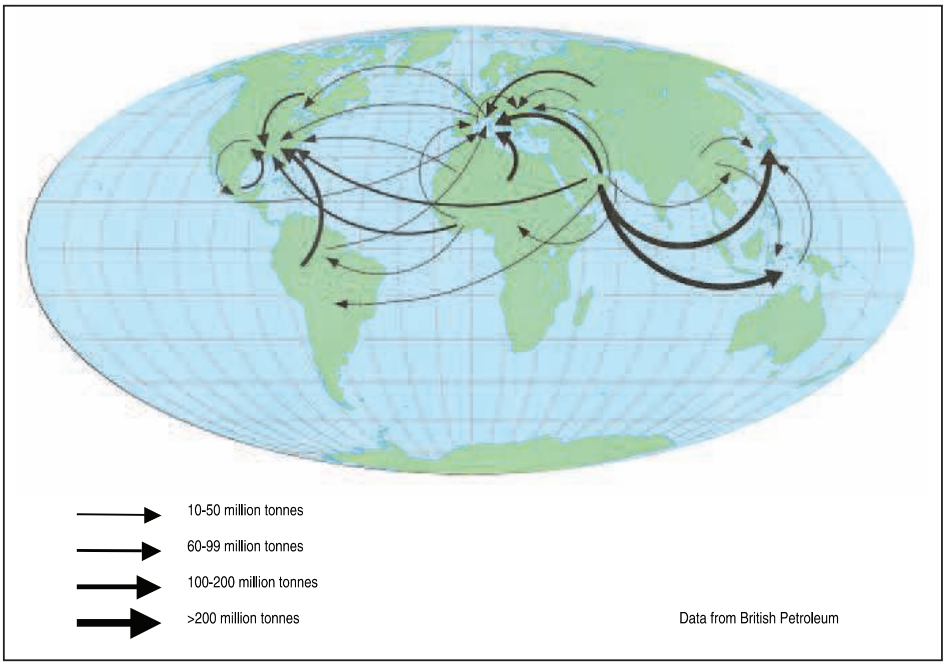


Table 23. Average annual percentage of oil spilled, per oil tonnage transported, by tankers

Year	Percentage
1974-1977	0.029%
1978-1987	0.022%
1988-1997	0.012%
Source: Etkin 1999c	

139 Trends of the amount of oil transported by tankers that is spilled, expressed as average annual percentages of the amounts transported (using BP data, Fig. 18 and Table 22), are shown in Table 23. Data on petroleum transport were not available for 1968-1973. The general trend is that the estimated mean annual percentage of spilled oil in transit decreased during 1974-1997. During 1974-1977, the estimated mean annual percentage of oil transported by tankers that is spilled was 0.029%. In 1978-1987, the estimated mean annual percentage was 0.022%. From 1988-1997, the percentage dropped again to 0.012%. Estimates of the percentages of oil spilled will vary based on the source of the data on amounts of oil transported per year, being lower if the amounts of oil transported are taken to be higher.

140 The reduction in oil spillage from tankers, despite increases in production and transport during the last ten years, makes the overall reduction in accidental spillage from tankers more remarkable. Despite greater opportunities to spill more oil, i.e. more oil transport is occurring, fewer spills have occurred and less oil has been released in accidental spills into the marine environment. This is due to the efforts of governments, IGOs, and industry. Nonetheless, some of the recent tanker spills e.g. *Erika* 1999, *Prestige* 2002, have involved large volumes, have caused considerable coastal damage, and invoked high cleanup costs. Individual spill events cause many effects and cost a lot for clean up and compensation.

3.3.4 Regional analysis of accidental spillage data from all sources

141 In a study by Etkin (1999e), using the methodology described in Section 2.3.5, the numbers and amounts of accidental oil spills over 0.17 tonnes were estimated for each region (Figure 6). The data were revised using information from the ERC database. The updated numbers and amounts per region are shown in Figures 19-36. In viewing these figures, it is essential that the scales of the *Y* axis, representing spill number and spill amounts, be noted carefully when making comparisons between regions; the scales vary considerably among the 18 regions.

142 In summary, there is quite different spill activity in different parts of the world. Some regions have higher numbers of spills due to their location in the vicinity of high vessel traffic areas e.g. NW Atlantic, or due to being areas of high commerce, tanker traffic, and exploratory and production activities, such as Region 4 (Gulf of Mexico/Caribbean Sea), Region 7 (the North Sea), and Region 9 (the Mediterranean). Most spills, particularly from vessels, still occur in port areas or in vessel traffic lanes. Facility spills and spills from nearshore or shoreline pipelines also tend to occur in port areas where they are usually located. Spillage statistics in any one year can be greatly skewed by the occurrence of one or more very large incidents. In general, over the last ten-year period evaluated (1988-97), the occurrence of accidental spills of all sizes has declined in most regions compared to the previous two 10-year periods (exceptions being the Black Sea, portions of Africa, the Persian Gulf and Australia).

143 The history of spills in the 18 global regions is described below and shown in Figures 20 – 37, on which the notable regional spills are noted. The regions are:

Region 1	Northeast Pacific Ocean: Figure 19
Region 2	Southeast Pacific Ocean: Figure 20
Region 3	North Atlantic Ocean: Figure 21
Region 4	Gulf of Mexico/Caribbean Sea: Figure 22
Region 5	Southwest Atlantic Ocean: Figure 23
Region 6	Northeast Atlantic Ocean: Figure 24
Region 7	North Sea: Figure 25
Region 8	Baltic Sea: Figure 26
Region 9	Mediterranean Sea: Figure 27
Region 10	Black Sea: Figure 28
Region 11	West/Central African Atlantic: Figure 29
Region 12	Southern Africa: Figure 30
Region 13	Eastern African Indian Ocean: Figure 31
Region 14	Red Sea/Gulf of Aden: Figure 32
Region 15	Gulf Area: Figure 33
Region 16	Arabian Sea/Indian Ocean: Figure 34
Region 17	East Asian/Southeast Asian Seas: Figure 35
Region 18	Australian/New Zealand Pacific: Figure 36

144 As with the analyses done on accidental spillages on an international basis, both from specific point sources and from all point source types added together, spillage in any one year can be greatly skewed by the occurrence of one or more very large incidents. The approximate locations of spills of at least 5,000 tonnes in the last decade (1988-1997) are shown on the map in Figure 37. The notable spills in each region are briefly described.

145 In addition, the estimation technique results in "zero" values for spill numbers for years in which there were no reported spills, although it is likely that there were small spills in those years. In addition, there are apparent sudden "spikes" in spillage for years in which a few larger spills were reported. This is a weakness of this estimation technique. An example of this phenomenon is shown in Figure 28. The numbers represented in these figures should only be viewed with regard to general trends in these regions, due to incomplete data records and spill reporting.

146 Region 1 (Northeast Pacific Ocean), while showing an increase in spill number during the

last period (1988-1997), has had an overall decline in spillage amounts, as a large amount of accidental spillage occurred during 1977 (Figure 19). The exceptionally large 1977 spillage was due to the 106,071-tonne spill from the tanker *Hawaiian Patriot* in the Pacific Ocean 590 km off Hawaii.

147 Region 2 (Southeast Pacific Ocean) has shown little change in the estimated number of spills during the last period compared to previous years (Figure 20). However, a considerably smaller amount was spilled in the last period, after several years of relatively high accidental spillage during 1973-1980. The higher spillage can, in large part, be attributed to the *Napier* tanker spill of 38,571 tonnes off Chile in 1973, the 35,100-tonne spill from the tanker *St. Peter* off Colombia in 1976, and the tanker *Caribbean Sea* spill of 32,143 tonnes off El Salvador in 1977.

148 Despite its very high commerce and tanker traffic, Region 3 (North Atlantic Ocean, i.e. north-west and north central Atlantic) has shown a slight reduction in the estimated number of spills in the last period (Figure 21) compared to the previous two periods. Estimated spillage amounts have been relatively low compared to previous years, with the exception of 1979 and 1988. In 1979, the *Atlantic Empress* spilled 141,000 tonnes 800 km east of Barbados. The tanker *Athenian Venture* spill and the large *Odyssey* tanker spill, both at sea in the North Atlantic Ocean, contributed 36,000 tonnes and nearly 147,000 tonnes, respectively, in 1988. This region has also experienced two other spills of at least 5,000 tonnes in the last decade - a vessel spill of 5,000 tonnes in Sandy Hook Channel, New York, USA, in 1988, and the *Berge Broker* spill of 13,600 tonnes, off Nova Scotia, Canada, in 1990. The North West Atlantic's Grand Banks and Scotian Shelf also experience chronic oiling from ship's illegal discharges of waste oils, in unknown quantities but with significant impacts on pelagic seabirds of hemispheric importance and nearby shorelines (Lock and Deneault 2000; Wells 2001; Wiese et al. 2001; Wiese 2002).

149 The high commerce areas, tanker traffic, and exploratory and production activities of Region 4 (Gulf of Mexico/Caribbean Sea) continue to experience a high number of spills (Figure 22) each year. There are an estimated 250 spills each year, although the numbers have decreased slightly in the last period (1988-1997). Over 50,000 tonnes of spillage occurred only in 1996. However, the estimated annual spillage amount in the Gulf of Mexico and Caribbean Sea still continues to be of concern. Region 4 is notable for the *Ixtoc I* exploratory well blowout in 1979; this spill still holds the record as being the largest spill from a single point source in the records since 1959. In addition, during 1979, the tankers *Aegean Captain* and *Atlantic Empress* collided 32 km northeast of Trinidad and Tobago. In this collision, the *Aegean Captain* spilled 14,660 tonnes of oil, while the *Atlantic Empress* spilled 145,252 tonnes, and an additional 141,102 tonnes while being towed from the collision site two weeks later; this incident is also described for Region 3. During 1988-1997, this region experienced three large spills: 17,000 tonnes from the *Mega Borg* tanker explosion off Texas, USA, in 1990; a spill of 5,500 tonnes from pipelines that burst during flooding in the San Jacinto River estuary in Houston, Texas, USA; and a spill of nearly 36,000 tonnes from a tanker which exploded while unloading at a utility plant in Veracruz, Mexico, in 1996.

Figure 19.
Estimated Oil Spillage in Region 1 (Northeast Pacific Ocean) (Based on Etkin 1999g; IOSD Oil Spill Data)

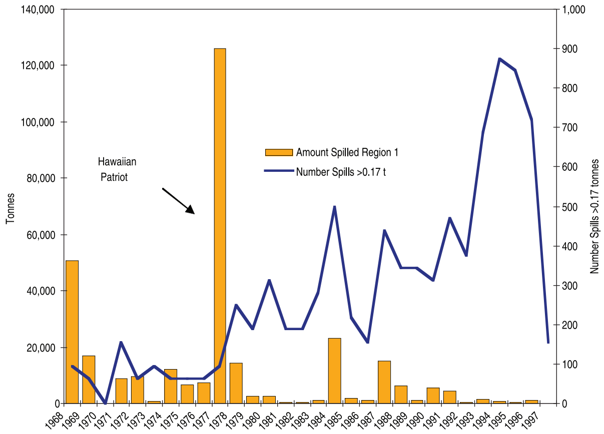


Figure 20.
Estimated Oil Spillage in Region 2 (Southeast Pacific Ocean) (Based on Etkin 1999g; IOSD Spill Data)

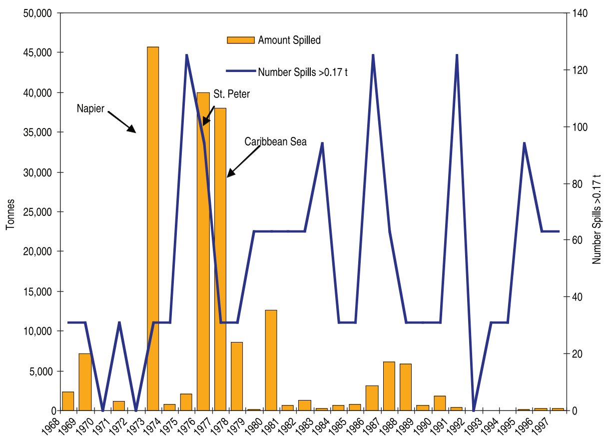


Figure 21.
Estimated Oil Spillage in Region 3 (North Atlantic Ocean) (Based on Etkin 1999g; IOSD Spill Data)

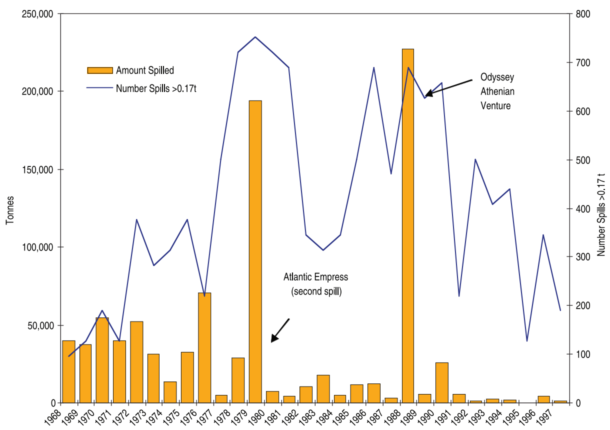
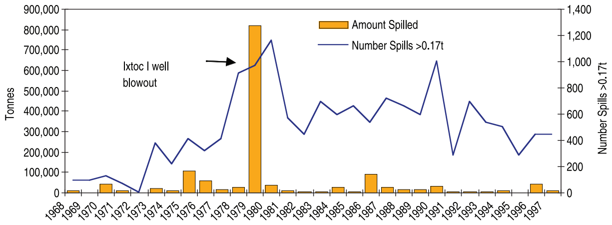


Figure 22.
Estimated Oil Spillage in Region 4 (Gulf of Mexico/ Caribbean Sea) (Based on Etkin 1999g; IOSD Spill Data)



150 Region 5 (Southwest Atlantic Ocean) has shown a slight reduction in the estimated annual number of spills, with between 60 to 155 spills reported each year (Figure 23). Years 1974 and 1982 showed unusually high spillage numbers. At the same time, the spills have contributed less than 1,000 tonnes per year. The area had a large spill from the tanker *Metula*, which spilled over 47,000 tonnes in the Strait of Magellan, Chile, during 1974; this spill has been intensively studied (NRC 1985). This area had one spill of 5,000 tonnes from the tanker *Oshima Spirit*, which grounded in the Strait of Magellan near Punta Arenas, Chile, in 1988. The year 1997 has two incidences, with the tanker *Nissos Amorgos* spill of nearly 3,600 tonnes in Lake Maracaibo, Venezuela, and the *San Jorge* spill of nearly 4,500 tonnes of crude oil in the outer Rio de la Plata, Uruguay.

151 There has also been a slight reduction in the estimated annual number of spills reported in Region 6 (Northeast Atlantic Ocean) (Figure 24). The estimated annual amount of oil spilled has increased, however, since the relatively calm period of the previous decade (1978-87). There were also several years of high spillage in the 1970s, the most notable spills being the tanker *Urquiola* spill of 95,700 tonnes at La Coruma's port, Spain, in 1976 and the tanker *Amoco Cadiz* spill of 1978 with 233, 565 tonnes off Portsall on the Brittany coast of France. The northeastern Atlantic region experienced six very large tanker spills in the 1988-1997 period. These include: the tanker *Marao* spill of 5,000 tonnes in Portugal in 1989; the tanker *Khark 5* spill of 70,000 tonnes off the coasts of Morocco and Spain in 1989; the tanker *Aegean Sea* spill of 74,000 tonnes in the La Coruma's port of Spain, in 1992; the tanker *Braer* spill of 83,000-85,000 tonnes in Scotland, United Kingdom, in 1993; the tanker *Sea Empress* spill of 72,000 tonnes in the Milford Haven estuary, United Kingdom, in 1996; and the tanker *Bona Fulmar* spill of 6,800 tonnes in the Dover Strait in 1997. Most recently, the region experienced the *Erika* spill of heavy fuel oil off France (1999) and the sinking of the tanker *Prestige*, carrying heavy fuel oil, in deep waters off northwest Spain in November 2002.

152 The North Sea (Region 7), with its high tanker traffic and exploration and production activities, continues to experience on average an estimated 100 spills per year in the last period (1988-1997) (Figure 25). The estimated average annual amount spilled has decreased from previous decades, although in 1997 there were over 370 spills and 10,000 tonnes in spillage. The year 1971 stands out for this region with the very large spillage of 107,100 tonnes in the tanker *Texaco Denmark* incident off Belgium. The North Sea region had one spill of at least 5,000 tonnes in 1993, when the tanker *British Trent* spilled 5,100 tonnes off Ostende, Belgium. This region is, of course, best known for the landmark spill, of the *Torrey Canyon* on the Cornwall coast in 1967, which drew so much scientific, public and political attention to the problem of coastal oil pollution. Concerns about impacts on seabirds continue, and one study based on beached bird surveys indicates a decline in chronic oiling in the North Sea (Camphuysen 1998).

Figure 23.
Estimated Oil Spillage in Region 5 (Southwest Atlantic Ocean) (Based on Etkin 1999g; IOSD Spill Data)

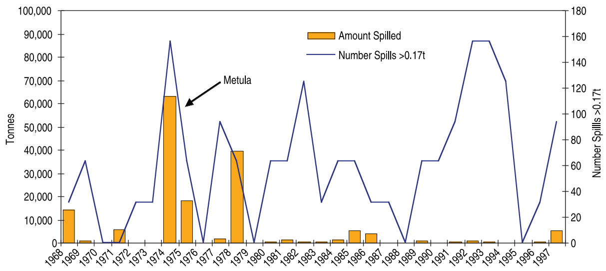


Figure 24.
Estimated Oil Spillage in Region 6 (Northeast Atlantic Ocean) (Based on Etkin 1999g; IOSD Spill Data)

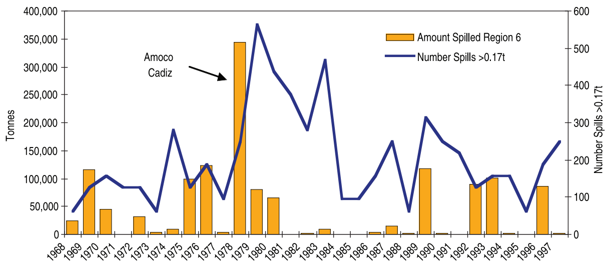
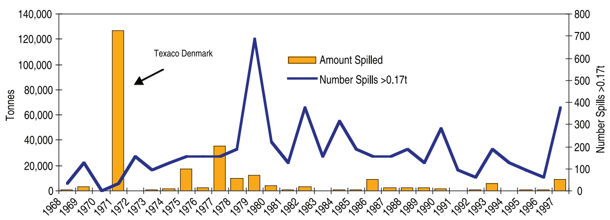


Figure 25.
Estimated Oil Spillage in Region 7 (North Sea) (Based on Etkin 1999g; IOSD Spill Data)



153 The Baltic Sea area (Region 8) had slightly more spills in the last decade (Figure 26). These spills tend to be small with the total amount of estimated spillage generally being less than 1,500 tonnes per year. This area experienced no high-spillage years in the last period (1988-1997), but did

have four such years in 1970, 1979, 1981, and 1983. In 1979, the tanker *Antonio Gramsci* spilled 4,942 tonnes of oil off Ventspils, Latvia. In 1981, the tanker Globe Assimi spilled 14,740 tonnes of oil near Klaipeda, Lithuania. The tanker *Bellona* spilled 24,684 tonnes of oil in the Kattegat, near Gothenburg port, Sweden, in 1983. Some of the Baltic spills have been extensively studied (e.g. NRC 1985).

154 The Mediterranean Sea (Region 9) continues to experience 200 or more of spills annually (Figure 27), reflecting its high commercial activity. In fact, the estimated spill number has risen in the last period compared to the previous ten-year period. The period 1975 - 1980 was a time of high estimated spill amounts, attributed to several high-volume vessel spills. In 1976, the tanker *Al Dammam* spilled 15,714 tonnes of oil in Agioi Theodori, Greece. In 1979, there were two major spills in the Mediterranean - the tanker *Messiniaki Frontis* spill of 16,602 tonnes off Crete, Greece, and the cargo carrier *Vera Berlingieri* spill of 5,940 tonnes off Fiumicino, Italy. In 1980, the tanker *Irenes Serenade* spilled 124,500 tonnes of oil into Navarino Bay, off Pylos port, Greece. During the last decade, the Mediterranean Sea experienced two spills over 5,000 tonnes - the *Sea Spirit* tanker spill of 9,900 tonnes off Spain in 1990, and the *Haven* spill of 144,000 tonnes in Genoa, Italy, in 1991. Oil pollution control has figured prominently in the work of the United Nations Mediterranean Seas Programme and Action Plan, with a Regional Oil Combating Center in Malta (Skjaerseth 2002).

