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Bonn Agreement
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Technical Sub Report 7: Offshore Installations Oil Spill Risk Analysis

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Co-financed by the EU -
Civil Protection Financial Instrument

DOCUMENT TITLE: Offshore Installations Oil Spill Risk Analysis
TASK: E5
AUTHOR: C. Van der Tak, Y. Koldenhof, J. van Doorn
PUBLISHED ON: 18 March 2014

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The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution.

Currently the area has no overall risk assessment for marine pollution; risk is mapped with a variety of national risk assessments which are undertaken with differing methodologies; thus reducing comparability.

The BE-AWARE project is therefore undertaking the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios.

The project outcomes will improve disaster prevention by allowing North Sea States to better focus their resources on areas of high risk.

The project is a two year initiative (2012-2014), co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway.

Contents

Executive summary

The main objective of the BE-AWARE project is to conduct an area-wide risk assessment of the spillage of oil and HNS. There are two main sources of oil pollution risk in the Bonn Agreement area: accidents between ships either due to ship-ship collisions and groundings; and accidents involving spills from offshore installations (oil and gas platforms, wind farms and other fixed objects) either due to being hit by vessels or from the installations themselves.

This task deals with the spillage from accidents involving offshore installations. Three possible scenarios are considered:

- Spillage from the ship due to damage as a result of a collision/contact between a ship and an offshore installation; this can be platforms or wind turbines or other structures *(ship – platform or ship - turbine)*;
- Spillage from the offshore installation due to damage as a result of a collision/contact between a ship and an offshore installation *(platform or FPSO spills by collision)*;
- Spillage from the offshore installation due to events on board of the installation that lead to damage that results in a spillage of oil *(platform operation spills)*.

The computation of the spillage from a ship due to a collision or contact between a ship and an offshore installation starts with a computation of the collision probability. This computation is made with the SAMSON model using the traffic databases for 2011 and 2020 as developed within the BE-AWARE project. A spillage will only occur when the cargo tank is penetrated, and this depends on the collision energy. When a loaded fuel tank or cargo tank is penetrated, bunker oil or cargo oil is spilt.

When an oil platform is hit by a ship the probability that this collision will result in a spillage also depends on the kinetic energy. It is assumed that above 50 MJ there is a probability of a spillage from the platform.

Finally an assessment has been made of the probability of a spill from daily operations and blow-outs from platforms. For blow-outs a distinction is made between oil and gas wells and Normal wells and High Pressure and High Temperature (HPHT) wells. For each specific operation the probability of a blow-out is specified together with the number of operations per year. For each country in the Bonn Agreement area the number of platforms, FPSOs and wells is known including the number of HPHT wells. Similar information is available for the leakage of oil. Combining this information results in the amount of oil spilt from platforms during daily operations.

As with all risk analyses of this type some assumptions were made to simplify the calculations and allow a regional comparison to be undertaken within the restraints of the project. In the offshore analysis due to the high level of regulation in the North Sea area it was assumed that the risks of general operational accidents were similar in different North Sea countries and these were applied uniformly to all installations with the exception of HPHT installations. Also the uncertainty for the larger blow-out events is higher as they happen so rarely. This was of course a simplification but was adequate for a regional comparison with other risk types.

The table below contains the resulting spill frequencies and the tonnes spilt per year. The results are presented for 2011 and 2020 and in the last block the increase from 2011 to 2020 is indicated. From 2011 to 2020 there was an increase in spill frequencies and the total amount spilled with a large contribution from ship – wind turbine collisions.

The results of this study are exchanged with COWI and included in the overall analyses of the amount of oil spilled.

	2011		2020		2020/2011	
	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tons	Frequency of spill per year	Volume of spills in tonnes
ship_platform	0.0141	78	0.0180	99	1.27	1.27
platform spills by collision	0.0893	86	0.1290	127	1.44	1.49
FPSO spills by collision	0.0004	5	0.0003	4	0.69	0.78
platform operation spills	1.9112	3420	1.9112	3420	1.00	1.00
ship_turbine	0.0064	26	0.0643	303	10.01	11.51
Grand Total	2.0215	3615	2.1228	3954	1.05	1.09

Table 0-1 Frequency and volume of spills for 2011 and 2020

The predicted 3420 tonnes spills per year for platforms operation spills is not the amount of oil that is yearly spilt. Ninety percent of the amount predicted would in fact be delivered by spills from events that occur less than once in 70 or 145 years, e.g. infrequent blow-out events. The oil spilt in these types of events can be very large.