155 The Black Sea (Region 10) has had an apparent increase in spills in both estimated number and amount (Figure 28). This may in part be due to increased reporting from this area since accurate information was largely unavailable before the 1980s. There may even have been considerable under-reporting during the 1990s. Much of the increase in spillage can also be attributed to increased shipping, particularly through the Bosporus Strait, the entrance into the Black Sea and the site of numerous collisions and spills. In the last period (1988-1997), spill number has ranged from an estimated 30 spills to 95 spills per year, with the largest amount recorded in 1990 when a total of nearly 2,500 tonnes spilled in 62 separate incidents. Prior to this, the Bosporus Strait was the site of two very large spills — the 1977 spill of 20,857 tonnes from the tanker *USSR 1*, and the 1979 spill of 98,255 tonnes from the tanker Independentza.

Figure 26.
Estimated Oil Spillage in Region 8 (Baltic Sea) (Based on Etkin 1999g; IOSD Spill Data)

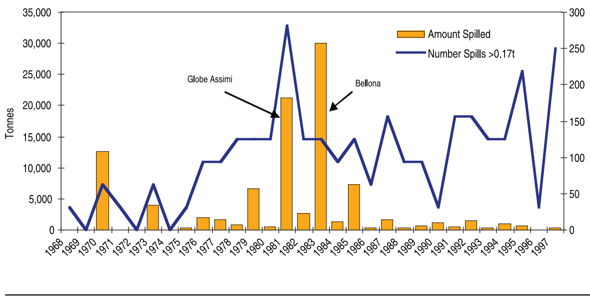


Figure 27.
Estimated Oil Spillage in Region 9 (Mediterranean Sea) (Based on Etkin 1999g; IOSD Spill Data)

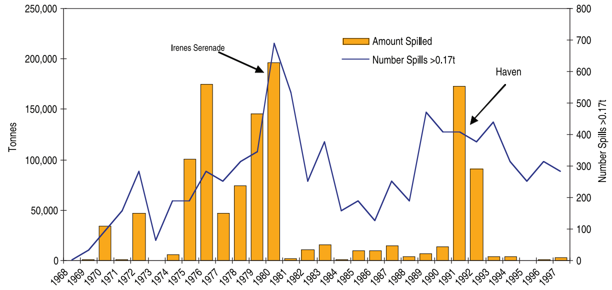
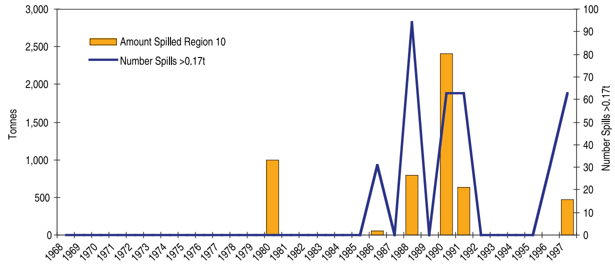
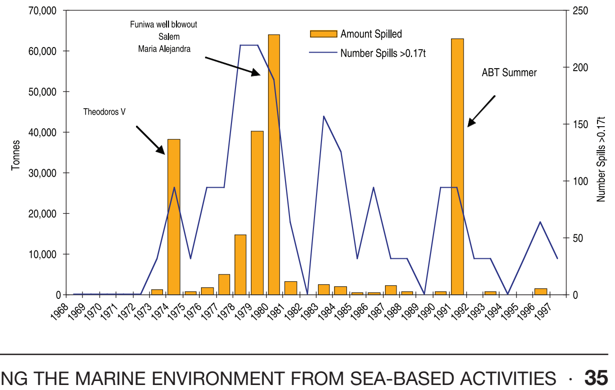


Figure 28.
Estimated Oil Spillage in Region 10 (Black Sea) (Based on Etkin 1999g; IOSD Spill Data)



156 Region 11 (West/Central African Atlantic), the Atlantic Ocean off the west and central portions of the African continent, has been vulnerable to spills from passing tankers as well as from spills associated with its own oil production and transport activities. Nevertheless, this region has shown a decrease in overall spills in terms of both estimated number of spills and estimated amount spilled over the last decade (Figure 29). The year 1991 was a notable exception when the tanker *ABT Summer* spilled 51,000 tonnes off Angola. The years 1974, 1979, and 1980 also showed relatively large amounts of spillage for this region. In 1974, the tanker *Theodoros V* spilled 20,857 tonnes 740 km off Senegal, and the tanker *Eleftheria* spilled 10,473 tonnes off Sierra Leone. In 1979, the tanker *Ioannis Angelicoussis* spilled 31,430 tonnes of oil into the Cabinda terminal port, in Malongo, Angola. The year 1980 was a particularly bad year with three large tanker spills — the *Salem* spilled 16,714 tonnes off Senegal, the *Maria Alejandra* spilled 4,187 tonnes of oil 160 km off Mauritania, and the Mycene spilled 4,187 tonnes off Sierra Leone. In addition, the *Funiwa 5* development well off Forcados, Nigeria, spilled 28,571 tonnes in a blowout during 1980.

Figure 29.
Estimated Oil Spillage in Region 11 (West/Central African Atlantic) (Based on Etkin 1999g; IOSD Spill Data).



157 The southern Atlantic region and Indian Ocean near the Cape of Good Hope off southern Africa (Region 12) has shown a slight increase in estimated accidental oil spill numbers (Figure 30) in the last ten years. However, the estimated total amounts spilled each year have consistently been below 20,000 tonnes. In 1983 this region experienced the largest recorded tanker spill of all time - the *Castillo de Bellver* spill of 267,000 tonnes off Table Bay, South Africa. During the last period (1988-97), there was one spill over 5,000 tonnes in this region — the tanker *Pacificos* spill of 11,000 tonnes in 1989 off South Africa.

158 Region 13, the Indian Ocean off eastern Africa, is at high risk for spillages due to heavy tanker traffic passing from the Middle East towards the Atlantic. This region has shown an increase in the numbers of spills (Figure 31) with respect to a relative lull in the 1980s, which followed a period of more spills in the mid- to late-1970s. Between 1988 and 1997, estimated spill amounts were quite low, with the exception of 1992, when a total of almost 65,000 tonnes spilled in 62 incidents, including the *Katina P.* spill of 51,000 tonnes, off South Africa in the Indian Ocean.

159 The Red Sea and Gulf of Aden areas (Region 14) are at risk due to high tanker and other shipping activity through the Suez Canal. This region has shown a slight decrease in both spill numbers (Figure 32) and spill amounts in the last period (1988-1997) compared to previous ones. Since 1988, two years, namely 1989 and 1990, showed disproportionately high spillage amounts due mainly to two very large tanker spills.

160 Region 15, the Persian/Arabian Gulf area, is a notably busy area for tanker transport, oil terminals, and oil production. Estimated spill numbers have decreased in the last decade compared to the previous decade (Figure 33), in large part because the years 1986 and 1987 had so many tanker incidents related to war action in the 1980-88 Iran-Iraq War. That period (1978-1987) had experienced large amounts of oil spilled in conjunction with that war and the 1983 *Nowruz* well blowout that spilled over 400,000 tonnes into Gulf waters. Estimated spill amounts have decreased in the last period (1988-1997) with the notable exception of the massive spillage that occurred in 1991 during the Gulf War; an estimated 10,530,768 tonnes of oil from several terminals, tankers, and other sources reportedly combined to become one massive slick in the northern Gulf. In addition to the Gulf War spillage, the only other incident over 5,000 tonnes in the last decade was the 16,000-tonne spill from the tanker Seki, which grounded off Fujairah, United Arab Emirates in 1994.

161 The Arabian Sea and Indian Ocean off India and surrounding nations (Region 16) experienced a relatively low number of spills in the last 10-year period (Figure 34), virtually unchanged from the previous period. The estimated annual spillage amount decreased slightly in the last period with the notable exception of two very large incidents off Bombay, India, in 1989 and 1993. In 1989, the *Puppy P.* tanker incident resulted in the spillage of 5,500 tonnes, and an offshore pipeline spilled nearly 6,500 tonnes of oil in 1993.

Figure 30.
Estimated Oil Spillage in Region 12 (Southern Affrica) (Based on Etkin 1999g; IOSD Spill Data)

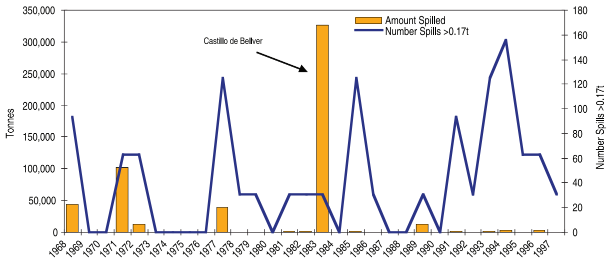


Figure 31.
Estimated Oil Spillage in Region 13 (Eastern African Indian Ocean) (Based on Etkin 1999g; IOSD Spill Data)

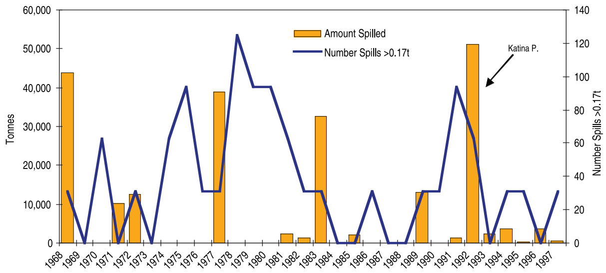


Figure 32.
Estimated Oil Spillage in Region 14 (Red Sea/Gulf of Aden) (Based on Etkin 1999g; IOSD Spill Data)

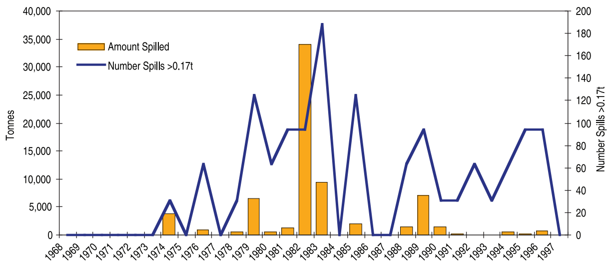


Figure 33.
Estimated Oil Spillage in Region 15 (Gulf Area) (Based on Etkin 1999g; IOSD Spill Data)

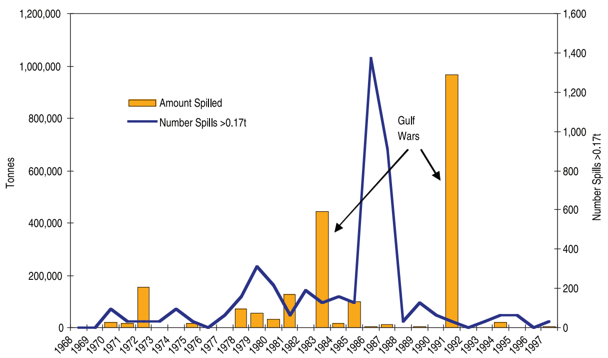
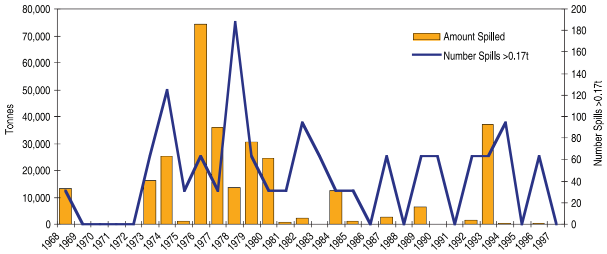


Figure 34.
Estimated Oil Spillage in Region 16 (Arabian Sea/ Indian Ocean) (Based on Etkin 1999g; IOSD Spill Data)



162 In the last period (1988-1997) in Region 17 (East Asian/Southeast Asian Seas), an area of high commerce, the estimated annual spill number increased. However, it is not as high as it had been in the period 1974-1980 (Figure 35). Spill amounts were also slightly higher during this period, although again not as high as it had been in the period 1974-1980. This region experienced nine tanker spills of at least 5,000 tonnes between 1988 and 1997. These were: the *Century Dawn* spill of 10,700 tonnes in Singapore in 1988; the *Vishru* spill of 5,280 tonnes in the Philippines in 1989; the *Nagasaki Spirit* spill of 13,000 tonnes in the Malacca Strait, Malaysia, in 1992; the *Maersk Navigator* spill of nearly 25,000 tonnes in the Malacca Strait, Malaysia, in 1993; the *Frontier Express* spill of 7,800 tonnes in the Yellow Sea off South Korea in 1993; the *Thanassis A.* spill of 37,000 tonnes in the South China Sea off Hong Kong in 1994; the *Nakhodka* spill of 6,200 tonnes in Japan in 1997; the *DaQing 243* spill of 17,000 tonnes in the estuary of the Yanghtze River, China, in 1997; and the *Evoikos* spill of 28,600 tonnes in the Singapore Strait in 1997.

163 Region 18, the seas around Australia and New Zealand, had a steady number of spills (Figure 36) over the last two decades, averaging 50 spills per year. Estimated spill amount has been less than in other regions with amounts of no more than 1,000 tonnes annually. There were notable exceptions in 1975, which saw the tanker *Princess Anne Marie* spill of 14,800 tonnes 700 km off Western Australia, and 1991, which saw the tanker *Kirki* spill of 17,700 tonnes off Cervantes, Western Australia, which remains the largest spill in Australia's history.

164 Globally, spills occur randomly, with respect to location, time, volume/amount and type of oil spilled (Figure 37). However, about half the regions (3, 4, 6, 7, 8, 9, 10, 12, 13, 15 and 17) are more oiled recently than others, from ships and other sea-based activities, and hence at greater risk. Not surprisingly, these regions have high shipping and oil production/refining activity.

3.3.5 Sunken vessels

165 Both merchant vessel casualties and military vessel casualties are in this category of ships sunken on purpose. Calculating the losses of oils with accuracy, taking into account all types of oils, including cargo, for such casualties is virtually impossible given the variability in ship types, cargoes and absence of records. For example, it is impossible to know for most casualties exactly how much oil in each category was onboard the vessels e.g. how much fuel oil remained, how much waste machinery oil had been generated. Oil lost with casualties reported since 1968, particularly for larger vessels (tankers), will largely be captured in the estimates given in Section 3.3.1 (accidental spillage from all sources data). For vessels lost before this date, or for smaller vessels, no reliable estimates can be derived. Shipping casualty statistics, therefore, provide only an indication of the potential scale of the problem. This is, however, far from a trivial issue from an ecological point of view. Many of the vessels which have floundered and sunk, particularly in coastal waters, may break up over time, and may generate mystery spills and pelagic and littoral tar, all of which pose a risk to marine organisms and public amenities along the coasts. This is a particularly acute problem at present (circa 2003) for many islands in the western Pacific, a long-term consequence of World War II. Continuing work on this important but poorly documented input source is discussed later in the report.

Figure 35.
Estimated Oil Spillage in Region 17 (East Asian/ Southeast Asian Seas) (Based on Etkin 1999g; IOSD Spill Data)

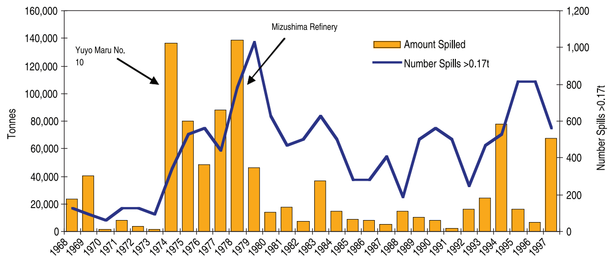
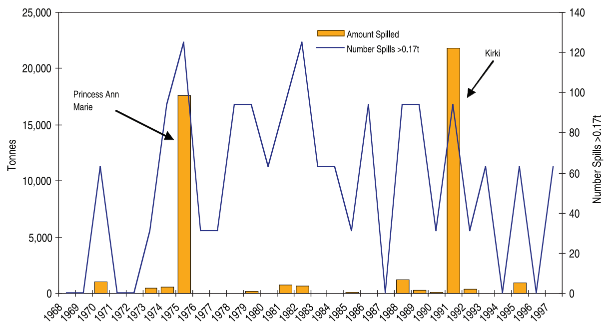


Figure 36.
Estimated Oil Spillage in Region 18 (Australian/New Zealand Pacific) (Based on Etkin 1999g; IOSD Spill Data)



3.3.5.1 Merchant vessel casualties

166 In 1997, the number of merchant vessels in the world fleet was 85,494 (~85,500), with an aggregate gross tonnage of 522.2 million tons. This figure considers only vessels above 100 gross tons. (Lloyds Register, 1998a). This compares to figures in

the year 1939 of 29,763 vessels with an aggregate gross tonnage of around 68.5 million tons. Between 1939 and 1997, a total of 21,486 vessels were recorded as total losses (actual and constructive) comprising a gross tonnage of 76 million tons (Lloyds Register, 1991; 1992; 1993; 1994; 1995; 1996; 1997; 1998b). This figure includes merchant vessels lost as a result of acts of war. This amounted to 5,915 vessels of gross tonnage 25,537,630 tons between 1939 and 1946, approximately a third of the total. It is not clear whether these figures include data for the Japanese merchant fleet that declined from 6.1 million gross tons in 1941 to 1.8 million tons in 1945 (Elting 2000). Casualties occurring in recent years, since 1968 in the context of this report, which have resulted in the release of oil to the environment are recorded under Section 3.3.1.

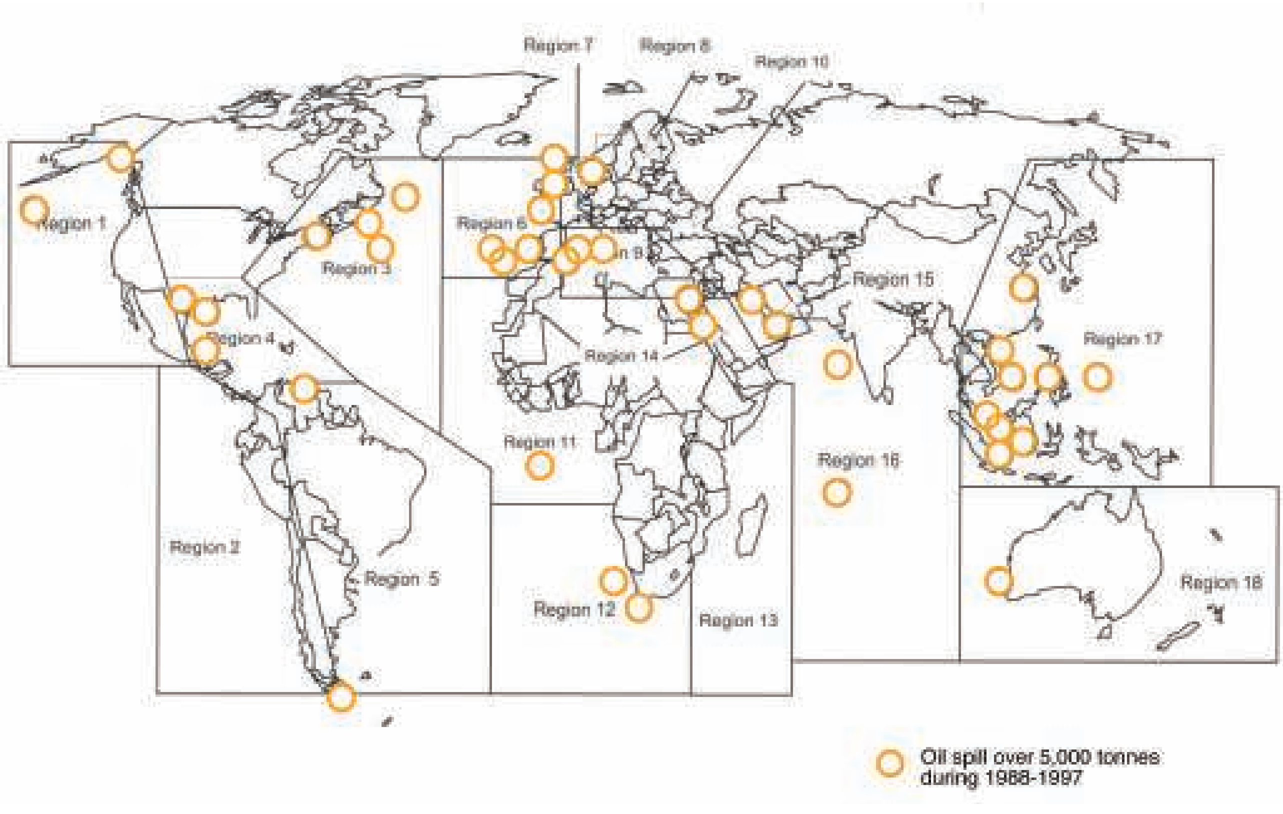
167 Many vessels were lost with their remaining bunker, lubricating and hydraulic oils and with oil (fuel and crude) carried as cargo. Such oils have the potential to continuously or intermittently enter the marine environment as a result of deterioration or disturbance of the wreck. This is illustrated by documented problems with sunken military vessels in Norwegian and United Kingdom waters (Section 3.3.5.2), and with specific vessels, such as the *Luchenbach* off the coast of California, with chronic leaks and dead oiled seabirds on beaches (Wiese, pers. comm.), and the barge *Irving Whale* in the southern Gulf of St. Lawrence, also with chronic leaking of oil and persistent slicks killing seabirds. The *Irving Whale* sank in 1970 in 67 m of water (Environment Canada 1996a) and slowly leaked some 1100 metric tonnes of heavy marine fuel (Bunker C) oil in the period to 1990 (Environment Canada 1996b). This comprised some 27% of the original cargo. The barge lost oil up to the time of salvage by the government, in summer of 1996.

168 The considerable technical challenges and costs involved in removing oil cargoes, even from vessels sunk in accessible waters, are exemplified by the raising of the *Irving Whale*. The story of this vessel covered a period of 26 years, involved a comprehensive operational assessment (Environment Canada 1996a), and ended with the wreck being lifted off the bottom in a salvage operation in 1996 at the cost of $CAD 38 million. The wreck was moved by barge to Halifax, Nova Scotia where the residual hydrocarbon cargo was recovered together with some of the PCBs present in the cargo heating system. The remaining PCBs, now in the Gulf of St. Lawrence sediments and biota, may pose a greater risk to marine life than the barge's oil cargo (Environment Canada 1996 b).

169 There are a number of difficulties in estimating actual and potential future inputs of oil to marine waters from lost ships. These include:

.1 Bunker oils and crude oil cargoes are often recovered from casualties. For example, the International Salvage Union reported that in 1994, marine salvage companies responded to over 120 shipping casualties. 1.25 million tonnes of oil cargoes were salvaged from 14 vessels. A total of 53,000 tonnes of bunker oils was recovered from an unspecified number of vessels (Lacey, 1995).

Figure 37. Regional Oil Spill Analysis (Oil Spills Over 5,000 tonnes 1988-1997) (Etkin 1999g; IOSD Spill Data)



.2 Over the period 1939-1997, there have been changes in the fuels used by ships. The initial phase of this period saw the progressive transition from coal to oil. Subsequently, there have been qualitative changes in the grades of fuel oils used by ships. Modern marine fuel oils are kept liquid by heating the settling and service tank(s) to approx. 60 degrees C and such oils form sticky masses when discharged to the sea. Earlier bunker oils produce thick slicks on seawater with a low evaporation rate (see Corbett & Fischbeck, 1997; Hofer, 1999). Accordingly, there is likely to be variation in the potential of fuel oils in wrecks to escape to the environment depending upon the characteristics of the fuel. But as shown by the *Arrow* (1970) and *Irving Whale* (1970) spills in Canada and the 2002 *Prestige* fuel oil spill off Spain (an accident, not a casualty), heavy oil at great depth still flows and can escape into the water column and to the sea surface.

.3 Under-reporting of casualties is acknowledged. In particular, casualty returns do not include ships of less than 100 gross tons, pleasure craft, naval auxiliaries or ships restricted to service in harbours or on rivers and canals (Lloyds Register, 1998a). In addition, casualty returns until 1994 (Lloyds Register 1994) explicitly state that losses in the smaller gross tonnage ranges (100-499 and 500-999 gross tons) are probably understated. The smaller vessels, nonetheless, may contain significant quantities of oil. Two fishing vessels of 87 and 76 gross tons, each reported as casualties in 1997 in Scottish waters, resulted in the loss of 10 tonnes of marine fuel oils contained in their fuel tanks. In other incidents in Scottish waters in 1997, small fishing vessel casualties lost at least 19.5 tonnes of fuel oils to sea (ACOPS 1998) after the vessels floundered. It was not possible in this study to calculate the total oil inputs from such casualties worldwide.

.4 Casualty returns include both constructive and actual total losses. Constructive losses may subsequently be broken up or repaired and returned to service. In these cases, hydrocarbon contents are not necessarily lost to sea.

.5 Casualty returns include details of the ship type (e.g. oil tanker, bulk carrier) but not of the cargoes and bunkers carried at the time of the loss.

3.3.5.2 Military vessel casualties

170 Military vessels (i.e. naval ships) lost at sea, including those lost in combat, are excluded from the annual reporting through Lloyds Register of Shipping. Nonetheless, some collated records exist for some military craft for WWII (1939-1945) and subsequent years. These show that between 1939 and 1945, some 104 French military vessels were lost at sea (164,369 tons) and a further 99 scuttled (196,251 tons) (Couhat 1971). Equivalent figures for German vessels between 1939 and 1947 are 841 (1,040,000 tons) lost and 365 (426,000 tons) scuttled (Taylor 1966). Between 1939 and 1959, 1,577 United Kingdom fighting ships were lost at sea (1,746,000 tons) and 21 were expended as targets or scuttled between 1940 and 1961 (41,290 tons) (Lenton & Colledge 1964). The bulk of fighting vessel losses occurred as a result of conflict. Although these data are incomplete with respect to information for *inter alia* the Imperial Japanese Navy (estimated losses of 302 vessels), the US Navy (estimated losses of 146 vessels) (Elting 2000), and British Commonwealth Navies operating as part of the United Kingdom Royal Navy, they illustrate that the aggregate tonnages are a relatively small proportion of merchant shipping tonnages lost over the same period. Evaluation is also made difficult by the fact that numbers and tonnages are approximate only. Smaller vessels and landing craft may not be included other than in the figures for the United Kingdom Royal Navy. An unrecorded number of ships were transferred between national navies (e.g. USA to Canada) or raised after scuttling (and sometimes re-sunk thereafter). Tonnages, moreover, may be given as registered or displacement, with warships given as standard rather than displacement tonnages according to class and submarines as surfaced rather than submerged displacement.

171 Nonetheless, military casualties are documented for causing significant releases of oil into marine ecosystems. For example, the German naval vessel *Blucher* was sunk in the Oslofjord, Norway, in 1940. Following chronic leakage of bunker fuel over a number of years, an operation was carried out to tap and drain the tanks. Recovery of this oil was completed in 1995. Details of the operation were summarized by the Norwegian State Pollution Control Authority (SFT 1995). More recently, the oil cargo on a naval oil tanker USS *Mississinewa*, sunk in 1944 within Ulithi Lagoon in the NW Pacific and leaking after a cyclone, was recovered (ASA 2003). ASA (2003) also reports the presence of another 1800 known WWII wrecks in the South Pacific alone, loaded with oils, chemicals and ordnance.

172 In United Kingdom waters, the wreck of *HMS Royal Oak*, a major second world war casualty sunk in October 1939, has been identified as a continuing source of beach pollution to Scapa Flow, an anchorage in the Shetland Islands (ACOPS 1998). Subsequent anecdotal evidence (Orcadian Daily News 2000) indicated that some 1000 tonnes of oil were contained in the wreck and were leaking at a rate of between 300-500 litres per day. Efforts to tap into the hull and remove the oil are planned following the failure of hull patches and collection devices to contain the oil. However, the planned operations are complicated by the fact that the wreck is a designated war grave for the 833 men killed when the vessel was torpedoed and sunk.

173 In general, reliable estimates of actual and potential oil losses to the marine environment from military vessel casualties are rendered impossible by the same factors that apply to merchant vessels. Records are unlikely to exist of smaller casualties such as landing craft and barges and while WWI & II Allied losses are likely to be well documented, the same is not true of vessels lost by the other combatants e.g. in the Pacific theatre. In addition and not surprisingly, no reliable records of bunker contents at the time of the sinking exist. Finally, a large number of ships were scuttled at the end of both WWI and WWII as part of disarmament programmes and also to dispose of surplus munitions and chemical weapons. However, it seems probable that bunkers were largely emptied prior to scuttling, and some of the vessels were towed to the sites where they were scuttled.

174 As noted above, the occurrence and location of sunken vessels is also linked to the occurrence of pelagic and littoral tar (Section 5.8). The tar may be coming from both historic ship losses (i.e. marine casualties as discussed above) and the operation of ships today. Distinguishing between "old" and "new" sources of oil is now possible using modern, oil chemistry, fingerprinting techniques (Page *et al.* 1995, and others). This becomes important if tar amounts and distributions are used to monitor ship pollution and/or the effectiveness of MARPOL and other regulatory instruments, i.e. coastal oiling may reflect old wrecks still containing oil cargo or bunkered fuel oil, rather than or in addition to existing oiling events.

175 In general, therefore, it is not possible to derive reliable estimates for oil lost at sea by marine casualties and the annual inputs coming from these sources. Some indication of the scale of the problem can be determined by simply assuming that a fixed amount of oil has been lost with each vessel. Given the total casualties of approximately 23,000 ships since 1939, and assuming that between 1 tonne and 100 tonnes of oil was lost with each wreck, results in an aggregate estimate of between 23,000-2.3 million tonnes of total oil lost at sea with these vessels. The accuracy of these estimates is impossible to ascertain, but even the upper bound value is plausible.

176 Given their frequent location near coastlines and the aging condition of the wrecks, further research should be immediately directed to quantifying the oil input from war-related casualties (sunken vessels) with greater precision, and the degree to which this poses a future risk to the marine environment.

3.4 Dry docking of ships

3.4.1 Tankers

177 NRC (1985) and MEPC (1990) determined that some 4,000 tons of oil discharges were coming from dry-docking. Since the 1990 report, a number of changes have again occurred which would affect these estimates, such as the Enhanced Survey Program (ESP) that sets tighter requirements for oil tankers and dry bulkers.

178 For the majority of dry-dockings, it will not be necessary to clean the cargo tanks. Twice every 5 years, according to current regulations (circa 2003) (T.J. Gunner, pers. comm.), tankers have to visit a repair yard with dry-docking facilities in order to re-coat their anti-fouling system. Also, it will not always be necessary to desludge all tanks at a single dry-docking.

179 Notwithstanding MARPOL 73/78's improvement of enforcement procedures, oil refineries now require tankers to carry out the minimum COW requirements as provided in MARPOL. The application of COW removes sludge from a tanker's cargo tanks, so that it may be discharged to shore receiving tanks. The minimum COW requirement is, on average, 60% of the cargo tank capacity for the non-SBT tankers and 25% for the SBT and double hull tankers. The vessel will normally perform tank cleaning while on a ballast leg of a voyage, or while en route to the dry dock.

180 Taking into account the above factors, it is estimated that of the world's tanker fleet of 321.1 million dwt (circa 2001), 2% of the tankers discharge sludge/slop amounting to 0.2% of their dead weight prior to and during their dry-docking. Under MARPOL 73/78 regulations, this waste should be disposed of at shore-based reception facilities. Owing to the lack of statistics on delivery of slops to these facilities, 0.2% remains as the worst-case discharge scenario. This figure was 0.2% in the 1990 report (MEPC 1990); owing to increased efficiency in COW, there is no reason to believe that this will have increased. Dry docking intervals would be twice every 5 years. Hence, the annual discharge of oil that is discharged into the sea from dry docking of tankers becomes:

321.1 million dwt x 0.02 x 0.001 x 12/30 = **2569 tonnes/yr. or ~2600 tonnes/yr.**

3.4.2 Other vessels

181 MEPC (1990) does not deal with other vessels, on the assumption that the quantity of oil discharged into the sea from such operations would be negligible. Under the IMO's Enhanced Survey Programme (IMO Assembly Resolutions A.744 & A.746), dry bulker ships (totalling 8680 in number, Fairplay Database 2000) will be subjected to stricter maintenance programmes than in earlier years, hence requiring more hot work, i.e. structural work with torches, adjacent to fuel oil tanks. These tanks will thus need cleaning and gas freeing for hot work. Thus, it is reasonable to expect that 2% of the dry bulkers will discharge approximately 10 tonnes sludge and tank washing prior to dry-docking, or upon entry into the dry-docking yards. Again, this is the worst-case scenario owing to the requirement

under MARPOL to unload waste oils at the dry dock or to a reception facility on shore. The annual discharge due to dry-docking into the sea then becomes:

8680 ships x 10 tons x 0.02 x 0.2 = **347 tonnes/yr. or 350 tonnes/yr.**

In summary, the total oil discharge during dry docking = **2916 tonnes/yr. or 2900 tonnes/yr.**

3.5 Recycling of ships

182 In this study, the term 'ship recycling' applies to the breaking up and dismantling of ships at the end of their useful life. In the majority of cases, this is carried out on beaches on the Indian sub-Continent. Furthermore, as issues of concern under IMO and ILO bodies, the practice of "ship scrapping" has been referred to as "Recycling". This is further validated as it is estimated that 95% of a vessel will be reused or recycled.

183 The focus on ship demolition is now placed on beach operations as recycling sites, rather than on berth operations. Recycling is very labour-intensive and there is very little concern for workers' safety and protection of the environment. Workers are exposed to many toxic chemicals and fumes, there are physical hazards, and chemicals enter the local air and water. Bangladesh, China, India, Pakistan and Vietnam are the main breaking centres, using beaches and cheap labour. Health and environmental issues associated with recycling are now being actively addressed through IMO.

184 When a single hulled, non-STB tanker reaches 25 years of age, it will have to be upgraded, or proceed to demolition. When this category of tanker reaches 30 years of age, it can no longer trade, and will go for demolition. Thus, a massive scrapping or recycling of tankers can be anticipated in the coming years. INTERTANKO estimates that 25 tankers will be phased out in 2003, 97 in 2004, 142 in 2005, 134 in 2006 and 71 in 2007 (Hydrostatic Balance Loading Publication, August 1997), a total of 469 tankers over 5 years.

185 Ships going for demolition in India will need to arrive gas-free (i.e. slop-free) for hot work. Those proceeding to Pakistan and Bangladesh can be delivered 'gas-free for tank entry'; that means the ships are not cleaned out and thus they will have sludge and oily residues onboard. This condition can be obtained by slightly ballasting cargo tanks. Tankers sold for demolition are mostly cleaned and made slop free using facilities that are available in Fujairah (United Arab Emirates) and Singapore. To become gas-free, large tankers will normally generate between 500 to 1000 tons of slops for delivery to reception facilities. These slops have a commercial value.

186 Two categories of oil can be established to calculate the quantities of oil discharged into the marine environment during scrapping operations:

.1 fuels, hydraulic oils and lubricating oils (all ships); and
.2 cargo residues and oil sludge (tankers).

3.5.1 Hydraulic oils, lubricating oils and fuels (all ships)

187 Hydraulic and lubricating oils have a considerable second hand value owing to their initial high cost. They are being recovered from the ships for resale (DNV 1999). Two types of fuel will remain on board when a vessel is sent for recycling, fuel oil for the main engines and marine diesel oils (MDO) for the generators. The majority of breaking yards specify a common quantity to be available on board the vessel before it is beached. Common requirements call for one day's worth of fuel oil (estimated at 60 tonnes for a diesel engine VLCC) and 8 days worth of MDO to be on-board when the vessel is to be beached.

188 Owing to the high value of the fuel oil (US$180/tonne, based on 2000 figures), fuel oil will be recovered for re-sale and re-use. The MDO will be used up on board during the breaking procedure to run generators for powering tools and lighting. What remains after breaking will be transferred and used for smaller generators on shore or will be sold.

189 The engine waste oil (i.e. oil sludge) remaining on board would be found in the sludge tank. This would have little or no value and would need to be disposed of elsewhere. It can be assumed that the majority of the oil sludge would end up in the marine environment. In the 1999 DNVPS study, it was estimated that for a 290,000 dwt tanker, some 5m^3 (4.5 tonnes) of oil sludge would remain in the sludge tank. Alternatively, this can be expressed as 0.00156% of oil sludge per ship and applied to the year 2000 dead weight numbers, i.e. 21.2 million dwt. Thus, the amount of oil disposed of, from all ships while being recycled, is:

21.2 million dwt* x 0.0000156 = **330 tonnes/yr.**
(*estimated dwt of all ships being recycled per year)

3.5.2 Cargo residues/oil sludge (tankers)

190 Industry sources state that an average VLCC has some 600 tonnes of oil, mixed with sand and rust, remaining in its cargo tanks. Based on the DNVPS figures for a VLCC, this equates to 0.2% oil cargo remaining on board a tanker before being sent for recycling. On the basis that:

1. some of this oil has some residual value and is received by the breaking yard for re-sale or re-use; and

2. tankers being sent for scrapping in locations requiring gas-free conditions have to remove most, if not all, oil residues in the cargo tanks (in 2000, 38% of tankers went for scrapping in India where legislation requires gas freeing), there is approximately 50%

removal of the waste cargo oil. This would bring the percentage estimate in line with MEPC (1990), where 0.1% waste oil from each tanker cargo was calculated as discharged into the marine environment. The following estimation, using year 2000 tanker scrap numbers from Intertanko, i.e. 14.5 million dwt, can be given for cargo oil entering the marine environment during recycling:

14.5 mill dwt x 0.001 = **14,500 tonnes/yr.**

191 The estimate of total oils (of all types), therefore, entering the marine environment from ship scrapping and recycling is: **14,830 tonnes/yr. or 14800 tonnes/yr.**

3.6 Operational discharges from ships operating under sovereign immunity

192 Under Article 96 of the United Nations Convention on the Law of the Sea (UNCLOS, 1982), ships owned or operated by a State and used only on governmental non-commercial service "shall, on the high seas, have complete immunity from the jurisdiction of any State other than the flag State". More obviously, warships on the high seas also have complete immunity under Article 95 of UNCLOS. Each State is expected to act in accordance with treaty provisions for the protection of the marine environment. For this study, it has been impossible to find data that relate specifically to this area only, i.e. oil discharged on the high seas during routine operations of all types of vessels operating under sovereign immunity. Moreover, it is assumed that the discharges of these vessels have already been included under other inputs in this report, and would likely be negligible to prevent detection.

3.7 Deliberate discharges of oil to save life at sea

193 Under the MARPOL 73/78 Convention (IMO 1997a), steps taken to save life at sea include the deliberate discharge of oil if required, i.e. oil can dampen wave activity around a stricken boat or vessel. While this practice is not banned under the convention, there are no reliable records of this type of incident. It is believed that this type of discharge occurs very rarely, if it occurs at all, therefore, for this report the annual input is assumed to be zero.

4 EXPLORATION AND PRODUCTION IN THE OFFSHORE

4.1 Introduction

194 The development of established hydrocarbon reservoirs and the identification and development of new ones continues to play a major role in the oil and gas sector. Between 25 and 30% of global production is estimated to come now from offshore reservoirs, with the principal producing areas being located in the Gulf of Mexico, the North Sea, Brazil and West Africa. There is also offshore production in Southeast Asia and Australia. Technological advances in surveying, drilling and production have allowed a substantial move to deepwater locations; these fields are likely to become more important in future years.

195Some 6,000 oil and gas installations are presently operating in the marine environment. These include fixed steel and concrete structures, floating steel and concrete structures, and sub-sea production units. Many of these structures are manned; however, a significant number are unmanned. The fixed and floating structures range in size from a few thousand tonnes, to in excess of half a million tonnes for the large concrete structures, e.g. Hibernia, and structures placed in sea areas prone to seasonal ice and icebergs e.g. off Newfoundland. More recently, with the advent of deep water technology, there has been a move away from traditional structures fixed into the sea-bed to custom built, Floating Production, Storage and Offloading units (FPSOs) which, though anchored at a production site, are capable of being moved to different areas more easily than ‘conventional’ structures. The global distribution of platforms in the marine environment is shown in Figure 38. By far the greatest number of installations (>4000) is located in the Gulf of Mexico, with smaller numbers in other producing areas. Figure 38 does not identify production platforms in Atlantic Canada (*ie* Scotian Shelf and Grand Banks, with at least 7 platforms to date).

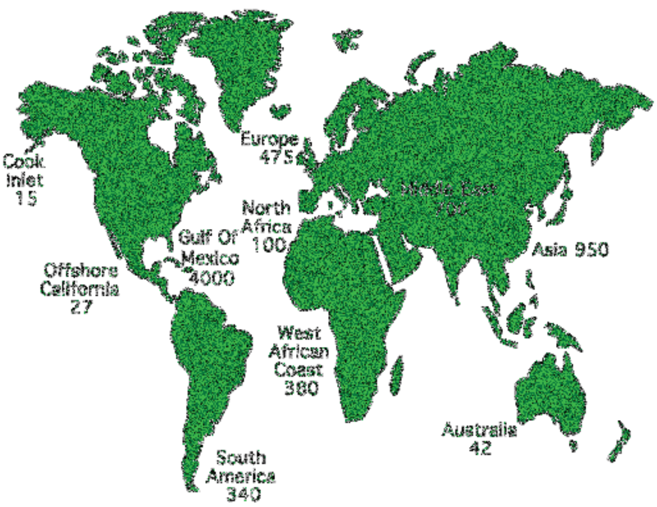
196 Exploration for and exploitation of offshore hydrocarbon reserves have a number of discrete phases. Surveying the underlying geological structures involves non-invasive acoustic techniques; there are no releases of hydrocarbons during this phase of the process. Following identification of potential deposits, exploratory drilling may be initiated to determine whether there are economically recoverable hydrocarbons in the prospects. During exploration drilling, cuttings contaminated with oil-based drilling fluids may be discharged to the sea, although it is frequently in the companies’ economic interests to maximise the re-use of otherwise expensive drilling fluids. During appraisal drilling and possibly during extended well testing, produced fluids (Gas and Oil) may need to be flared for safety reasons. Further releases of contaminated cuttings can be expected during both appraisal drilling and eventually from the development of production well systems. However, the major discharge of hydrocarbons will take place during the production phase. There are no collated data on hydrocarbon discharges during exploration drilling with which to develop a global input estimate.