The results of this study have been used to compute the exceedance probability of a spill size. This result is shown in the next figure:

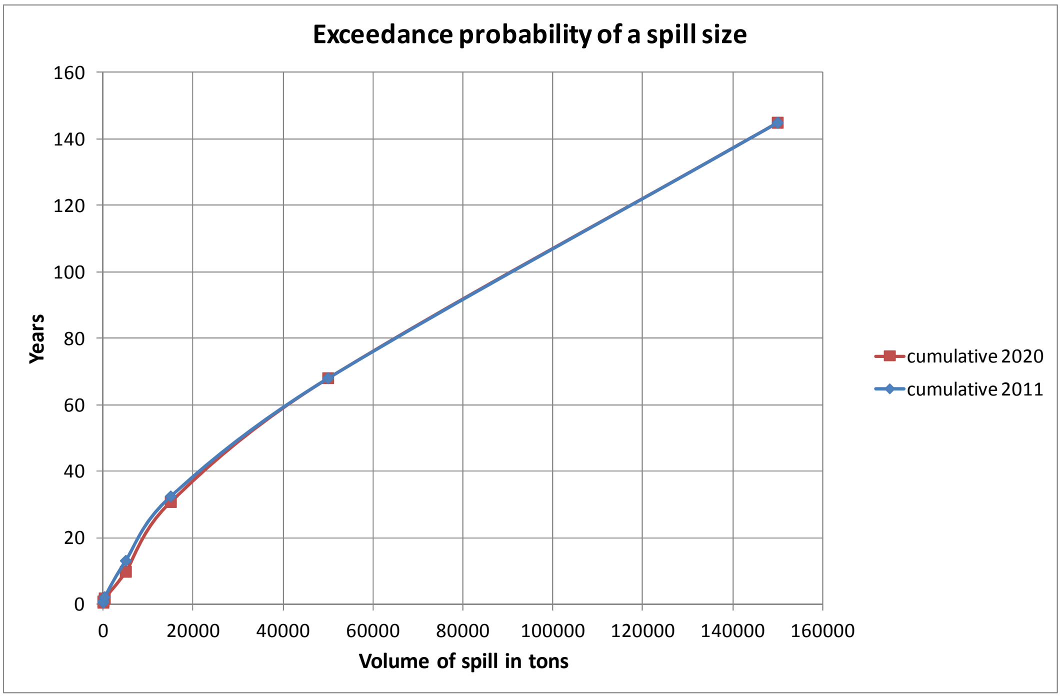

Figure 0-1 Exceedance probability of a spill with a certain size

This figure shows that a spill larger than 40,000 tonnes can be expected once in 60 years. A spill size larger than 90,000 tonnes is expected once in 100 years.

Mitigating measures to reduce the outflow of oil

The BE-AWARE methodology takes into consideration existing risk reducing measures, however possible response measures will only be addressed in a second phase (BE-AWARE II) where the outflow of oil will be modelled. Therefore recent advances in technology, particularly for blow-out accidents such as subsea capping and dispersant application equipment are not taken into consideration in this report.

1. Introduction

The main objective of the BE-AWARE project is to conduct an area-wide risk assessment of the spillage of oil and HNS. There are two main sources of oil pollution risk in the Bonn Agreement area, accidents between ships, either due to ship-ship collisions or due to grounding and accidents involving spills from offshore installations (oil and gas platforms, wind farms and other fixed objects) either due to being hit by vessels or from the installations themselves. The risk of spills from ship-ship collisions or groundings is dealt with in Technical Sub-report 8: Maritime oil spill risk analysis and therefore this report focuses on the risk from offshore installations.

There are three possible scenarios that lead to the spillages of oil from accidents involving offshore installations:

- Spillage from the ship due to damage as a result of a collision/contact between a ship and an offshore installation; this can be platforms, wind turbines or other structures;
- Spillage from the offshore installation due to damage as a result of a collision/contact between a ship and an offshore installation;
- Spillage from the offshore installation due to events on board of the installation that lead to damage that results in a spillage of oil (this means without the interference of a ship).

In this report all three risks are addressed. The first two scenarios are studied with the SAMSON model. For the risk of collision/contact between ships and platforms two approaches have been followed. The first approach is based on a version of SAMSON that can use AIS data as input. The second approach is based on the normal SAMSON approach, based on a traffic database. The traffic databases used in this study are outlined in Technical Sub-report 1: Ship Traffic.

Report structure

The report is divided in the following sections:

- Section 2 contains the objective of this research project.
- Section 3 describes the methodology for the calculation of probability of collisions and the resulting spillage of oil.
- Section 4 describes the approach for this study.
- Section 5 describes the platform collisions risk for 2011 based on AIS data.
- Section 6 describes the collision risk for platforms and wind farms with the BE-AWARE traffic databases.
- Section 7 describes the spills from platforms.
- Section 8 describes spills from offshore oil installations due to daily operations and blow outs
- Section 9 Summary and conclusions.

2. Objective

The objective of this task is to determine the oil spill frequencies from offshore installations or due to the presence of offshore installations. This spill probability is divided into three possible contributions: spillage from a ship due to a collision with an offshore construction, spillage from the offshore construction due to the collision of a vessel, spillage from an offshore structure due to an event on the structure.

The results of this task will be included in the overall risk assessment regarding the spillage of oil in the Bonn Agreement area.

3. Methodology

3.1 General description of spill calculation

The calculation of a possible spill from a vessel involved in a collision with an offshore installation follows the process described below.

1 Determine the number of exposures. (An exposure can be explained as a certain elementary “traffic situation” which is representative for a certain type of collision.)

2 Calculate the probability of a collision by multiplying the number of exposures with their respective casualty rate. (The casualty rate is the probability that the exposure leads to a real collision with a platform or wind turbine.)

$$p_{collision} = n_{exposures}\, Casrat$$

3 Determine the probability that a collision results in an outflow due to the penetration of a cargo or bunker tank.

4 Determine the probability of an outflow of a certain substance by multiplying the probability of penetration of a cargo or bunker tank with the probability that this tank contains the specific substance.

$$p_{spill} = n_{exposures}\, Casrat\; p_{penetration}\, p_{substance}$$

5 Determine the spill size based on the tank size and the penetration location.

$$V_{spill} = n_{exposures}\, Casrat\; p_{penetration}\, p_{substance}\, V_{tank}$$

All these values will be totalled per platform or wind turbine.

3.2 Traffic modelling

The standard way of modelling traffic in MARIN’s navigational risk analysis programme SAMSON is to define the route structure and the traffic intensity. The route structure is built up by a combination of waypoints and connections between those waypoints (called links). The traffic intensity is defined as the number of ship movements along each link per ship type and ship size, and a lateral distribution per link. In order to use the same basis for these calculations as will be used for the other frequency calculations within BE-AWARE, such as ship-ship collisions and groundings, the calculations will not be based on the standard MARIN traffic database, derived from the LLI voyage database. For the platform calculations normally the AIS data would be used directly in the computations. However, to be able to make calculations for 2020 for both platforms and wind farms it is necessary to use a traffic database. This traffic database takes into account all changes in the North Sea between now and 2020, e.g. new wind farms and changes in the Traffic Separation Schemes. To be able to assess the impact of the increase in traffic, computations have also been executed with the 2011 traffic database. Both databases are developed by COWI and described in BE-AWARE Technical Sub-report 1: Ship Traffic.

Traffic modelling on the basis of the BE-AWARE database

For the BE-AWARE project COWI has developed a traffic database based on AIS data. Traffic databases were developed for 2011 and 2020. As the spatial arrangement of the Bonn Agreement area will change in the coming years it is not possible to use the AIS data for a future situation. The most important changes are the development of wind farms and the changes in the traffic scheme in the Dutch part of the North Sea. Using the database for both years makes the results of the computations comparable. This will also solve the problem of lack of coverage.

Traffic modelling on the basis of AIS

The results for the BE-AWARE project have all been computed on the basis of the traffic databases developed by the project. However, for the ship - platform collision risk an analysis has been developed directly based on AIS. This analysis was developed because not all ships contributing to the collision risk are included in the traffic database, e.g. work boats and supply and standby vessels.

As AIS is an actual representation of traffic. Traffic is modelled much more accurately then when based on a traffic database. However a drawback is that coverage is not guaranteed. It is possible that there are gaps in the data. From experience we know that the coverage is good in the Dutch part of the North Sea. Coverage is poor in the central part of the North Sea.

3.3 Collision frequencies

The probability of a collision between ship and platform or ship and wind turbine are computed for each specific ship type and size sailing with a specific speed. From this probability the expected spill frequency as a consequence of the collision is computed.