4.2 Operational discharges from offshore installations

4.2.1 Machinery space discharges

197 Discharges of oily water from machinery spaces fall under the purview of MARPOL 73/78, except where stricter national regulations apply. This imposes a concentration standard and disposal requirements in relation to rate of release and dilution. Such discharges are thought to be minimal.

Figure 38. Worldwide distribution of offshore oil and gas platforms (circa 2000)



Consequently, there appears to be no requirement to report monitoring data to regulatory agencies. In some instances, for operational reasons, drainage space discharges are blended into produced water streams and are treated in that process train.

4.2.2 Drilling discharges

198 Drilling fluids play essential roles in providing for the safety and effectiveness of the drilling process. Drilling fluids are the means for maintaining pressure on the formations being drilled, removing cuttings from the borehole, protecting and supporting the borehole wall, protecting permeable zones from formation damage, and cooling and lubricating the drill bit and drill string.

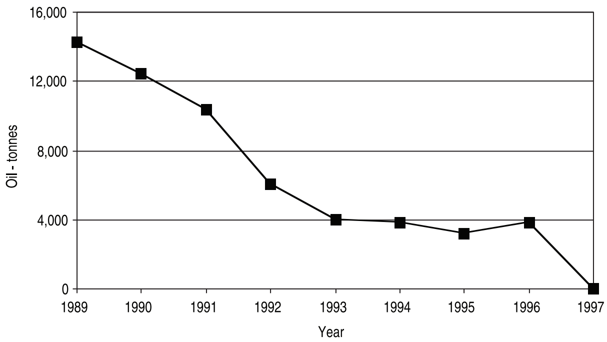
199 Three basic types of drilling fluids are currently in use: water-based fluids, oil-based fluids and synthetic-based fluids. Oil-based fluids are used when drilling conditions require more stabilization of the borehole, greater lubricity, and more resistance to thermal degradation than are provided by water-based fluids. They are often used where specific problematic formations may be encountered. Oil-based fluids are frequently used in offshore drilling operations because the well paths are deviated, rather than vertical, in order to reach distant parts of the reservoir from a fixed drilling location. Deviated wells typically have increased requirements for lubricity and well bore stability compared to vertical wells.

200 Almost twenty years ago, concern was expressed that diesel oil-based drilling fluids had adverse effects on the marine environment. In some producing areas, these concerns initiated regulatory action to curtail their discharge[16]. As a consequence of these regulatory activities, discharges of cuttings contaminated with diesel oil-based mud have almost completely ceased in the areas covered by those regulations (see Table 24). Moreover, oilbased muds, introduced as substitutes for diesel-based systems, have also fallen under regulatory control.

201 The phase out of the discharges of oil-contaminated cuttings in the North Sea is illustrated in Table 24 (data compiled by OGP 1999) and Figure 39.[17]

202 Data on use and discharge of cuttings contaminated by oil-based muds are not available for other producing areas, beyond Europe, North America and Australia where both use and discharge have almost ended.

Figure 39.
Inputs of oil on cuttings into the North Sea



4.2.3 Produced water discharges

203 Water occurs naturally in geological oil reservoirs and is extracted from formations along with the hydrocarbons. Produced water and hydrocarbons are separated at the site of production by physical and chemical techniques. The water phase may be re-injected into the reservoir to maintain pressure and thereby to enhance recovery. At some locations, where the subterranean geology permits, produced water can be re-injected as a means of disposal. However, for geological and other reasons, this is option is not widely available, and treated produced water containing small (10^3 x ambient) amounts of dispersed and dissolved oil is most often discharged at sea (Neff 2002; Lee et al. 2005).

204 In the initial stages of exploiting a hydrocarbon deposit, production water volumes may be low. As the field matures, however, volumes of production water usually rise and in mature areas, water amounts of in excess of 90% are not unusual.

205 In many producing areas, local and/or regional regulatory authorities have imposed a quality standard for oil in produced water. Numerical standards range from approximately 30 mg oil per litre of produced water, to approximately 100 mg l^{-1}.

Table 24. Input of oil into the North Sea of oil-based fluids on drill cuttings, in tonnes

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Oil on cuttings - tonnes	14,248	12,385	10,332	6,089	3,948	3,820	3,180	3,826	?

[16] In the case of drilling discharges, 'oil' released refers to oil used in the drilling fluid and not fluids arising from the formations being drilled.
[17] In 2000, the OSPAR Commission covering the Northeast Atlantic, including the North Sea, adopted a Decision which prohibits the discharge of cuttings contaminated with Oil-Based Muds, unless the concentration of fluid on cuttings is less than 1%.

In others, discharge targets or standards have not been established. However, it is clearly in the operators' interests to maximize the separation of oil (product) from water, if only from an economic perspective. Care must be taken, however, in making direct comparisons between the numerical standards defined in different regions. Since oil is a complex mixture of organic components, analysis of oil in water is non-specific and results of determinations will be dependent upon the analytical method used. Thus, numerical differences in standards do not necessarily reflect different regional views on environmental protection. Consequently, for this and other reasons, care must be taken comparing and combining input estimates from different producing regions.

206 There are relatively few comprehensive records of discharges of oil in produced water that can be incorporated into this study. However, those that are available (e.g. Neff 2002) cover the principal offshore production provinces and can indicate the relative magnitude of oil from offshore E&P activities in relation to other sources.

207 Data from the United States Minerals Management Service (USMMS) (Dannenberger, pers. comm. to J. Campbell) for the Gulf of Mexico show that, in 1996 and 1997, the input of produced water into the marine environment was approximately 72 million cubic metres. Less than 5% of produced water that was generated was re-injected into the reservoir. The produced water volume equates to an annual oil input of approximately **2,900 tonnes**, assuming an oil content of 40 mg oil per litre of water.[18] In Australia, average annual releases of oil in production water have been estimated as **1,450 tonnes** (again on the basis of a mean concentration of 40 mg oil per litre of water).

208 In the North Sea, oil-producing reservoirs are approaching maturity and volumes of produced water are increasing. Very little produced water is re-injected into formations for disposal purposes. Figure 40 shows the increase in volume of produced water discharged over the last seven years. Inputs of oil to the North Sea via produced water discharges are shown in Table 25 and Figure 41. Predicted increases in the volume of produced water can be translated into predictions of oil input to the North Sea of around **12,000 tonnes** (by 2002).

Figure 40.
Produced water discharge to the North Sea

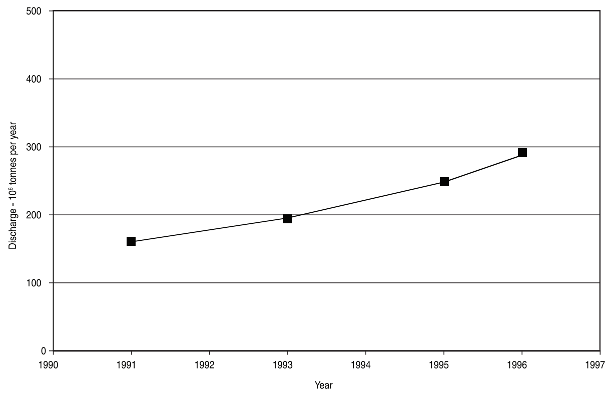
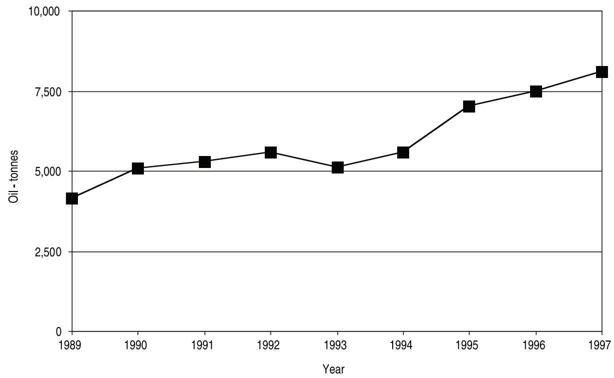


Figure 41.
Input of oil from produced water discharges to the North Sea



209 The input data reported above reflect the situation in only a portion of the offshore producing areas – the Gulf of Mexico and the North Sea. Data are unavailable in published form for other producing areas, making it difficult or impossible to extrapolate to global input estimates. Amounts and composition of production water will vary from reservoir to reservoir, within reservoirs and as the reservoir matures (Neff 2002). In relation to produced water, for example, it is necessary to understand the profile of water production in each of the areas for which data have not been available. Moreover, the data for some areas where reports are available are largely worst case estimates, since calculations of load have assumed discharge at the existing regulatory limit.

Table 25. Oil inputs to the North Sea from discharges of produced water

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Oil discharge - tonnes	4119	5058	5289	5572	5108	5589	6998	7465	8109

[18] Data supplied by the United States Environmental Protection Agency conflict with MMS data. Total volume of produced water discharged annually is estimated as twice that provided by MMS.

Improving the quality and coverage of the data requires more thorough involvement of the regional regulators, industry associations and oil companies. This presupposes that the appropriate data are required to be collected, i.e. that there is a regulatory requirement. There are also constraints on extrapolating input information on discharges of drilling fluids associated with cuttings. The most reliable information will be obtained on a field-by-field basis.

210 In 1997, the governments of Netherlands and Brazil co-hosted a conference of international experts on the effects of offshore activities on the environment. The conference was an initiative under the umbrella of the United Nations Commission on Sustainable Development. A major outcome of this conference was the recognition that greater transparency was required of offshore activities. The Oil and Gas Industry is currently considering the mechanisms by which this transparency might be achieved, including the development of performance indicators that are likely to include input statistics.

211 Using the above average figures from the Gulf of Mexico (2,900 tonnes/yr.), Australia (1,450 tonnes/yr.), and the North Sea (12,000 tonnes/yr.), the total estimated annual input of oil from offshore operations into the sea is estimated to be **16,350 tonnes/yr, or ~16,400 tonnes/yr**.

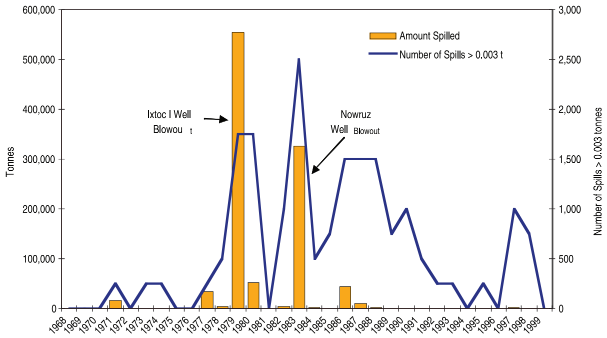
4.2.4 Air emissions (Non-methane volatile organic compounds or VOCs)

212 Since the extraction and processing of offshore oil deposits is a 'closed' system, losses of volatile components (VOCs) are considered to be minimal. Sources are the occasional venting and flaring of gases accumulated during the production process or during handling of the processed crude oil. Losses of VOCs during transfer of oil to cargo tankers are addressed in Section 3.1.6 and 3.1.7.

4.3 Accidental discharges from exploration and production activities

213 The estimated annual number of accidental marine spills from exploration and production activities, including spills from platforms, wells and rigs, but not including offshore pipelines (included in Section 4.4.2), and the amounts spilled from these sources, are shown in Figure 42. The largest known spillages from exploration and production sources to date occurred in 1979 and 1983. The 1979 spill was caused by the *Ixtoc I* exploratory well blowout; a total of 476,190 tonnes of oil spilled into the Gulf of Mexico off Ciudad del Carmen, Mexico, over 295 days. This is the largest spill from a single point source in recorded history. In 1983, the *Nowruz* well blowout in the Nowruz Field of Iran poured a total of 272,100 tonnes of oil into the Persian Gulf over 196 days. These spills were so large that each day of oil release was an amount equivalent to a significant ship spill. Each of these two blowouts is treated in this analysis as one continuous release and hence as one spill incident. Spillage rates for the *Ixtoc I* well blowout were estimated at 4,300 tonnes per day for the first 10 weeks of the spill. The spillage rate then slowed to 1,429 tonnes per day for three months after relief wells were dug. The rate slowed to 285 tonnes per day for the next three months, then to 57 tonnes per day for the last three weeks before the well was finally capped. Similarly, the *Nowruz* well released oil at a rate of 571-1,429 tonnes per day until it was capped six and one half months later. Data on such releases are generally self-reported estimates from industry, and seldom are ranges or confidence limits provided.

Figure 42.
Estimated Annual Oil Spills From Exploration & Production Facilities 1968-1999 (Based on Environmental Research Consulting Database)



214 Catastrophic exploration and production activity spills, such as the *Ixtoc I* spill of 1979-1980 that involved the spillage of more than 476,000 tonnes of oil, are even more rare than extremely large tanker spills. Although it was a rare event (one in 35 years), the *Ixtoc I* spill was the largest total amount of oil released from one man-made point source in recorded history. While the likelihood of another, extremely large, well blowout is extremely small and has been vastly reduced by current methodologies and technology, the possibility still exists and should be borne in mind. No very large exploration and production spills over 5,000 tonnes occurred in the period 1988-97.

215 While there have been no marine production and exploration spills over 2,000 tonnes during the past decade (the 1990s), there have been seven spills over 350 tonnes during this time period, all but one in the North Sea. In 1988, the *Piper Alpha* rig exploded in the North Sea off Aberdeen, Scotland, United Kingdom, spilling 750 tonnes of oil directly to the sea. Later that same year, a floating production platform spilled 1,500 tonnes in Fulmar oilfield, in the North Sea, off the United Kingdom. In 1990, a well in the Troll offshore oilfield in the North Sea, off Norway, spilled 361 tonnes during well testing. In 1992, a platform in the North Sea Statfjord oil field spilled 827 tonnes of oil off Norway due to an operational error. Also in 1992, the Greenhill Petroleum production well blowout off Timbalier Bay, Louisiana, USA, spilled 1,600 tonnes of oil into the Gulf of Mexico. Another North Sea platform spilled 500 tonnes in 1995 off Germany after structural damage by field operators. In 1997, a floating storage

platform named the *Captain Field* spilled 680 tonnes of oil in the North Sea in the United Kingdom sector of the North Sea.

216 The analysis resulted in an average input of **600 tonnes/yr.** into the marine environment from accidental releases from exploration and production activities during the years 1988-1997. There is no additional breakdown for larger spills since there were no spills in this range from exploration and production activities during this time period.

4.4 Pipelines

4.4.1 Operational discharges

217 Pipeline transmission of oil from offshore production sites to coastal refineries and distribution installations in some areas represents a major means of delivery. For example, almost 60% of the oil produced in the North Sea is delivered to land via pipeline. Operational discharges of oil from pipelines are small and occur during commissioning, maintenance and decommissioning phases. There are no published data available for routine, accidental discharges from pipelines. Major releases only occur as a result of accidents.

4.4.2 Accidental releases from pipelines

218 Figure 43 shows the estimated annual number of oil spills and amounts of oil spilled into the marine environment from accidental releases from offshore or coastal pipelines. The annual estimate of oil input during the period 1988-1997 is 2,800 tonnes. This spillage represents a slight increase in estimated annual amounts spilled compared to the previous two time periods, in which 1,800 tonnes of oil spilled annually from pipelines in 1968-1977 and 2,100 tonnes spilled annually in 1978-1987. The lower input values from the first time period are in large part due to incomplete reporting of pipeline spills. At the same time, estimated numbers of spills have risen sharply from an average of 47 spills per year in 1968-1977, to 188 spills per year in 1978-1987, to 228 spills per year during the last decade. This apparent increase in numbers of pipeline spills needs further examination.

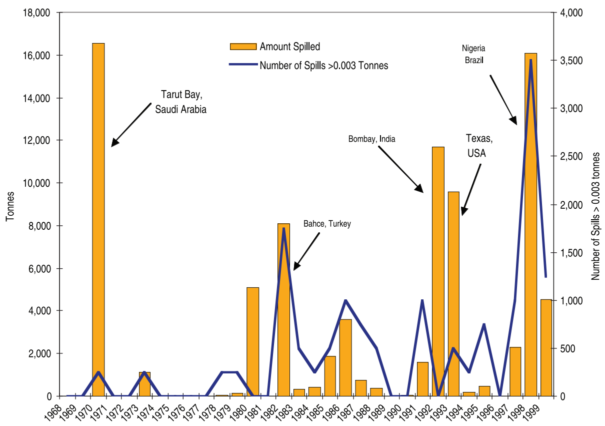
219 During 1988-1997, there were two offshore or coastal pipeline spills that involved more than 5,000 tonnes. There was a spill of 6,463 tonnes after an offshore pipeline ruptured in the Arabian Sea off Bombay, India, in 1993, and a spill of 5,497 tonnes of oil from several pipelines in the San Jacinto River estuary in Houston, Texas, USA, after flood damage in 1994. Relative to catastrophic vessel spills, such pipeline spills are rare, comprising only 4.9% of spills over 5,000 tonnes in the last 10-year period.

220 Prior to this period (1988-97), three other very large marine pipeline spills were reported: a spill of 22,950 tonnes into the Gulf of Mexico, after a ship's anchor damaged an offshore pipeline off Grand Isle, Louisiana, USA, in 1967; a rupture of a coastal pipeline that spilled 14,290 tonnes of oil into Tarut Bay, Saudi Arabia, in 1970; and a coastal pipeline rupture into the Mediterranean Sea at Bahce, Turkey, in 1982. Large pipeline spills occurred during 1998 in both Nigeria and Brazil, accounting for the large peak in that year; these incidents are not included in the overall spill input analysis which was limited to 1988-1997.

221 Taking into account inputs from these larger incidents, the pipeline input estimates are as follows:

900 tonnes/yr. in <5,000-tonne spills
plus an average of 1,900 tonnes/yr. in spills >5,000 tonnes
for an overall average input from pipelines of **2,800 tonnes/yr.**

Figure 43.
Estimated Annual Oil Spills from Marine Pipelines 1968-1999 (Based on Environmental research Consulting)



4.5 Offshore exploration and production - summary

222 The estimated annual inputs of oil from offshore exploration and production are **19,750 tonnes/yr. or ~20,000 tonnes/yr.** This is certainly an under estimate of unknown magnitude, due to the absence of data from many areas of the world where the offshore industry is operating under less demanding regulatory regimes than in the North Sea and the Gulf of Mexico, the areas upon which the input numbers were estimated.

5 OTHER INPUTS OF OIL INTO THE SEA FROM SEA-BASED ACTIVITIES AND RELATED TOPICS

5.1 Coastal refineries, oil storage facilities and marine terminals

5.1.1 Operational oil inputs from coastal refineries

223 Some oil and oil-derived compounds leave refinery facilities in wastewater effluents. This is water that is extracted from the crude oil itself or is used in various processes in the refinery. Concentrations of oil in the effluents are generally in the order of several parts per million (ppm, measured as total oil and grease, or as total petroleum hydrocarbons). Oily effluents can be treated in wastewater treatment systems and/or by oil/water separators before the water is introduced into the receiving estuarine or coastal environment.

224 Many countries have laws and regulations limiting the amount of oil that can be present in such effluents. Not all refinery operators abide by these rules and enforcement of regulations varies by location. Theoretically, the amount of waste oil that enters the sea from refinery effluents should be minimal in a fairly modern and well-maintained facility. In most developed countries, the effluents contain on average 5 ppm of oil. In developing countries and countries with refineries that are not well maintained or are operated under compromised conditions, oil concentrations in the effluents are often as high as 25 ppm.

225 An estimate of the total amounts of oil entering the marine environment due to operational spillage from coastal refineries is shown in Tables 26 and 27 for coastal countries having refineries and for the 18 regions shown in Figure 6. Estimates are based on the total crude refining capacities of coastal or estuarine refineries (Table 26). The following assumptions were made:

.1 refineries produce, on average, 4.5 units of wastewater per unit of refining capacity, as shown by CONCAWE (1994) and EDF (Epstein et al.1995) studies;

.2 effluents contain 5 ppm to 25 ppm of oil, depending on the condition and operating practices of the refineries; and

.3 refineries operate all year round.