The calculations will be performed by using the ship-contact model within the safety assessment model SAMSON. This model is described below.

The platforms were modelled either as rectangles or circular shapes, depending on the actual shape of the platform, defined by a position, length, width and orientation. Wind turbines are modelled in a similar way: each wind turbine is a separate “platform” with a circular shape and a diameter as specified per wind farm.

As the calculations are time consuming, the calculations will not be done for each wind turbine separately. Instead, the calculations are done for each of the corner turbines for each wind farm and one or more turbines in the centre of the wind farm. By calculating a weighted average probability of each turbine, depending on its position in the wind farm, and multiplying this probability for the number of turbines in the wind farm, the total probability is obtained.

Two causes of contact between a ship and an object are distinguished during accident analyses:

- A ramming contact as a result of a navigational error;
- A drifting contact as a result of a mechanical failure of the engine or steering engine.

The first type is due to a human error in the vicinity of an object that cannot be recovered or is only discovered after the point of no return. The second type is the result of a power failure near an object.

The relevant exposures (elementary “traffic situations” which are representative for a certain type of collision) for contact between a ship and an object are:

- Ramming opportunity for a ramming contact;
- Danger miles for a drifting contact.

3.3.1 Contact with an object as a result of a navigational error (ramming)

In Figure 3-1 a vessel is shown at a distance x from the last waypoint. The vessel proceeds to the next waypoint where the vessel has to change course. For a given position of the vessel 3 lines are drawn on either side of the vessel track with an interval of 10˚. These lines indicate possible paths of the vessel after a navigational error has occurred. The object near the vessel is defined as a sequence of straight lines connecting the vertices. Each straight line is characterised by two geographic positions. In the figure they are denoted as 1 and 2. Whether or not this edge of the object will be hit by the vessel depends on the following matters:

- The position at which the error happens;
- The direction of the ship after the error has occurred;
- The possibility that the error is recovered in time; depending on the distance between the ship and the object, as well as the sailing speed.

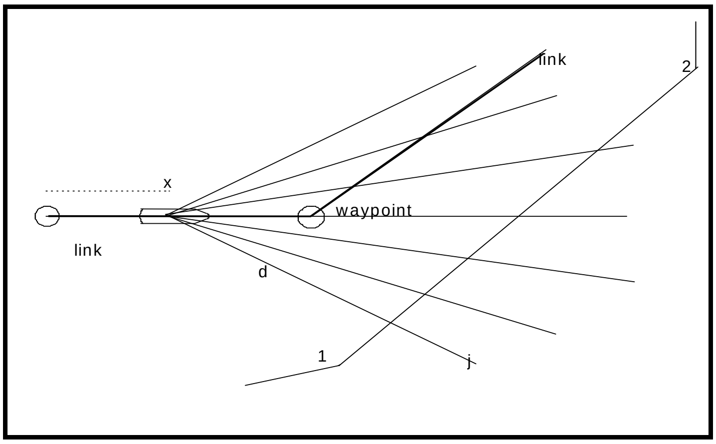

Figure 3-1 Definition of ramming opportunity

A ramming contact with the object due to a navigational error can start at each position on the link. The speed at which the navigational error occurs is assumed to be equal to the service speed. The distance to the object which is expressed by the number of ship lengths is determined both for the initial course line and for the six new lines. The distribution over the possible directions after the error occurred is as follows: 0.05, 0.1, 0.2, 0.3, 0.2, 0.1, 0.05 for the respective directions -30˚, -20˚, -10˚, 0˚, 10˚, 20˚ and 30˚.

The number of ship lengths that are available in each direction towards the object indicate the available time for the navigator to mitigate the consequences in case of a navigational error. The probability of a ramming contact with an object given a navigational error is related to the distance and ship length as follows:

$$p_{nav} = \int_{x_1}^{x_2} e^{-a\frac{d_\psi(x)}{L_i}} dx \qquad (3\text{-}1)$$

with

a = Danger measure (dimensionless parameter with a standard value of 0.1)

d_ψ = Distance of the vessel on the link to the object in direction ψ

L_i = Ship length of class i

x = Position of the vessel on a link

p_{nav} = Probability of a ramming contact with an object in case of a navigational error

The number of ramming opportunities given a navigational error is now given by the following expression.

$$RO_k = \sum_\psi \sum_i p_\psi N_{ij} \int_{x_1}^{x_2} e^{-a\frac{d_\psi(x)}{L_i}} dx \qquad (3\text{-}2)$$

with

N_{ij} = Number of vessels using link j of vessel class i

p_{ψ} = Probability of a course in direction ψ

RO_k = Ramming opportunity for an object on link k

When the links are created for each AIS message separately, the number of ships per link (N_{ij}) is equal to 1 (see Chapter 5).

The number of contacts can be calculated by multiplying the number of ramming opportunities with the probability of a navigational error:

$$\#contacts_{NE} = CASRAT_{RO} \sum_{k} RO_{k} \tag{3-3}$$

with

NE = navigational error

$CASRAT_{RO}$ = matrix with the probability of a navigational error

The CASRAT parameter calibrates the ramming model with the actual observed accidents. Several studies have been performed in order to derive the relationship between the probability on a navigational error and the probability on a contact as a result of such an error, specific for the North Sea area, see (Van der Tak, 1995) and (Koldenhof, 2004). By taking into account the developments in ship sizes and the composition of the world fleet and using the derived relationship, the casualty rates are annually updated based on the worldwide and regional casualty statistics.

3.3.2 Contact as a result of an engine failure (drifting)

The danger miles are that part of the link between x_1 and x_2 at which a loss of propulsion of a ship poses a potential threat to the object. The vessel will drift in a direction indicated by the environmental conditions. To determine if a ship will actually drift against the object, it is necessary to know the time needed to drift from the link to the object. To calculate this so-called drifting time, first the distance between the point on the link where the engine failure occurs and the object is calculated. If the drifting time is larger than the time to repair the engine, the ship can drift against the object.

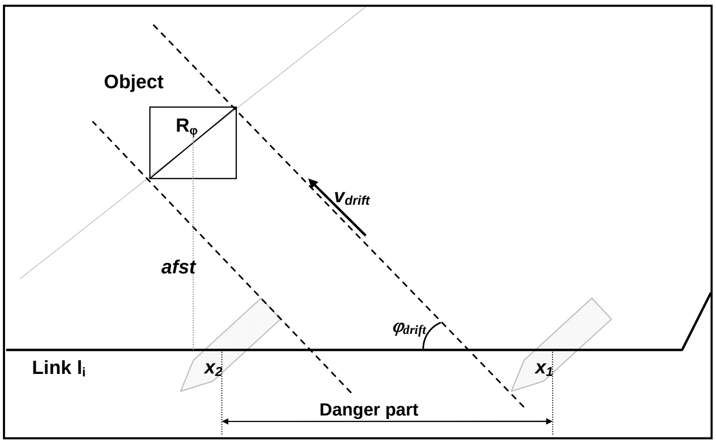

Figure 3-2 Definition of a drifting contact

If a ship is at point x on the link, the distance to the object is given by r(x) and the drifting time by:

$$t_s = \frac{\mathrm{r(x)}}{v_{dbin}} \tag{3-4}$$

with

t_s = Drifting time (hr)

$r(x)$ = Distance of a point x on a link to the object

v_{dbin} = Resulting drifting speed of ship *i* in loading condition *n* at Beaufort scale number b

In this model the drifting speed is assumed to depend on the Beaufort class. Given that an engine failure occurs, the probability that the duration of engine failure is larger than the drifting time to the object can be based on statistical data described as follows:

$$P_{EF}(t > t_s) = 1 \qquad \text{for } t<0.25\text{hr} \qquad (3\text{-}5)$$

$$P_{EF}(t > t_s) = \frac{1}{1.5(t_s-0.25)+1} \qquad \text{for } t\geq 0.25\text{hr}$$

Based on these parameters, the *danger miles* can be determined for each link. The danger miles describe the number of nautical miles on each link where, if an engine failure occurs on board a specific vessel, the object could be hit by the vessel. This distance is shown in e object.

Figure 3-2 as the “danger part”. Wind conditions, current conditions, ship characteristics and the geometry of the object are taken into account.

The number of contacts is determined by multiplying the summation of the danger miles for all links with the engine failure rate CASRAT_{EF} as follows:

$$\#contacts_{EF} = CASRAT_{EF\,0-7}\sum_{k}\sum_{b=0}^{7} p_b DM_{bk} + CASRAT_{EF\,8up}\sum_{k}\sum_{b=8}^{11} p_b DM_{bk} \qquad (3\text{-}6)$$

$CASRAT_{EF0-7}$ = Engine failure rate for 0-7 Beaufort

$CASRAT_{EF\,8up}$ = Engine failure rate for 8-11 Beaufort

p_b = Probability of Beaufort class b

DM_{bk} = Number of danger miles per link

As for the ramming model, the CASRAT parameters serve as calibration parameters for the drifting model and represent the probability that an engine failure in the danger part actually leads to an accident.