226 Based on these assumptions, the estimated maximum total annual input of oil into the marine environment from refineries would be approximately 180,000 tonnes of oil per year. The actual number could be as low as one-quarter to one-half of this amount if the less efficient refineries were actually releasing less than 25 ppm of oil in their effluents and were operating on a less than full-time schedule. The best estimate is, therefore, **45,000-180,000 tonnes/yr**. A median value for oil inputs from refineries would be **112,500 tonnes/yr, or 113,000 tonnes/yr.**

5.1.2 Accidental releases from coastal facilities

227 Figure 44 shows the estimated annual number of oil spills and amounts of oil spilled into the marine environment from accidental releases from coastal facilities. The spill number appears to have decreased over the last decade, while the spill amount has stayed fairly constant over the last three decades, with the notable exceptions of the years 1978, 1981, and 1991. The average annual input is **2,400 tonnes/yr.**

228 Notable facility oil spills include: the 1974 spill of 39,500 tonnes from the Mizushima Refinery in Kurashiki, Japan; a 1978 spill of 11,430 tonnes after an explosion in a Texaco storage facility in Los Angeles, California, USA; an earthquake-related spill of 60,200 tonnes from a Tohoku Oil facility in Sendai, Japan, in 1978; a spill of 21,430 tonnes of oil from a storage depot in Beira, Mozambique in 1979; a 1980 spill of 10,714 tonnes from a Petroleos Mexicanos facility in Coatzacoalcos, Mexico; a spill of 106,000 tonnes from a Kuwait Oil terminal in Shuybah, Kuwait, in 1981; a spill of 11,565 tonnes from a Texaco tank farm in Newark, New Jersey, USA in 1983; and a spill of 34,286 tonnes from the Refineria Las Minas in Colon, Panama, in 1986.

229 War-related incidents involving coastal facilities are included in estimates of overall war-related spillage. This is particularly important in relation to estimates of inputs into the Arabian (Persian) Gulf, given the hostilities of 1991 and 2003.

5.2 Reception facilities

230 Oily waste that is generated onboard ships has often been regarded as "waste" for disposal. It is the oil from all of the sources identified in Sections 3.1 and 3.2 – from oil recovered from ballast water, to oil in machinery spaces aboard tankers and non-tankers, to fuel oil sludge.

231 Reception facilities exist in many countries, intended for the receipt of these oily wastes (IMO 2000; Intertanko 1996a; 1997; 1998b). A variety of separating techniques for oily waste are in use at reception facilities; these include filtration, centrifuges, flotation and separation from water in large settling tanks and ponds (Intertanko 1996a; 1998b). Disposal techniques for oily waste at the facilities include landfill, sludge farming and incineration. However, there is also wastewater that after filtering should contain no more than 5 ppm oil. Such treated wastewater will be discharged into the sea.

Table 26. Estimated Maximum Coastal Oil Refinery Effluent Output[1] Regional Estimates (1988-1997) (Source: Etkin, Environmental Research Consulting)

Region Number	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
1	2,562,900 bpd 366,129 tpd	168,943,805,200 gal 639,454,221 m^3	844,662 gal 2,873 t
2	743,920 bpd 106,274 tpd	49,038,462,400 gal 185,611,137 m^3	1,225,980 gal 4170 t
3	2,236,665 bpd 3189,524 tpd	153,371,430,200 gal 580,512,605 m^3	766,752 gal 2,608 t
4	11,174,650 bpd 1,596,379 tpd	736,621,753,400 gal 2,788,121,701 m^3	8,891,442 gal 30,243 t
5	2,140,505 bpd 305,786 tpd	141,254,292,200 gal 534,064,910 m^3	3,527,412 gal 11,998 t
6	1,651,328 bpd 235,904 tpd	108,853,890,300 gal 412,013,211 m^3	2,647,470 gal 9,005 t
7	4,557,840 bpd 651,120 tpd	300,448,255,100 gal 1,137,200,057 m^3	1,502,046 gal 5,109 t
8	1,227,100 bpd 175,300 tpd	80,889,204,890 gal 306,166,559 m^3	1,4458,534 gal 4,961 t
9	7,624,289 bpd 1,089,184 tpd	502,585,506,800 gal 1,902,291,850 m^3	6,641,166 gal 22,589 t
10	1,644,380 bpd 234,911 tpd	108,395,885,100 gal 410,279,656 m^3	2,709,798 gal 9,217 t
11	695,550 bpd 94,221 tpd	45,849,960,470 gal 173,542,621 m^3	1,146,306 gal 3,899 t
12	4,560,500 bpd 651,500 tpd	28,345,169,920 gal 107,286,790 m^3	142,002 gal 483 t
13	123,350 bpd 17,621 tpd	8,131,108,764 gal 30,776,339 m^3	203,154 gal 691 t
14	581,853 bpd 83,122 tpd	38,355,167,890 gal 145,174,746 m^3	958,734 gal 3,261 t
15	4,213,800 bpd 601,971 tpd	277,769,482,100 gal 1,051,360,644 m^3	6,943,986 gal 23,619 t
16	1,616,052 bpd 230,865 tpd	106,528,531,900 gal 403,211,703 m^3	2,663,052 gal 9,058 t
17	10,891,400 bpd 1,555,914 tpd	717,950,196,700 gal 2,717,449,647 m^3	12,054,294 gal 41,001 t
18	782,300 bpd 111,757 tpd	51,568,433,670 gal 195,187,107 m^3	368,970 gal 1,255 t

[1]Estimates represent *maximum* values based on assumptions that refineries operate at full capacity year-round, effluents are 5 ppm or 25 ppm oil depending on national laws and practices, and refineries produce 4.5 units of wastewater per unit refining capacity; actual discharges may be as low as 25-50% of these amounts if refineries on less than full-time schedule.
[2]Figures derived from PennWell Oil Directories.
[3]Estimates based on independent study by Etkin (1999) using assumptions above; CONCAWE Report 3/94 *Trends in Oil Discharged With Aqueous Effluents from Oil Refineries in Western Europe – 1993 Survey*; Environmental Defense Fund (Epstein, L. , S. Greetham, and A. Karuba) 1995, *Ranking Refineries.*

Table 27. Estimated Maximum Coastal Oil Refinery Effluent Output National Estimates (1988-1997) (Source: Etkin, Environmental Research Consulting)

Country	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
Albania	40,000 bpd 5,714 tpd	2,636,760,121 gal 9,980,167 m^3	65,915 gal 224.20 t
Algeria	530,000 bpd 75,714 tpd	34,937,070,089 gal 132,237,207 m^3	873,389 gal 2,970.71 t
Angola	32,100 bpd 4,586 tpd	2,115,999,993 gal 8,009,084 m^3	52,896 gal 179.92 t
Argentina	709,485 bpd 101,355 tpd	46,768,541,596 gal 177,019,461 m^3	1,169,162 gal 3,976.74 t
Australia	698,000 bpd 99,714 tpd	46,011,461,965 gal 174,153,906 m^3	230,058 gal 782.51 t
Bahrain	243,000 bpd 34,714 tpd	16,018,317,070 gal 60,629,512 m^3	400,440 gal 1,362.04 t
Bangladesh	31,200 bpd 4,457 tpd	2,056,673,826 gal 7,784,530 m^3	51,415 gal 174.88 t
Barbados	3,000 bpd 429 tpd	197,756,870 gal 748,512 m^3	4,945 gal 16.82 t
Belgium	607,000 bpd 86,714 tpd	40,012,832,933 gal 151,449,027 m^3	200,064 gal 680.49 t
Brazil	1,402,520 bpd 200,360 tpd	92,452,715,772 gal 349,934,579 m^3	2,311,216 gal 7,861.28 t
Brunei	8,500 bpd 1,214 tpd	560,311,397 gal 2,120,785 m^3	14,006 gal 47.64 t
Bulgaria	300,000 bpd 42,857 tpd	19,775,699,986 gal 74,851,249 m^3	494,370 gal 1,681.53 t
Cameroon	42,000 bpd 6,000 tpd	2,768,598,035 gal 10,479,175 m^3	69,211 gal 235.41 t
Canada	778,900 bpd 111,271 tpd	51,344,309,111 gal 194,338,793 m^3	256,721 gal 873.20 t
Chile	143,700 bpd 20,529 tpd	9,472,560,222 gal 35,853,748 m^3	236,802 gal 805.45 t
China	2,200,000 bpd 314,286 tpd	145,021,800,072 gal 548,909,160 m^3	3,625,385 gal 12,331.24 t
Columbia	264,400 bpd 37,771 tpd	17,428,983,644 gal 65,968,901 m^3	435,705 gal 1,481.99 t
Congo	21,000 bpd 3,000 tpd	1,384,298,885 gal 5,239,587 m^3	34,607 gal 117.71 t
Costa Rica	15,000 bpd 2,143 tpd	988,784,880 gal 3,742,562 m^3	24,720 gal 84.08 t
Croatia	143,472 bpd 20,496 tpd	9,457,530,676 gal 35,796,861 m^3	236,429 gal 804.18 t
Cyprus	18,600 bpd 2,657 tpd	1,226,093,283 gal 4,640,777 m^3	30,652 gal 104.26 t
Denmark	183,500 bpd 26,214 tpd	12,096,136,499 gal 45,784,014 m^3	60,482 gal 205.72 t

Table 27. (cont'd)

Country	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
Dom. Rep.	48,000 bpd 6,857 tpd	3,164,112,040 gal 11,976,200 m^3	79,101 gal 269.05 t
Ecuador	147,000 bpd 21,000 tpd	9,690,092,990 gal 36,677,112 m^3	242,241 gal 823.95 t
Egypt	532,153 bpd 76,022 tpd	35,078,993,574 gal 132,774,389 m^3	876,937 gal 2,982.78 t
El Salvador	15,100 bpd 2,157 tpd	995,376,935 gal 3,767,513 m^3	24,884 gal 84.64 t
Ethiopia	18,000 bpd 2,571 tpd	1,186,542,015 gal 4,491,075 m^3	29,662 gal 100.89 t
Finland	200,000 bpd 28,571 tpd	13,183,800,079 gal 49,900,833 m^3	329,580 gal 1,121.02 t
France	1,851,430 bpd 264,490 tpd	122,044,414,315 gal 461,939,494 m^3	610,223 gal 2,075.59 t
Gabon	24,000 bpd 3,429 tpd	1,582,056,020 gal 5,988,100 m^3	39,549 gal 134.52 t
Germany	409,000 bpd 58,429 tpd	26,960,871,033 gal 102,047,203 m^3	134,805 gal 458.52 t
Ghana	26,600 bpd 3,800 tpd	1,753,445,466 gal 6,636,811 m^3	43,835 gal 149.10 t
Greece	395,500 bpd 56,500 tpd	26,070,964,587 gal 98,678,897 m^3	651,745 gal 2,216.82 t
Guatemala	16,000 bpd 2,286 tpd	1,054,704,101 gal 3,992,067 m^3	26,366 gal 89.68 t
Honduras	14,000 bpd 2,000 tpd	922,865,924 gal 3,493,058 m^3	23,070 gal 78.47 t
India	1,046,827 bpd 149,547 tpd	69,005,789,019 gal 261,187,695 m^3	1,725,069 gal 5,867.58 t
Indonesia	860,200 bpd 122,886 tpd	56,703,523,944 gal 214,623,482 m^3	1,417,527 gal 4,821.52 t
Iran	1,089,300 bpd 155,614 tpd	71,805,566,617 gal 271,784,885 m^3	1,795,061 gal 6,105.65 t
Iraq	318,500 bpd 45,500 tpd	20,995,210,479 gal 79,467,076 m^3	524,858 gal 1,785.23 t
Ireland	56,000 bpd 8,000 tpd	3,691,463,959 gal 13,972,233 m^3	18,457 gal 62.78 t
Israel	221,000 bpd 31,571 tpd	14,568,098,964 gal 55,140,420 m^3	72,841 gal 247.76 t
Italy	2,420,358 bpd 345,765 tpd	159,547,578,952 gal 603,889,398 m^3	797,737 gal 2,713.39 t
Jamaica	32,000 bpd 4,571 tpd	2,109,407,939 gal 7,984,133 m^3	52,732 gal 179.36 t
Japan	4,470,650 bpd 638,664 tpd	294,700,777,454 gal 1,115,445,789 m^3	1,473,504 gal 5,011.92 t
Kenya	90,000 bpd 12,857 tpd	5,932,709,811 gal 22,455,374 m^3	148,311 gal 504.46 t

Table 27. (cont'd)

Country	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
Korea, N.	42,000 bpd 6,000 tpd	2,768,598,035 gal 10,479,175 m^3	69,211 gal 235.41 t
Korea, S.	1,147,100 bpd 163,871 tpd	75,615,684,909 gal 286,206,226 m^3	1,890,308 gal 6,429.62 t
Kuwait	368,000 bpd 52,571 tpd	24,258,191,954 gal 91,817,532 m^3	606,428 gal 2,062.68 t
Lebanon	37,500 bpd 5,357 tpd	2,471,962,465 gal 9,356,406 m^3	61,796 gal 210.19 t
Liberia	15,000 bpd 2,143 tpd	988,874,880 gal 3,742,562 m^3	24,720 gal 84.08 t
Libya	348,400 bpd 49,771 tpd	22,966,179,714 gal 86,927,251 m^3	574,129 gal 1,952.82 t
Lithuania	266,600 bpd 38,086 tpd	17,547,005,402 gal 66,517,810 m^3	439,330 gal 1,494.32 t
Madagascar	16,350 bpd 2,336 tpd	1,077,775,631 gal 4,079,393 m^3	26,942 gal 91.64 t
Malaysia	263,000 bpd 37,571 tpd	17,336,696,999 gal 65,619,595 m^3	433,397 gal 1,474.14 t
Martinique	16,000 bpd 2,286 tpd	1,054,704,101 gal 3,992,067 m^3	26,366 gal 89.68 t
Mexico	1,524,000 bpd 217,714 tpd	100,460,555,949 gal 380,244,345 m^3	2,511,404 gal 8,542.19 t
Morocco	154,600 bpd 22,086 tpd	10,191,077,485 gal 38,573,344 m^3	254,766 gal 866.55 t
Myanmar	32,000 bpd 4,572 tpd	2,109,407,939 gal 7,984,133 m^3	52,732 gal 179.36 t
Netherlands	1,230,500 bpd 175,786 tpd	81,113,329,447 gal 307,014,873 m^3	405,567 gal 1,379.48 t
Neth. Antilles	470,000 bpd 67,143 tpd	30,981,930,039 gal 117,266,957 m^3	774,514 gal 2,634.40 t
New Zealand	84,300 bpd 12,043 tpd	5,556,971,704 gal 21,033,201 m^3	27,786 gal 94.51 t
Nicaragua	16,000 bpd 2,286 tpd	1,054,704,101 gal 3,992,067 m^3	26,366 gal 89.68 t
Nigeria	433,250 bpd 61,893 tpd	28,559,406,792 gal 108,097,679 m^3	713,953 gal 2,428.41 t
Norway	285,200 bpd 40,743 tpd	18,800,098,685 gal 71,158,587 m^3	94,001 gal 319.73 t
Oman	80,000 bpd 11,429 tpd	5,273,519,979 gal 19,960,333 m^3	131,833 gal 448.41 t
Pakistan	120,975 bpd 17,282 tpd	7,974,550,977 gal 30,183,766 m^3	199,356 gal 678.08 t
Panama	100,000 bpd 14,286 tpd	6,591,899,907 gal 24,950,416 m^3	164,790 gal 560.51 t
Peru	188,820 bpd 26,974 tpd	12,446,825,539 gal 47,111,376 m^3	311,158 gal 1,058.36 t

Table 27. (cont'd)

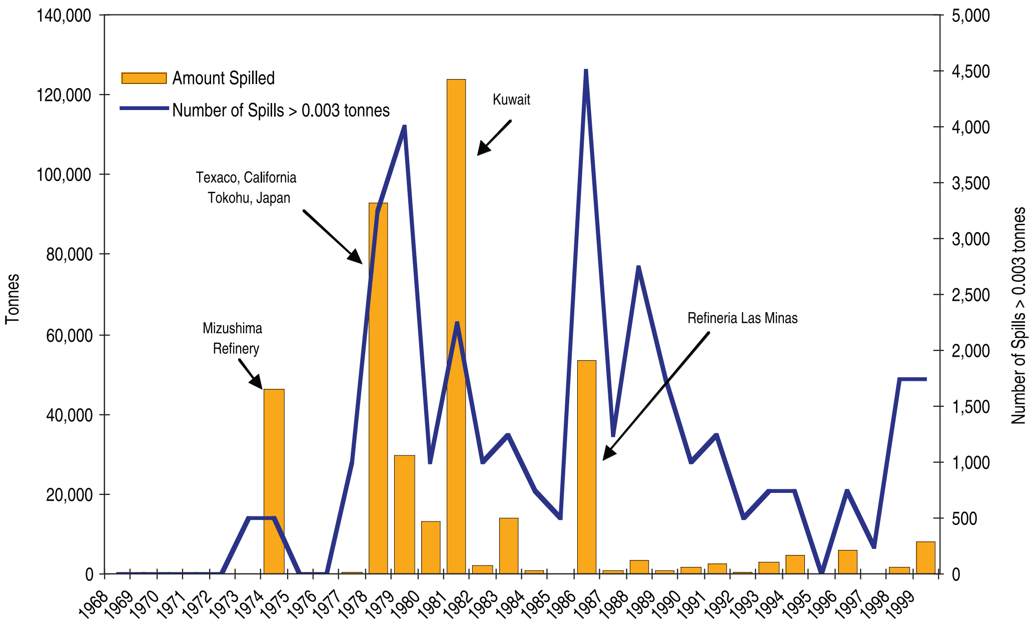
Country	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
Philippines	278,450 bpd 39,779 tpd	18,335,145,463 gal 69,474,434 m^3	458,858 gal 1,560.74 t
Poland	333,000 bpd 47,571 tpd	21,951,026,881 gal 83,084,886 m^3	548,751 gal 1,866.50 t
Portugal	294,000 bpd 42,000 tpd	19,380,185,981 gal 73,354,224 m^3	484,483 gal 1,647.90 t
Puerto Rico US	127,000 bpd 8,143 tpd	8,371,713,062 gal 31,687,029 m^3	41,860 gal 142.38 t
Qatar	60,000 bpd 8,571 tpd	3,955,140,050 gal 14,970,250 m^3	98,875 gal 336.31 t
Romania	733,102 bpd 104,729 tpd	48,325,350,664 gal 182,912,001 m^3	1,208,081 gal 4,109.12 t
Russian Fed.	630,800 bpd 90,114 tpd	41,581,705,109 gal 157,387,226 m^3	1,039,496 gal 3,535.70 t
Saudi Arabia	1,862,500 bpd 266,071 tpd	122,774,137,621 gal 464,701,505 m^3	3,069,219 gal 10,439.52 t
Senegal	22,600 bpd 3,229 tpd	1,489,769,375 gal 5,638,794 m^3	37,244 gal 126.68 t
Sierra Leone	10,000 bpd 1,429 tpd	659,190,096 gal 2,495,042 m^3	16,479 gal 56.05 t
Singapore	1,029,000 bpd 147,000 tpd	67,830,650,933 gal 256,739,784 m^3	1,659,692 gal 5,767.66 t
Slovenia	14,700 bpd 2,100 tpd	969,009,246 gal 3,667,711 m^3	24,226 gal 82.40 t
Somalia	10,000 bpd 1,429 tpd	659,190,096 gal 2,495,042 m^3	16,479 gal 56.05 t
South Africa	430,500 bpd 61,500 tpd	28,378,129,542 gal 107,411,542 m^3	141,890 gal 482.62 t
Spain	1,301,328 bpd 185,904 tpd	85,782,240,407 gal 324,686,754 m^3	428,911 gal 1,458.88 t
Sri Lanka	50,000 bpd 7,143 tpd	3,295,949,954 gal 12,475,208 m^3	82,396 gal 280.26 t
Sudan	21,700 bpd 3,100 tpd	1,430,442,208 gal 5,414,240 m^3	35,759 gal 121.63 t
Sweden	427,500 bpd 61,071 tpd	28,180,372,526 gal 106,663,030 m^3	140,902 gal 479.26 t
Syria	237,394 bpd 33,913 tpd	15,648,774,982 gal 59,230,791 m^3	391,202 gal 1,330.62 t
Thailand	220,550 bpd 31,506 tpd	14,538,435,381 gal 55,028,143 m^3	363,446 gal 1,236.21 t
Trinidad	246,000 bpd 35,143 tpd	16,216073,941 gal 61,378,024 m^3	405,385 gal 1,378.86 t
Tunisia	34,000 bpd 4,857 tpd	2,241,246,116 gal 8,483,142 m^3	56,028 gal 190.57 t
Turkey	713,580 bpd 101,940 tpd	47,038,480,020 gal 178,041,181 m^3	1,175,912 gal 3,999.70 t

Table 27. (cont'd)

Country	Coastal Refinery Daily Crude Capacity[2] Barrels per day (Tonnes per day)	Estimated Annual Effluent Output[3] US Gallons (m^3)	Estimated Annual Oil Discharge in Effluent[3] US Gallons per year (Tonnes per year)
United Arab Emirates	192,500 bpd 27,500 tpd	12,689,407,374 gal 48,029,551 m^3	317,220 gal 1,078.98 t
United Kingdom	1,842,640 bpd 263,234 tpd	121,464,986,198 gal 459,746,352 m^3	607,325 gal 2,065.73 t
United States of America	10,606,215 bpd 1,515,174 tpd	699,151,086,688 gal 2,646,294,802 m^3	3,495,754 gal 11,890.32 t
Uruguay	28,500 bpd 4,071 tpd	1,878.691,590 gal 7,110,869 m^3	46,967 gal 159.75 t
Venezuela	1,167,000 bpd 166,714 tpd	76,927,473,048 gal 291,171,359 m^3	1,923,101 gal 6,541.16 t
Virgin I. US	545,000 bpd 77,857 tpd	35,925,854,970 gal 135,979,769 m^3	179,628 gal 610.98 t
Yemen	114,500 bpd 16,357 tpd	7,547,725,573 gal 28,568,227 m^3	188,686 gal 641.79 t
Yugoslavia	444,233 bpd 63,462 tpd	29,283,395,109 gal 110,837,983 m^3	732,054 gal 2,489.98 t
Others	542,500 bpd 77,500 tpd	35,761,057,578 gal 135,356,009 m^3	893,986 gal 3,040.77 t
TOTAL	**54,893,382 bpd 7,841,912 tpd**	**3,618,516,849,000 US gal 13,696,127,360 m^3 p/yr.**	**52,786,962 US gal p/yr. 179,547.49 tonnes p/yr.**

[1]Estimates represent *maximum* values based on assumptions that refineries operate at full capacity year-round, effluents are 5 ppm or 25 ppm oil depending on national laws and practices, and refineries produce 4.5 units of wastewater per unit refining capacity; actual discharges may be as low as 25-50% of these amounts if refineries on less than full-time schedule.
[2]Figures derived from PennWell Oil Directories.
[3]Estimates based on independent study by Etkin1999 using assumptions above; CONCAWE Report 3/94 *Trends in Oil Discharged With Aqueous Effluents from Oil Refineries in Western Europe – 1993 Survey*; Environmental Defense Fund, Epstein, L, S. Greetham, and A. Karuba, 1995, *Ranking Refineries.*

Figure 44. Estimated Annual Oil Spills From Coastal Facilities 1968-1999 (Based on Environmental Research Consulting Database)



232 The IMO has data on reported reception facilities (MEPC 1990; Carpenter and Macgill 2003). There is no established international standard applicable to discharges from reception facilities. The Oslo and Paris Commission has agreed on an OSPAR recommendation for reception facilities with a throughput above 5 tonnes of oil per year; this limits the oil content in effluents from reception facilities in North West Europe to 15 mg oil/litre of effluent (PARCOM Recommendation 87/2).

233 Reception facilities are thought to be a significant coastal, sea-based, i.e. from ships, source of oil(s) into the marine environment. However, no regional or global statistics on oil content and volumes of their discharges were found. Hence, it is not possible at this time to estimate an average annual input of oil into the sea from reception facilities worldwide.

5.3 Oil in waste materials dumped at sea

234 The presence of oil in sediments and dredging spoils from harbours, usually described as polycyclic aromatic hydrocarbons (PAHs) of all kinds, is considered to be in such low total quantities as to not be a significant oil input, for the purposes of this study (Robert Engler, USA, pers. comm.). Consideration of this input would best fit under land-based activities, in any event. Such oil inputs are regulated internationally under the London Convention, 1972.

5.4 Fuel dumps from aircraft

235 Aircraft inputs of oil into the sea were considered, more to determine the magnitude of this source than to include it as a ship or other sea-based activity source. They are almost always overlooked as a source input of hydrocarbons to the sea. Slicks formed from aviation fuel could be taken, initially, as a boat or ship-originating source; chemical analysis would sort out the origin, but time and resources might be lost in the investigation.

236 Aircraft sometimes dump aviation fuel (jet fuels, largely kerosenes) prior to landing. This is either as part of normal practice to lighten aircraft weight if a plane has to return to an airport unexpectedly, or in extreme emergencies to reduce risks of fire and explosion if a disabled aircraft is attempting to land (e.g. Swiss Air 111, Sept.1998, off Peggy's Cove, Nova Scotia, Canada). Such practice is regarded by operators as an uncommon event (British Airways 2000a). Dumping may take place over water bodies if they are close by; this sometimes occurs over the lower Great Lakes (M. Fingas, pers. comm. to D. Etkin). Selection of a dumpsite over water theoretically minimizes the potential hazards to humans. There apparently are no accurate collated statistics publicly available regarding the frequency of fuel dumps, site locations and quantities on a global basis. Military aircraft in the United States were required to report non-combat fuel jettisoning events between 1973 and 1978 as part of a study conducted over 3? years. This study reported some 1000 jettisoning incidents per year for the US Air Force as a whole (Clewell, 1980). In addition, discharges of unburned fuel are possible as a result of design/operational characteristics of individual engines, generally in vapour form. For example, one airline operating a fleet of some 277 aircraft reported losses of unburned hydrocarbons of 3,100 tonnes *per annum* for the period 1999-2000 (British Airways 2000a & b).

237 Released fuel is likely to evaporate to some degree and, therefore, not reach the earth's surface. Also, weather conditions and fuel type will likely influence deposited quantities (see: Clewell, 1983; Good & Clewell 1979). In an evaluation of the potential hazard of fuel jettisoning, the US Agency for Toxic Substances and Disease Registry (ATSDR 1999) considered that more than 98% of fuel released at an altitude of 1,500m and at above freezing temperatures would evaporate before reaching the ground. Moreover, at warmer temperatures, no liquid fuel was detected on the ground when fuel had been released at 750m altitude.

238 Hence, although fuel jettisoning by aircraft is a recognized hydrocarbon-oil source input to the sea (though not usually considered a sea-based activity), the lack of collated statistics means that estimates of input amounts are not available or possible to calculate accurately. For this reason and the presumed infrequency of the events, this activity is considered unlikely to constitute a significant input of oil to the oceans.

5.5 Small craft activity

5.5.1 Outboard engines

239 Small, predominantly leisure, craft[19] are significant users of fuel oils and lubricants. They are a potentially important source of oil and hydrocarbons into the sea. While it is anticipated that large spills of outboard fuels are comparatively rare and will have been captured in existing statistics, it is probable that hydrocarbons will be lost during refuelling and fuel transfer activities. Over-priming and choking of outboard engines by inexperienced or incompetent operators can also lead to losses of fuel from carburettors and of lubricating oils to marine waters. While these losses are comparatively minor, the very large number of outboard engines globally means that they are collectively of significance. Based upon the analysis of tricyclic terpanes, contamination of sediments and biota with outboard lubricating oils could be clearly differentiated from automotive lubricants in a Canadian study, testifying to the potential significance of these inputs and the interest in monitoring such contamination (Bieger *et al.* 1996).

[18] For the purposes of this study, small craft are those operating on either 2 or 4-stroke engines. In the context of regulating organotin-containing marine paints, previously used on small boats, small craft are those 25 m or under, in length, at the waterline.

240 The use of outboard engines, the design of which changed little in the past 50 years until very recently (NRC 2003), is known to introduce oil derived hydrocarbons to the waters in which they operate (Wachs *et al.* 1992; Wachs & Wagner 1990; Juttner *et al.* 1995). These derive both from partially combusted fuels and from lubricants. Outboard motors operating on a two-stroke cycle have been particularly studied and in many cases these engines introduce the exhaust directly below the water surface. One early study (Coates & Lassanske 1990) based upon a notional average duty cycle and conducted by outboard motor manufacturers suggested that a 70-horsepower two-stroke engine would emit 1.5kg of hydrocarbons per hour of use, comprising around 8.3% of the fuel/lubricant mix consumed (19-23 litres or 5-6 US gallons per hour). Subsequently, published data (USEPA 1991) showing substantially higher hydrocarbon emissions from two-stroke outboard motors of the order of 25-30% of the fuel consumed and these engines are considered to be the second largest average non-road engine contributors to national emissions of hydrocarbons, emitting some 30% of the total (see USEPA 1996). Very recently, however, i.e. in the past 5 years (NRC 2003), manufacturers claim a reduction in emissions of 50-80% from outboard motors (Walker, pers. comm.), a fact not considered in the calculations below.

241 Other figures reported in the literature for smaller engines (10 horsepower) indicate that between 205-483g of unburned hydrocarbons are emitted per litre of fuel consumed. This is dependent upon design and operating characteristics (see: Wachs *et al.* 1992; Wachs & Wagner 1990). These figures are consistent with those derived by the USEPA (1991). One of the first estimates produced of the significance of outboard engine emissions drew on the estimates of Coates and Lassanske (1990) to produce a lower bound value and a higher bound value was derived according to USEPA (1991) with a number of additional assumptions (Mele 1993).

242 Mele (1993) assumed that a 70 horsepower outboard (considered a typically sized engine) emits around 8.3% of the fuel and lubricant mix consumed as a lower bound, and as an upper bound emits 25% of the mix at a 20% flat throttle setting. Further, it was assumed that 8 million recreational craft, two-thirds of the total registered in the US, make 80 million trips annually and that each trip consumes an average of 20 US gallons a trip (i.e. 10 trips per boat annually of around 4 hours duration). Thus, the annual outboard motor fuel consumption in this sector can be estimated at 1.6 billion gallons. These assumptions appear to be reasonable. This translates to a total hydrocarbon emission into air and water of between 133 and 400 million gallons annually. If it is assumed that one gallon equates to 2.81 kilos, this translates to emissions of between 374,818 (~375,000) tonnes and 1,127,272 (~1,100,000) tonnes of hydrocarbons per annum into air and water in the US alone. It was estimated based on a 1980 study that there are 800,000 outboard engines in use in Canada (see: Warrington, 1999). Making the same assumptions applied to the US situation, a range of between 37,481 (~37,000) and 112,272 (~112,000) tonnes of hydrocarbons are emitted into air and water by such engines in Canada annually.

243 Estimates of the US emissions can be arrived at in an alternative manner using figures provided by the USEPA (1991). This report estimates that typical annual operation of between 74-142 boats with outboard engines will generate 10 tonnes per annum of hydrocarbons into air and water. On the basis of the eight million boats existing in the US of this type, this translates to between 563,380 tonnes and 1.081 million tonnes annually into air and water, of the same order of magnitude as the estimates made by Mele (1993).

244 Considerable uncertainties exist in the above estimates, in addition to those introduced by assuming operation patterns and fuel consumption and annual usage. They arise from the fact that differences in emissions can result from the use of synthetic as opposed to mineral oil lubricants (see Wachs *et al.* 1992) and from the substitution of normal gasoline with other fuels such as alkylate-based petrol/gasoline (see: Ostermark & Petersson, 1993). In addition, the use of MTBE may also modify the emission profile (Gabele & Pyle 2000). Finally, the above estimates make no allowance for particulates emitted and the hydrocarbons (particularly PAH) associated with these (see Kado *et al.* 2000), nor the relative proportions of hydrocarbons entering air and water, respectively.

5.5.2 Inboard engines

245 Four stroke engines comprise a small proportion of outboard engines but inboard and stern drive engines are mainly of this type. These engines, which burn gasoline/petrol, emit a wide variety of hydrocarbons (aromatic hydrocarbons and aldehydes, as analysed in water) in the exhaust (Juttner, 1994; Kado *et al.* 2000). However, the design and operational characteristics of the inboard engines mean that combustion efficiency is greater and lubricant losses are significantly less than with outboard engines (USEPA 1991; 2000). Many inboard engines emit exhaust above the water surface but often through a port carrying the engine cooling water as well. Diesel marine engines, in common with their counterparts in terrestrial use and in common use in many countries, will likely emit similar hydrocarbons (no analysis was found of such emissions to water), although such engines are primarily of concern due to their particulate emissions (USEPA 1999).

246 For the US, Mele (1993) made the assumption that 4 million US leisure water craft are powered by stern-drive/inboard engines and that the additional fuel consumption amounts to 0.8 billion gallons per year. Assuming that emissions of hydro-

carbons are a maximum of 8.3% of hydrocarbons consumed (the lower bound estimated for two-stroke motors), this accounts for an additional 187,127 (~187,000) tonnes of hydrocarbon inputs, to air and water, per year from leisure craft in the US. This is probably an extreme scenario. It is generally considered that the emissions from 4-stroke engines are an order of magnitude less than those from a 2-stroke engine of equivalent power (USEPA 1991; Juttner *et al.* 1995). Assuming, emissions of around 2.5% of fuel consumption, this implies 56,363 (~56,000) tonnes of hydrocarbons per year in the US entering the air and water from leisure water craft.

5.5.3 Small craft activity: Overview

247 Estimates of hydrocarbon emissions to the air and aquatic environments in the US of up to 1.12 million tonnes annually from 2-stroke marine engines (Range 374,818-1.12 million tonnes) and around 187,000 tonnes (Range 56,363-187,127 tonnes) from four stroke inboard engines represent a maximum input, due to fate of introduced hydrocarbons and the partitioning between air and water not being quantified. Sources of potential uncertainty in the estimates include:

.1 average usage and engine load factors may be subject to considerable variation on a local and seasonal basis;

.2 hydrocarbons emitted through engine exhaust, even below the water surface as is the case with most outboard engines, are likely to be only partially retained in the water column since some components are highly volatile. It is necessary to determine the relative proportions of hydrocarbons staying in the water and entering the air and staying airborne, in order to make exact estimates of the hydrocarbon contribution to the water column;

.3 it has been assumed that all outboard engines are of the 2-stroke type, whereas some (albeit a minority) operate on a 4-stroke cycle;

.4 not all engines are operated in the marine environment, and some will operate in environments with no direct connection with the sea;

.5 the assumption is that all engines are on average 70 horsepower, whereas some are of greater and some of lesser power. No breakdown of this is currently available; and

.6. no consideration has been made of commercial engine emissions.

248 It is not clear to what extent the small craft input estimates have relevance to other areas of the world. While small (leisure) craft are also numerous in other countries, no statistical breakdown with precise numbers appears to be available for countries outside the US and Canada. Assuming, conservatively, that the US has at least 10% of the global total of 2-stroke outboard motors, this leads to a global emission of hydrocarbons, to the air and water of aquatic environments, of 3.7-11.2 million tonnes annually. On the same basis, 4-stroke motors would emit in the range of 0.58-1.87 million tonnes of hydrocarbons. Totalling the top and bottom of each range leads to an estimate of 4.28-13.7 million tonnes, or 4.3-13.7 million tonnes of hydrocarbon emissions per year, to the air and aquatic environments.

249 It was not possible in our study to estimate the impact upon the above estimates of the fate of these hydrocarbons, nor the proportion emitted to marine waters as opposed to freshwater systems, nor the relative proportion in air versus water. It has simply been assumed that since these hydrocarbons are mostly introduced directly into the water from the exhaust, they represent *de facto* an input. If it is assumed that fully half of these emissions take place directly to marine waters, then a final (imprecise) estimate of inputs is between 2.14-5.6, or **a median of 3.9 million tonnes/yr.** Notwithstanding any imprecision in these estimates, it can be surmized that if the US situation is representative, then small marine engines, particularly those operating on a 2-stroke cycle, constitute a highly significant potential input of oil derived hydrocarbons to the marine environment on a global basis.

250 The NRC (2003) study developed an equation for loading estimates from recreational craft, based on the function of two-stroke engines, and considering the aromatic hydrocarbons that enter the water. Annual input estimates from two-stroke engines are "between 2,100 and 8,500 tonnes (average 5,300 tonnes) per year for coastal waters of the United States". Conservatively, if one adopts that estimate and it represents 10% of global total input from two-stroke engines (see above), a second estimate of annual input of oil from small leisure craft would be 10 x 5,300 tonnes or **53,000 tonnes/yr.**

251 Awareness of the significance of outboard and personal watercraft engines in relation to both air and water quality has resulted in legislation to bring these emissions under control. It is mandated in the US that all manufacturers must produce engines with 75% lower emissions by 2006 (see USEPA 2000). The precise impact of the regulations, staged over a period that began in 1998, will depend in part upon the degree to which older engines continue in use.

5.6 Natural oil seeps

252 Major inputs of oil into the sea occur from natural oil seeps in the seabed and oil entering from erosional processes in coastal land. Natural seeps contribute a major fraction; minor contributions are from erosional processes. Seeps were reviewed in NRC (1985, 2003) and in detail by Boehm

et al. (2000), Brown et al. (1996), Kvenvolden and Harbaugh (1983), MacDonald (1998), and Page et al. (1998).

253 The seepage of an area, i.e. the number of seeps per unit area and the rate for each seep, relates to its geological structure and the volume of associated sediment basins. Seeps are associated with regions of high tectonic activity, clustered within the continental margins where the thickness of sedimentary rocks that provide the needed source rocks for the seepage, exceeds a certain minimum. Thus, natural seeps occur along the Pacific Rim e.g. common in Alaskan waters, in central North America, in the Gulf of Mexico, in the eastern Arctic and around the Mediterranean Sea. These are known seeps, but it seems that many have not yet been discovered.

254 Oil seepage rates have been calculated, taking into account estimated oil deposits available for seepage within a reasonable geological time frame. Wilson et al. (1973a,b) made an estimate of 0.6 million tonnes/yr. The NRC Committee of 1975 made estimates of 0.2-6 million tonnes/yr. (NRC 1975). The NRC Committee on oil pollution, working from 1981-85, estimated that the average rate of oil seepage over time ranged from 0.02 to 2.0 million tonnes/yr., with a best estimate of 0.25 million tonnes/yr. (NRC 1985). Most recently, the NRC oil committee using the 1985 approach has determined the best estimate to be **600,000 tonnes/yr.** (NRC 2003; Kvenvolden 2004, pers.comm.), the same as Wilson's and NRC (1975) estimates, **with a range of 0.2-2 million tonnes/yr.** The estimate of oil entering the oceans each year from natural seeps may well increase as more seeps are discovered, particularly in Polar (Arctic, Antarctic) regions. The potential area of continental margins and oceanic spreading axes (see Kvenvolden and Simoneit 1990) where sub-marine seeps occur or may occur is vast, making a global inventory of seep inputs difficult with accuracy.

255 Crude oil entering the sea from natural seeps can be readily distinguished from other crude oils, as well as from other oil and hydrocarbon sources; qualitatively, it is also possible to distinguish sea-based sources of hydrocarbons from natural sources such as seeps and forest fires (Page et al. 1998). This is important not only for developing the overall oil input budgets, but also for determining the origin of tar in the ocean (pelagic and littoral) and quantitatively assessing its significance as an indicator of ship-based pollution (see Section 5.8 below).

5.7 Rocket launches

256 Rocket launches, though also not technically a sea-based source or activity, have the potential to introduce oil to the marine environment as a result of the release of unburnt propellant. No collated statistics exist but some data exist for individual projects. The environmental impact assessment of the "Sea launch" system which uses kerosene as a propellant, and which is designed to be launched from an offshore platform, suggests that stage 1 of this vehicle will contain some 2000kg of unused kerosene while stage 2 contains a residual 450 kg of this hydrocarbon propellant (ICF Kaiser, 1999).

257 While the second stage is expected to rupture or break up after separation from the main vehicle, this is only regarded as a possibility in the case of the first stage. Hence, while the residual contents of the second stage may be expected to evaporate high in the atmosphere (above 160km) in the case of the first stage, all or part of the residual kerosene may be expected to fall into the ocean after this stage separates at a height of 60km. The assessment (ICF Kaiser, 1999) predicts that any kerosene reaching the sea surface could be expected to form a slick covering several square kilometres. Given the volatile nature of kerosene, it is likely that the bulk will evaporate from the sea surface within a few hours and the hydrocarbons subsequently will degrade in the atmosphere.

258 Clearly, the actual tonnage of kerosene reaching the sea is dependent upon the number of launches and to what degree the detached stage maintains structural integrity after separation until impact in the sea. Projections indicate that some six launches per year are planned. Hence, potentially some 12 tonnes of kerosene could reach the sea surface annually. In the case of aborted launches, the quantities could be greater. The Sea Launch system at point of launch contains 89.7 tonnes of kerosene in the first stage, 22.9 tonnes in the second and 4.3 tonnes in the final stage. An aborted launch could cause all or part of this to enter the marine environment. In the industry, overall, there are no figures to indicate to what extent inputs of hydrocarbon propellant from rocket launches might be expected on a global basis. Hence, no input values are considered in this report in the context of ships and sea-based activities.

5.8 Tar distributions and their significance regarding inputs from ships

259 GESAMP's 1993 review of marine oil pollution as a global problem showed the ubiquitous nature of oiling and tarring of the world's beaches and coastlines (GESAMP 1993, p. 27-35). That review brought renewed attention to the potential impacts of oil inputs from ship-based activities, and concern about the regulatory effectiveness of MARPOL 73/78 and specific national legislation.

260 There is considerable information on the occurrence and quantities of tar on the world's seas and beaches (NRC 1985; GESAMP 1993; Butler *et al.* 1998). There are many tarred beaches around the world, from the Mediterranean to South East Asian seas. This oil is both weathered crude and refined heavy fuel product. It is highly persistent and in warmer locations contributes dissolved compounds

over time to the surrounding water and habitats. Often tar that reaches a shoreline is covered and uncovered in the annual cycles of the beaches, complicating monitoring programmes and data interpretation. Tar lumps and tar-sand patties can be buried in the sand of the supra-littoral zone of a coastline, probably for years (Butler and Wells, personal observations, Bermuda).

261 Tar reflects both natural and anthropogenic oil inputs. For example, in the Gulf of Mexico, tar is found along coastlines close to natural seep areas, which are very abundant in the Gulf (MacDonald 1998; also see Section 5.6). In contrast, in Bermuda, beach tar appears to reflect tanker ballast water discharges to the North Atlantic (Butler 1975; Butler *et al.* 1973, 1998), and may be showing an improvement, i.e. a reduction, in oil inputs from tankers plying the eastern North and mid-Atlantic as the oiling of Bermuda beaches has significantly declined in recent years (Butler *et al.* 1998; pers. observations and unpubl. data, BBSR).

262 Annual quantities of tar per coastline and per region are impossible to calculate globally with any accuracy, at this time, notwithstanding the large literature and considerable international interest in this topic (see Bibliography). For most locations, Bermuda perhaps being an exception, tar data are important primarily as a qualitative indicator of oil contamination, not as a quantitative indicator reflecting quantities entering the ocean. In this study, such inputs may be represented already in other discharge figures (Sections 3 and 4 above). The information on tar quantities, therefore, was not used in the overall oil inputs summary (Section 6).

5.9 Oil inputs from unidentified point sources

263 Oil inputs from unidentified point sources include vessel spills (illegal discharges), pipeline spills (leaks undetected by pressure meters or other pipeline technology), or unmapped natural seeps. This input is variable and unpredictable.

264 Figure 45 shows estimates on oil spills from unidentified point sources into the marine environment. Such spills generally involve a minor number of spills each year and, assuming the source is ships or pipelines, add a small amount of oil into the calculation for the total accidental input each year.

265 A notable exception was in 1980. Two large spills - one of 2,572 tonnes and one of 2,857 tonnes - in the Persian Gulf off Bahrain were reported and attributed to spills from “unidentifiable sources.” The spills were probably caused by war actions. Identity of the sources, whether tankers or oil facilities of some sort, was never verified by officials in the region.

266 The best estimate of oil input into the sea from unidentified point sources, during the years 1988-1997, is 200 tonnes/yr.

6 SUMMARY AND CONCLUSIONS

6.1 Summary

267 This section summarizes the above oil input sources, rationalizes the assignment and interpretive value of an average annual input figure for oil into the marine environment, and makes recommendations for future work.

268This study clearly shows the wide range of types and quantities of oil inputs from ship and sea-based activities, as well as the spatial and temporal variability of accidental spills globally.

269The estimated average annual inputs of oil into the sea, in tonnes per year for ships and other sea-based activities, based on the most recent 10 year-period of data available (1988-97) and the most recent published information, are shown in Table 28.

Figure 45.
Annual Amount of Oil Spilled From Unknown Sources 1968-1999 (Based on Environmental Research Consulting Database)

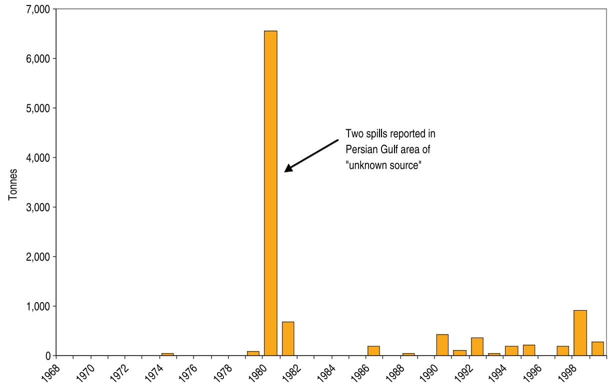


Table 28. Estimated Average Annual Inputs of Oil, in Metric Tonnes per Year (tonnes/yr. or t/yr.), into the Sea from Ships and Other Sea-based Activities. Data for accidents covered the 1988-97 period. Data are either calculated or measured. Large uncertainties of estimates are shown in brackets.

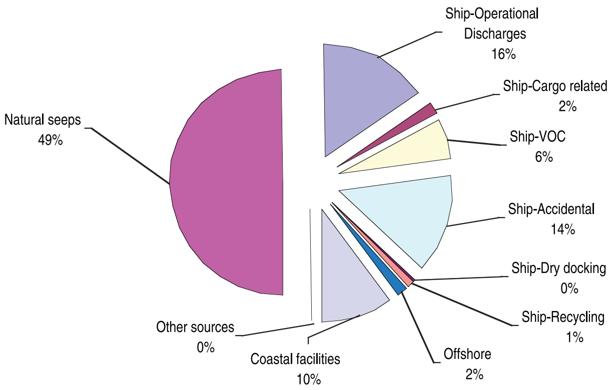
		Ranges(t/y)	Est.or Avg.(t/y)
(1) Ships - Discharges			
	Operational discharges		
	Machinery space bilge oil		1,880
	Fuel oil sludge		186,120
	Oily ballast (fuel tanks)		907
	Operational - cargo-related		
	Tank washing + oil in ballast		19,250
	VOC emissions-tankers	250-68,000	68,000
	Accidents		
	Tankers/barges	46,000-256,000	157,900
	Non-tankers		5,300
- Sunken ships (casualties)			[not possible to estimate]
- Dry docking			2,900
- Scrapping/recycling of ships			14,830
		Subtotal	(~ 457,000)
(2) Offshore E&P	Operational		16,350
	Accidents		600
	Pipelines		2,800
		Subtotal	19,750
(3) Coastal Facilities	Coastal refineries	45,000-180,000	112,500
	Accidents		2,400
		Subtotal	114,900
(4) Other Inputs			
(4.1) Reception facilities			no data
(4.2) Small craft activity		$2.14\text{-}5.6 \times 10^6$	3.9×10^6
OR using NRC (2003) methods			53,000
(4.3) Natural Seeps		0.02 – 2.0 x 106	600,000
(4.4) Other sources (unknown)			200
		Subtotal	> 653,200

Totals – ships (1) 457,000
- ships (1) plus offshore (2) 477,000
- ships (1) plus offshore (2) plus coastal facilities (3) 592,000
- small craft activity 53,000
- natural oil seeps 600,000
- GRAND TOTAL (minus oil seeps) .... 645,000 tonnes/yr.
- GRAND TOTAL (all inputs) .... 1,245,000 tonnes/yr.

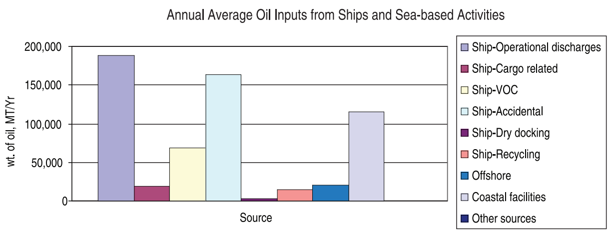
270 Table 28 and Figure 46 give an overview of the estimated quantities and relative proportions of the various oil inputs, keeping in mind the absence of confidence limits or ranges around most of the estimates, and the unpredictable annual occurrence of large shipping accidents. The greatest shipping inputs each year are from ships operational discharges (276,000 tonnes/yr.), including VOC emissions; shipping accidents (163,000 tonnes/yr.); and coastal facilities (115,000 tonnes/yr.). Small craft activity contributes a minimum of 53,000 tonnes/yr. Natural oil seeps also represent a very large input, at 600,000 tonnes/yr., and essentially the same tonnage input as the total of the shipping and small craft inputs combined (607,000 tonnes/yr.).

Figure 46.
Average annual inputs of oil into the sea from ships and other sea-based activities

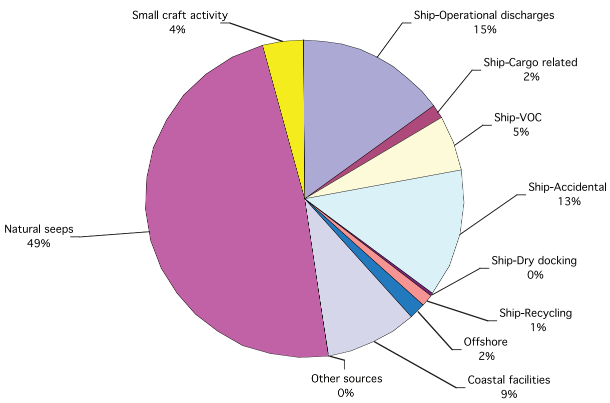
(a) by source, shown as proportions



(b) by source, shown in metric tonnes per year



(c) by source, as shown as proportions, and including small craft activity



271 Operational discharges from ships make up 45% of the input of 457,000 tonnes/yr. (ships), followed by shipping accidents at 36% of the input. Fuel oil sludge from vessels is the major routine operational input (186,120 or ~186,000 tonnes/yr.), or 68% of ship operational inputs. There are important ecological reasons to try to reduce this input, especially in coastal waters and in particularly sensitive marine areas of international importance for the conservation of wildlife. Oil tankers, which are often pointed at as major routine polluters, account for 10.3% of ship operational inputs, as tank washings and oil in ballast waters. Ship accidents are a major input still, even with the decline of large spills from tankers in recent years; they are a very variable source, and bad years can skew the statistics. Most accidents are coastal, and many are damaging to the ecology, regardless of spill size.

272 Coastal facilities contribute significantly to the combined inputs of ships, offshore and coastal facilities combined (19%), or 25.2% of ship inputs. VOC emissions make up 14.9% of ship inputs. Finally, offshore inputs, often considered by the public as a major input, represent a minimum of 4.1% of the total input from both ships and the offshore exploration and production (E&P) combined, or 4.3% of ship inputs. Estimates of oil inputs from this study can be compared with earlier estimates (Table 29).

Table 29.
Estimated inputs of petroleum hydrocarbons into the ocean due to marine transportation activities

	1981 (million tonnes)	1989 (million tonnes)	This study* 1988-97 (mt/jr.)
Tanker operations	0.7	0.159	0.087
Tanker accidents	0.4	0.114	0.158
Bilge and fuel oil discharges	0.3	0.253	0.189
Dry-docking	0.03	0.004	0.003
Marine terminals (including bunkering operations)	0.002	0.030	n.d.
Non-tanker accidents	0.02	0.007	0.005
Scrapping of ships	-	0.003	0.015
TOTAL:	1.47	0.57	0.46

Sources: NRC (1985); IMO (1990); *GESAMP 2004 (No. 75)
Adapted from GESAMP (1993).

273 This study, as a whole, shows that ship inputs of oil can be and have been reduced in recent years, through cleaner ships, the use of SBT, the use of reception facilities if available, and fewer accidents resulting in large spills. There has been significant progress reducing major sea-based activity inputs since the 1970s. While ship inputs continue to be reduced over the next few years, attention should also focus on reducing the contributions of coastal facilities, and small recreational crafts (small craft

activity). More effort is needed to ensure that legal operational inputs from ships in all regions are restricted to areas well away from aggregations of marine wildlife and sensitive marine habitats.

274 The marked decrease in operational discharges from ships over the last three decades and, in particular, over the last 10 years may be attributed to the greater ratification and subsequent implementation by shipping firms of MARPOL 73/78 requirements under Annex I. Aspects such as a decrease in permissible discharge limits on waste oil for all vessel types and the introduction of segregated ballast combined with the natural increase in newer tanker types (accelerated phase-out of pre-MARPOL tankers) will all contribute to a steady decrease in future years. Significant attention to the tanker sector owing to increased public attention following major spill incidents has meant that tanker monitoring by flag and port state authorities has been dramatically stepped up with consequent improvements in discharge quantities. In addition, requirements from responsible chartering parties means that most tankers should now comply with all international legislation as a minimum, thereby decreasing the non-compliance input percentage. Further improvements in fuel quality, engineering technology such as enhanced purification systems, and waste oil filtering equipment will see this decrease continue over the next decade (2000-2010). Aside from technical improvements adopted by the shipping industry, many management systems have also contributed to a greater awareness of environmental impacts and a decrease in discharges from shipping. The mandatory introduction of the International Safety Management Code for tankers in 1997 and the voluntary adoption of the ISO 14001 standard on environmental management will also be contributing factors to the decrease, and will be even more so in the future.

275 A significant input noted in the study, and not accounted for in the earlier MEPC Report (MEPC 1990), was the VOC contribution to oil in the marine environment. This previously unrecognized yet substantial contribution to both atmospheric and marine pollution has already been researched with regards to its reduction. Having carried out a significant proportion of the research into this emission, the tanker sector has already established a voluntary procedure known as the VOCON, the use of which can reduce emissions of VOC from the carriage of crude oil by up to 80%. The refinement and further adoption of this methodology should result in a further reduction in VOC emissions.

276 Significant efforts were made on the assessment of tanker related discharges owing to the detail and attention paid to this input category, i.e. operational inputs from ships, in previous studies. The continued scrutiny of this input has meant that a relatively accurate estimate of tanker discharge can be made, contrary to that of the other shipping sectors. The use of the Fairplay Database when acquiring fleet data for other vessel types may have limited the range which can be used and the potential for more or fewer numbers within each ship type to be given, i.e. the use of an alternative merchant fleet database may produce different estimates. The recently completed Bunker Convention highlights the growing attention to non-tank vessels and the increasing quantity of bunker fuel now being carried by some larger container and dry bulk ships, at times well in excess of moderately sized tankers. With the increasing diversity, size and speed of non-tank vessels, a future assessment would benefit from a more thorough investigation of this input category.

277 Small craft activity inputs are of considerable concern. They represent a significant input of oil-derived hydrocarbons to coastal waters, but there was no consensus as to how to make best estimates of this input, and global data on numbers of small craft were unavailable. This study finally took the conservative approach, using the latest estimates from the NRC (2003) report and projecting to a global figure of 53,000 tonnes that is included in the overall summary of inputs (Table 28). The inputs from small craft obviously represent a large input source of hydrocarbons to the coastal marine environment, much better methods for and estimates of global inputs are needed, and more regulation of inputs is required.

278 It proved impossible to make estimates of oil inputs from reception facilities. Reception facilities are considered by experienced mariners to be important oil input sources to coastal waters, but the input data are simply not available; it is known however that some facilities operate with good treatment, and many with little or none. It should be noted that ships are regulated for discharges of 15 ppm, whereas the comparable restriction (guidelines or regulations) for reception facilities is 30 ppm.

279 Sunken ships or casualties, particularly from past wars, represent a major threat to coastal environments, but annual inputs of oil are currently unknown. This problem is well recognized for island states in the southwest Pacific. It is important for governments to investigate sunken vessels containing oil within their EEZs, using risk assessment methodologies that take into account factors influencing hull corrosion (Hara, pers. comm.). The threat is serious enough to warrant concerted international assistance and action as soon as possible.

280 The input category “Unknown sources” proved to contribute small inputs. Oil seeps estimates were revised from the 1990 (MEPC) and earlier reports, following from NRC (2003).

281 A variety of other topics were assessed in Section 5, for completeness. Tar (i.e. tar balls and tar-sand lumps) is still found in many littoral (intertidal) and supra-littoral (above the tide mark) zones worldwide. Measuring the presence, quantities and composition of such tar in a number of carefully selected coastal and oceanic locations, involving local volunteers for the collections, may be one way

of monitoring ship's operational inputs and the effectiveness of both regulations under MARPOL 73/78, Annex 1, and relevant regulations of maritime States.

6.2 Data and information needs

282 From this study, it is clear that data on oil inputs from most shipping and other accidents can be obtained through existing mechanisms. In contrast, although reliable oil input data are available from oil production activities from the North Sea, North America, data are not readily available from key areas such as South America, the Gulf and South-East Asia. Hence, input estimates from this sector are in error by an unknown amount.

283 Similarly, reliable data are available on tanker operations from engineering-based calculations but data are lacking from operations and from shipping other than tankers. Other missing data that appear to be of major concern are the quantities of VOC releases during loading and unloading operations of tankers. It is known that there is a substantial release of VOCs during loading, but releases during transit and unloading are less well known and should be assessed. Quantities of VOCs entering the ocean along shipping lanes need to be verified.

284 There is also a need for global data on oil inputs from small pleasure craft (outboard and inboard engines). Given the growing numbers of small craft and their activities in more sensitive coastal waters, efforts should be made to obtain reliable data for these activities.

285 It is vitally important to have accurate estimates and measures of oil inputs into the sea, both to test the efficacy of regulations and the change of shipping and treatment practices on behalf of cleaner marine environments, and to facilitate ecological risk assessments of oil and its components in marine ecosystems, from polar to tropical regions. A permanent, international information facility is needed that can collate the available data and information on oil inputs and issue periodic reports.

7 RECOMMENDATIONS

286 The collection, analysis and interpretation of oil input data should be coordinated, taking advantage of existing institutional data bases of agencies and industry. How this is to be achieved should be considered by IMO, UNESCO-IOC, ITOPF and other relevant organizations as soon as possible. It is particularly important to have a mechanism for rapidly updating oil input statistics of all kinds, in relation to ships and sea-based activities.

287 IMO could be considered as the lead agency in this effort and take steps to co-ordinate relevant United Nations and other organizations to achieve the establishment of an 'Oil and the Marine Environment' facility. Such a facility would collect and collate long-term data sets, establish a database, integrate the database to a Geographical Information System, prepare periodical reports, and interrelate to other relevant international programmes of a similar nature, such as the Norwegian MarMil programme.

288 Evaluations of oil inputs from sea-based sources, as reported above, should be carried out on a regular basis of five years, and should cover decades (appropriate blocks) of time since the 1990s. However, prior to conducting further input analyses, a re-evaluation of methodologies, sources of data and information, and necessary expertise should be conducted, and considered to be separate from the complex and time-consuming task of compiling the various input statistics.

289 The maintenance and precision of oil separators on ships should be evaluated and enhanced, in order to control and reduce operational discharges of waste oils.

290 The databases on spills from non-tankers should be strengthened.

291 Data were unavailable in the study for discharges from reception facilities, and should be addressed. The data from reception facilities, which are considered crucial to solving the persistent sea-based oiling problem, should include location, level of treatment, volumes of oily water treated, and levels of total oil in discharges to coastal waters.

292 Oil inputs from small craft activity (i.e. recreational craft) should be extensively monitored and annually summarized. Organization and funding of such an effort needs to be discussed within IMO.

293 Oil inputs from sunken vessels (e.g. war-related casualties) should be selectively monitored, given the number and location of vessels near vulnerable coastlines, and the ageing condition of the wrecks. The risks that such inputs pose to marine coastlines, living resources and ecosystems should be addressed with considerable urgency, given the aging condition of many WWII wrecks, and actions taken to reduce those risks.

294 An international coastal tar-monitoring programme should be initiated, to provide an up-to-date global picture of chronic oiling of coastal waters and coastlines from sea-based activities, i.e. shipping and natural sources (oil seeps). This would provide a measure of the long-term effectiveness of both international and national pollution regulations and guidelines followed by the shipping and oil industries. Tar monitoring could be accompanied with shoreline seabird monitoring, as in the Canadian BOAS (birds oiled at sea) programme.

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Initials pertain to members of the working group who contributed definitions for terms not found in standard reference works, technical papers, or the Oxford or Webster's dictionaries.

ANNEX

GLOSSARY AND ACRONYMS*

Accident - an event that is due to human or system error. It does not necessarily imply that there is no fault or possible intent (pgw). Something which happens unexpectedly and unintentionally, especially causing damage or injury. [Cambridge Internt'l. Dictionary of English].

Accidental discharge - an unintentional release of a substance or substances into the environment (pgw).

Accidental spillage - a release of substances or materials into a receiving environment that is due to human or system error. In the context of oil, it is a release, whether intentional or not, from a point source in one incident over a limited period of time other than what could be normally be expected as operational or MARPOL-permitted discharges. (See also of the objects involved is stationary e.g. a ship hitting a rock above water, a ship hitting a pier, a docked ship being hit by a moving ship. [pgw]

Allision - contact with fixed or floating objects other than ships, including docks, harbour facilities, bridges, or offshore structures (Gold et al. 2003).

ATSDR - Agency for Toxic Substances and Disease Registry (United States).

Ballast - heavy substances loaded by a vessel to improve stability. Seawater is commonly loaded in most vessels in the ballast tanks. [Sullivan 1996]. Ballast is loaded on board to obtain seaworthiness and achieve the sea keeping abilities of the vessel (T.J.Gunner).

Ballast oil - oil on a ship that has contaminated the ballast water, and may be discharged with it. [pgw]

Ballast tanks - compartments at the bottom of a ship or, in unusual cases (on bulk ore/oil carriers for example) on the sides that are filled with liquids for stability and to make the ship seaworthy. [Sullivan 1996].

Barge - a non-propelled, towed vessel that carries a liquid or solid cargo, in this context oil. [pgw]. A long boat with a flat bottom, used for carrying heavy loads (Cambridge Dictionaries Online).

BBSR - Bermuda Biological Station for Research, Inc.

* Please note: The source reference for each term is identified, in brackets, after the definition or description. MARPOL Annex I definitions (IMO 2002, p. 45-49) take precedence wherever relevant to this topic. The purpose of this glossary is to explain terms that are prominent in the text and important to clarify for the reader.

BHP - Brake horsepower - the power of an engine calculated in terms of the force needed to brake it. (Concise Oxford)

Bilge - the part of the ship's hull where the side curves around towards the bottom [Sullivan 1996]. Lower parts of holds, tanks and machinery spaces [Swindells 1997]. Area of a lower part of a hold where liquids collect and are pumped out at regular intervals [Brodie 1996].

Bilge oil - oil from the area in the lower part of the hold where surplus liquids collect and are pumped out at regular intervals. [fm/dst]

Bilge tanks - tank(s) on a vessel in which bilge water is stored [pgw].

Bilge water - accumulated water in bilges that has no use [Sullivan 1996]. A mixture including water and oil collected in the bilge of the machinery space in a ship as a result of leakage, drainage, etc. [IMO 1998]. The dirty water that collects in the bottom inside part of a ship. [Cambridge Dictionaries Online].

Blowout - an unintended and uncontrolled release of oil and/or gas at a wellhead, often under great pressure. Can occur on a platform or on the sea floor.

BOAS - birds oiled at sea program. An Environment Canada (Canadian Wildlife Service) programme monitoring the presence of oiled seabirds in offshore Atlantic Canada and along coastal Newfoundland, and relating such oiling to discharges (legal and illegal) from ships.

Bunker - a tank or compartment (on a boat or ship) for the storage of fuel. [Sullivan 1996].

Bunker oil - any hydrocarbon mineral oil, including lubricating oil, used or intended to be used for the operation or propulsion of the ship, and any residues of such oil. (Source: Draft International Convention on Civil Liability for Bunker Oil Pollution Damage, IMO, 2000)

Bunkering - replenishing the ship with fuel. [Sullivan 1996]

Cargo tanks - ship's tanks used for the carriage of cargo as opposed to, for instance, a ballast tank. [Brodie 1996].

Casualty - a serious or fatal accident. A person or thing injured, lost or destroyed. A disastrous occurrence due to sudden, unexpected or unusual cause. Accident; misfortune or mishap; that which comes by chance or without design. A loss from such an event or cause; as by fire, shipwreck, lightning, etc. [Black 1979].

CBT - clean ballast tanks - tanks on tankers used solely for ballast [pgw]

Clingage factor - an estimation of the percent of oil retained in a tank (fuel or cargo) due to its adherence to the tank walls and other surfaces (pgw).

Coastal Zone - a zone comprising coastal waters (including the lands there under) and the adjacent shore-lands; the zone strongly influenced by both sea and land and including smaller near-coast islands, transitional and inter-tidal areas, wetlands (mangroves and marshes) and beaches. [Clark 1998]

Coastal facility - in context of this report, it is any industrial infrastructure associated with the processing and transport of oil carried by ships, or coming ashore from the offshore production activities [pgw]

CONCAWE - Oil Companies' European Organization for Environment and Health Protection.

COW - crude oil washing, or crude oil washing system, is a cargo tank cleaning system that uses crude oil as the washing medium (see section 3.2) (tw, IAITO)

CPP - clean petroleum product. Refined products such as aviation spirit, motor spirit and kerosene. Also referred to as clean products or white products. [Brodie 1996].

CRUCOGSA - a Norwegian research programme studying the physical behaviour of crude oil influencing its carriage at sea.

DH - double hulled.

Discharge - release of a substance or material into a receiving environment. Discharges may be legal or illegal, intentional or unintentional. [pgw]. In relation to harmful substances or effluents containing such substances, means any release howsoever caused from a ship and includes any escape, disposal, spilling, leaking, pumping, emitting or emptying. [IMO 1997a].

DNVPS - DNV Petroleum Services. An international company based in London, United Kingdom, and Houston, Texas.

Double-hulled (DH) tanker - a tanker with both inner and outer bottom plating on the hull. [adapted from Swindells 1997]. System in tankers whereby an inner hull serves as protection against oil spills in the event of a ship running aground or coming into contact with another ship or solid object. Sometimes referred to as a double skin.

DPP - dirty petroleum product. Crude oils and their products, such as heavy fuel oils. Also referred to as black products. [adapted from Brodie 1996].

Drill cuttings - the solids resulting from drilling into sub-surface formations, and which are brought to the surface of the well in the drilling-fluid system. [GESAMP 1993].

Dry docking - the process by which a boat or ship enters a shipyard, for repairs and/or maintenance, and is taken out of the water.[pgw]

Dry bulk - cargo shipped in a dry state and in bulk, for example, grains, ore or cement. [Sullivan 1996].

Drybulker - a ship carrying a bulk cargo of a dry and/or solid (non-liquid) nature [pgw]

Deadweight - difference between a ship's loaded and light displacements, expressed in tons or tonnes. [Brodie 1996].

DNVPS - DNV Petroleum Services.

DPP - dirty petroleum product (usually in reference to a vessel carrying such products).

DWT - dead-weight tonnage or DWT is the number of English long tons (each weighing 2,240 lb.) that a vessel is capable of transporting, including cargo, passengers, crew, stores, and bunker fuel (Gold et al. 2003).

E&P Forum - Exploration and Production Forum. (based in London, United Kingdom).

EDF - Environmental Defense Fund (USA).

ESP - Enhanced Survey Program, for ships in dry docks

Effluent - a liquid discharge, untreated or treated, from a fixed (point-source) industrial or municipal site. [pgw]. (civil engineering) 1. Liquid waste water that results from sewage treatment or industrial processing. 2. Such waste liquid released into waterways. (chemical engineering). Any liquid or gas that is discharged from a processing operation. [Morris 1992].

ERC - Environmental Research Consulting (USA).

Estimation - the process of developing estimates, which are defined as the most reasonable, quantitatively-derived numbers describing a process, behaviour or event [pgw]

Estuary - a semi-enclosed littoral basin (embayment) of the coast in which fresh river water entering at its head mixes with saline water entering from the ocean. [Clark 1998]. Places where seawater is measurably diluted with fresh water; estuaries may take the form of well-demarcated valleys, semi-enclosed bays, or shallow lagoons often associated with sandbars at their seaward edge. [Mann 2000].

Flaring - the process of burning off waste or unwanted gases; commonly used on offshore oil and gas production platforms. [adapted from Swindells 1997]

FOBAS -

FPSO - floating production, storage and offloading unit. Used in the offshore oil and gas industry. [jc]

FSO - floating storage and offloading unit. [fm/dst]

Fuel oil - the heaviest grades of residual fuel used for marine and industrial purposes. [Sullivan 1996]. See Table 2 in ISO 8217:1996.

Fuel oil sludge - residual oils and other substances that collect at the bottom of a ship's bunker tanks. [pgw]

Gallon - an Imperial gallon is 4.54 litres; a US gallon is 0.833 of an Imperial gallon or 3.782 litres (see units and conversion table)

Gas-freeing - the process of cleaning dangerous and explosive airs or gases from empty petroleum tanks. [Sullivan 1996].

GESAMP - the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (formerly Marine Pollution), established in 1969. It is an advisory group to the United Nations and its bodies. It consists of both natural and social scientists, and encourages collaboration and coordination of activities within the United Nations system on matters relating to marine pollution and marine environmental protection. (Wells et al. 2002).

GIS - geographic information system(s). Computer-assisted systems that can input, store, retrieve, analyse and display geographically referenced information and enhance the analysis and display of interpreted geographic data (Clark 1998).

GPA - Global Programme of Action for the Protection of the Marine Environment from Land-based Activities. Otherwise known as the Washington Protocol, signed November 1995.

HBL - Hydrostatic balance loading (of tankers).

Hydrocarbons - A combination of hydrogen and carbon often found in gas and oil. [Sullivan 1996].

IGO - inter-governmental organization.

Illegal operational discharge - under MARPOL for oil, that would be a discharge of >15ppm or >30 litres oily waste per nautical mile within 50 nautical miles from a coastline. [pgw]

Illegal spill - the release of a material or substance into a receiving environment e.g. coastal or marine waters, that is not sanctioned by law, either national or international. [pgw]

ILO - International Labour Organization (United Nations).

IMO - International Maritime Organization (United Nations).

Incident - "means an event involving the actual or probable discharge into the sea of a harmful substance, or effluents containing such a substance" (IMO 1997, MARPOL 1973/78 volume)

Incidental discharge - same as an incident.

Intentional discharge - a release of oil done on purpose, not by accident. (pgw). Mitchell (1994) "uses the terms *intentional discharges* and *operational discharges* interchangeably, the point being to distinguish them from accidental oil spills. (p. 71)

INTERTANKO - International Association of Independent Tanker Owners, located in London, United Kingdom.

IOSD - International Oil Spill Database - a database of individual records of oil spill incidents maintained since 1978 by Cutter Information, Cambridge, MA., USA.

ISO - International Standards Organization.

ITOPF - International Tanker Owners Pollution Federation Limited.

Legal discharge - a discharge of oil condoned by law, either national or international. (pgw). Mitchell (1994) states that "tankers have essentially three legal methods of disposal available: discharge slops at sea within prescribed limits on content and rate and constrained by the total discharge standards, discharge slops during delivery by using LOT, and discharge slops at reception facilities after the ballast voyage" (p. 80-81).

Littoral (zone) - the intertidal zone, or the area of a beach between high water and low water marks [pgw]. The shoreline where a normal cycle of exposure and submersion by the tides occurs. [Morris 1992].

LOT - the load-on-top principle (see the MARPOL Convention Annex 1). The practice of loading a fresh cargo of oil on top of oil recovered from tank cleaning operations. Widely used on tankers engaged in the crude oil trade. The onboard water and oil mixture from ballasting and cleaning of tanks is pumped ashore at loading terminals with special reception facilities to reduce the risk of oil pollution at sea. [Swindells 1997].

MARPOL 73/78 - the International Convention for the Prevention of Pollution from Ships, or Articles, Protocols, Annexes, Unified Interpretations of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (IMO 1997a, 2002). It is the primary international convention dealing with pollution from ships and shipping, covering oil, chemical substances, sewage, garbage and air pollution.

Machinery - the main engine(s) and auxiliaries in a ship including deck machinery such as capstons, winches, pumps, lifts and door and ramp operating system. [Sullivan 1996].

Machinery space bilges - the lower parts of the machinery space of a ship [adapted from Swindells 1997]

Machinery space oils - oils from engines and other machinery on a vessel that end up in the bilge (also see definition of bilge water).

MDO - marine diesel oil.

MEPC - Marine Environment Protection Committee (of IMO).

Metric tonne - equivalent to 2,205 lb, in contrast to an Imperial or British ton of 2000 lb.

MMS - Minerals Management Service (United States).

MTBE - a chemical additive in gasoline, namely methyl *tert*-butyl ether (Gabele and Pyle 2000).

NA - North America(n)

Non-tankers - ships that are not carrying a liquid cargo [pgw]

Non-oil cargo vessels - ships carrying cargo other than oil [pgw]

ODME - oil discharge monitor.

OGP - The International Association of Oil and Gas Producers (based in London and Brussels).

OILPOL 1954 - International Convention for the Prevention of Pollution of the Sea by Oil 1954, amended in 1962 and 1969. Now effectively superseded by MARPOL 73/78. [Sullivan 1996]

Oil – for the purpose of Annex 1 of MARPOL 73/78, means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products (other than petrochemicals) [IMO 1997a].

Oil-based muds (OBM) - drilling fluids used at the well that contain hydrocarbon-based lubricants. [from GESAMP 1993]

Oil discharge - release of oil or oil-containing substance(s) into the marine environment [pgw].

Oil fingerprinting - analytical chemistry techniques used, often in combination, for identifying the source (s) of an oil. [pgw]. Recent fingerprinting systems use the unique characteristics of oil from different oil fields to distinguish the responsible tanker (source of a spill) from several suspects [adapted from Mitchell 1994]. Advanced techniques are described in Bence and Burns (1995), Boehm et al. (1997), and Page et al. (1995, 1998).

Oil sheen - an extremely thin layer or film of petroleum product causing some visual evidence on the water surface. [IMO 1998].

Oil slick - film of oil on the surface of the water [Sullivan 1996]. Usually caused by accident or spillage but can also be caused by natural oil seepage from the ocean floor. [Swindells 1997]. A thin film of oil on water. [IMO 1998b]. The oil in a slick can be mineral, vegetable or fish oil in origin.

Oil tanker - ship designed specifically for the carriage of oil in bulk. They range from a small coastal tanker usually carrying a finished product to an ultra large crude carrier (ULCC) that may be half of a million tons deadweight. [Swindells 1997].

Operational discharge - a release of a material or chemical from a ship, whether legal or illegal. Legal operational discharges of oil from ships are regulated under the MARPOL Convention (Annex 1).

Operational losses - intentional or unintentional losses of oil and oily wastes to the sea from the routine operation of a ship or offshore oil platform [pgw]

PAHs - polycyclic aromatic hydrocarbons - components of oil consisting of two or more fused aromatic (benzene) rings e.g. naphthalenes, phenanthrene, benzo-a-pyrene. [adapted from Neff 1979].

PCBs - polychlorinated biphenyls.

Pelagic - an oceanographic term meaning open ocean or water column.[pgw].

PSC - Port State Control.

Produced water - generated from oil and gas production operations. It consists of formation water (the water naturally present in the reservoir), flood water previously injected into the formation to maintain pressure, and/or, in the case of some gas production, condensed water. Its composition is quite complex and highly variable, consisting of water, dissolved and dispersed oils, salt and many other inorganic and organic constituents. [Adapted from Exploration and Production Forum 1994].

Reception facility - for oily residues and oily wastes, they are fixed installations and mobile or floating processing plants that exist at ports around the world to receive and treat oily waste and residues or slops from ships. [adapted from Sullivan 1996]

Recreational boating - boating, in small powered, partially powered or un-powered vessels, conducted for non-work purposes. [pgw].

Recycling - with reference to ships, see Scrapping.

Reefer vessel - ship having refrigerated holds for the transport of cold fruit and/or vegetables, or frozen cargo.

SBT - segregated ballast tank - a ballast only tank into which seawater used as ballast is loaded, and discharged through a separate piping and pumping system. [adapted from Swindells 1997].

SBT/DH - segregated ballast tank/double hulled (in reference to an oil tanker).

Scrapping - the process by which a ship is beached and broken up/ dismantled for scrap metal and other materials. [pgw]. "Ships are not scrapped but recycled, conforming with one of the basic principles of sustainable development. Recycling is defined by the World Wildlife Fund as 'the processing of waste or rubbish back into raw materials so that it can be made into new items'. It is undoubtedly beneficial – to the individual, the community and the planet" (Source: Report of ship recycling correspondence group to MEPC 46, IMO).

Sea-based activity (ies) - in context of this report and its mandate, it "includes all forms of shipping, especially in oil tankers and carriers, other commercial and non-commercial ships, as well as transportation through marine pipelines. They would further include offshore and coastal exploration and production, atmospheric emissions from such sea-based activities, coastal refineries and storage facilities, oil contaminated material disposed of at sea, and natural marine oil seeps".

Seeps - also called natural oil seeps. There are areas of the earth's crust where crude oil from underground reservoirs moves by natural forces to the surface. Located on land or underwater. [pgw]. A naturally occurring emergence of liquid petroleum at the (earth's) surface as a result of a slow, upward migration from its source through minute pores or fissures. (Academic Press, Dictionary of Science and Technology).

Ship - "means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms". (IMO 1997a).

Slops - tank cleaning residues retained on board a tanker in the slop tank for eventual disposal ashore or mixture with incoming cargo. [Sullivan 1996]. Mixture of water and oil residues from cargo tanks in oil tankers that may contain oil/water emulsions, paraffin wax, sediments and other tank residues. [IMO 1998]. Residue of a ship's cargo of oil together with the water used to clean the cargo tanks. [fm/dst].

Slop tank - tank in a tanker into which slops are pumped. [fm/dse]

Sludge - Deposits, generally from the purification of fuel and lubrication oils, consisting of mixtures including oil, paraffin wax, sediments and other tank residues. [IMO 1998b]. Oil sludge is heavy oily material that collects at the bottom of oil tanks (fuel or cargo) on a ship [pgw].

Sludge oil - as defined in MARPOL, is sludge from the fuel or lubricating oil separators, waste lubrication oil from main or auxiliary machinery, or waste oil from bilge water separators, oil filtering equipment or drip trays (IMO 2002).

Small craft - boats, predominantly leisure craft, operating on either 2 or 4-stroke engines. They are 25 m or under in length at the waterline.[pgw]

SOLAS - Convention on Safety of Life at Sea (IMO).

Sovereign immunity - Doctrine precludes litigant from asserting an otherwise meritorious cause of action against a sovereign or a party with sovereign attributes unless sovereign consents to suit. [Black 1979].

Spill - release of a substance or material from a source into a receiving environment. Spills may be legal or illegal, intentional or unintentional. [pgw]

Spills (small) - within the context of this GESAMP report, they are spills of oil between 0.17- 34 tonnes (50 US gal - 10,000 US gal.). [dse]

Spill estimation factor - a statistically derived value that is applied to the IOSD oil spill database in order to derive estimates of numbers and volumes of smaller spills (dse).

Spillage - the quantity of oil spilled from a particular incident (as opposed to the number of spills). (fm)

Standard - A legally enforceable numerical limit or narrative statement, such as in a regulation, statute, contract, or other legally binding document, that has been adopted from a criterion or an objective. [CCME 1999]. A level of quality. [Cambridge Dictionaries Online].

Tank washings - tank washing water containing cargo tank residues including oil, paraffin wax, sediment and other foreign matter such as tank cleaning chemicals. [IMO 1998].

Tanker - a ship constructed to carry liquid cargoes in bulk, in this context oil. They come in various sizes. [adapted from Sullivan 1996]. From ITOPF (2005), "tanker" means any ship (whether or not self-propelled) designed, constructed or adapted for the carriage by water in bulk of crude petroleum, hydrocarbon products and other liquid substance.

Tar balls - lumps of oil that form from oil discharged from ships, largely from the ballast of crude oil tankers, and that float on or near the sea surface, weather (i.e. lose fractions of the oil, becoming hardened and encrusted with organisms externally), and often contaminate coastlines and amenity beaches. [pgw]. Compact semi-solid or solid masses of highly weathered oil formed through the aggregation of viscous, high carbon number hydrocarbons with debris present in the water column; tar balls generally sink to the sea bottom but may be deposited on shorelines where they tend to resist further weathering. (Doerffer 1992). Oil that has evaporated and possible mixed with debris and has formed into a solid mass or solid form. [IMO 1998b].

Ton - an Imperial or British unit of weight equivalent to 2000 lb. [GESAMP 1993]; the weight ton is usually expressed in terms of the American short ton (2000 lb. or 907 kg.) (Gold et al. 2003). The English long ton is 2,240 lb or 1016 kg (Gold et al. 2003).

Tonne - a metric tonne, equivalent to 1000 kg or 2,205 lb. [GESAMP 1993; Gold et al 2003]

UNCED - United Nations Conference on Environment and Development. This conference was held in Rio de Janeiro in 1992 and produced Agenda 21 as well as several treaties.

UNCLOS - United Nations Convention on the Law of the Sea. It was signed in 1982 and formally became international law in 1994.

UNEP - United Nations Environment Programme. The environmental programme of the United Nations based in Geneva, Manila, Nairobi and The Hague (see www.unep.org).

Uncertainty factor - definition needed (p. 40, draft 3)

Venting - in the offshore sector, this refers to the release of gas at a well site [pgw]

VLCC - very large crude carrier.

VOCs - volatile organic compounds. Defined in the Clean Water Act (USA) to include all volatile hydrocarbons except methane, ethane, a wide range of CFCs or chlorofluorocarbons, HCFC (hydrochlorofluorocarbons), and a few others e.g. acetone (NRC 2003, p. 71) In the context of activities of the offshore oil industry, VOCs are categorized as methane and non-methane hydrocarbons. [pgw] VOCs are considered under Regulation 15, Annex VI, MARPOL, in the context of vapour emission control on tankers, and non-methane VOCs on gas carriers.

VOCON - a procedure developed by Intertanko which utilizes onboard equipment to help the crew of a ship minimize unnecessary cargo boil-off (The MotorShip, the Marine Technology Magazine, May 26th, 2004).

Volumes (gross, loaded, shore-based) - gross volume is the total volume, including entrained water, delivered as cargo to a tanker, and corrected to a temperature of either 15 degrees C or 60 degrees F. A loaded volume is the same as gross volume. A shore- based volume is the same as gross volume by convention. (T.J.Gunner)

WWI and WWII - World War One, 1914-1918; World War Two, 1939-1945.

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