3.4 Calculating spill sizes and spill frequencies based on calculated contacts

3.4.1 Determine number of collisions resulting in an outflow

The outflow model follows the chain of events between the contact to a possible outflow. An outflow occurs only when:

1. The damage takes place in the cargo or bunker part of the ship. Damage in front of the collision bulkhead or in the aft part of the ship will not result in an outflow. Of course the structural damage can be severe but there will be no direct threat to the environment.
2. The cargo or bunker tank is penetrated. In the case of a single hull ship the wing tank is penetrated when the ship hull is penetrated. In the case of a double hull tanker more energy is required to penetrate the inner hull, being the hull of the cargo or bunker tank.
3. The penetrated cargo or bunker tank is loaded. The cargo or bunker tank that is penetrated can be a ballast tank or empty.

The amount of outflow depends on the location of the hole and the size of the penetrated tank.

There are no publications available on the damage to ships as a consequence of a contact with a platform or wind turbine. Therefore, the outflow models are not based on measured data but on assumptions based on collisions between ships for which publications are available.

For a drifting contact, it is assumed that the ship drifts sideways against a platform with a speed below 3 knots. It is assumed that damage occurs to one or two of the outside tanks.

In a ramming contact, it is assumed that the ship hits the platform with full speed, head on. The assumed damage model is that of a collided ship in a collision between two ships. This damage model is based on studies carried out for IMO (IMO, 1992) and is implemented in SAMSON.

For the collision of a tanker, the information about the probability that a tanker is loaded with oil and the expected amount of cargo oil that is on board is based on the Oil Cargo Model outlined in Technical Sub-report 2.

3.4.2 Determine the probability of outflow of a certain substance

The probability that a certain substance will flow out of a penetrated tank follows from the probability that the damaged tank contains the specific substance.

The probability that a specific cargo tank contains a substance of a specific type of cargo depends on the probability that the tanker is loaded, its filling rate, the tank lay-out of the vessel and its loading state. The first two properties are derived by the oil cargo model. For the remaining two properties assumptions need to be made. These assumptions are the same as used in the ship-ship collision study. Also for the bunker tanks, the assumptions related to the filling rate of the different tanks will be the same as used in the ship-ship collision study, see Technical Sub-report 8: Maritime oil spill risk analysis.

3.4.3 Determine spill size

The spill size depends on the height of the penetration with respect to the waterline. For a penetration above the waterline, it is assumed that the amount of oil above the underside of the hole will flow out. For a penetration under the waterline it is assumed that the total volume of the tank will flow out which is a worst case scenario. This will not happen due to hydrostatic pressure, but over time, oil and water can interchange position.

4. Approach

4.1 Introduction

In the past the collision risk for platforms was always calculated with a traffic database containing the movements of route-bound ships on a link structure and the presence of non-route-bound by densities on a grid structure.

Since the introduction of AIS the trajectory sailed by each ship is known. It is clear that the accuracy of the risk assessment increases significantly when the individual trajectories of ships are used within the calculations. Therefore MARIN has started such a development to perform the risk assessment directly from the AIS messages. In fact the same method is used as in the past but now the risk is determined for each ship at the real geographical position in time steps of 6 minutes. The risk for each platform could be achieved by summarizing the risk over all time steps.

This approach cannot be applied for future traffic and future layouts because the AIS data describes only real traffic for the present layout. Especially for future wind farms the AIS approach cannot be applied because the inside area of a wind farm is free of traffic. Thus tracks through the wind farm area will not occur. In fact sailing behaviour changes in new wind farms. This is less the case with respect to offshore oil and gas installations because these objects are treated as obstructions to be avoided but are not always included in voyage plans.

For BE-AWARE the collision risk and spills have to be determined for the 2011 and 2020 traffic for all offshore installations, i.e. platforms and wind turbines in 2011 and 2020. As mentioned before the risk for future wind farm layouts cannot be determined directly from AIS because the ship routes change after completion of the wind farm. For the same reason the AIS cannot be used for the calculation of the risk for oil and gas installations in 2020.

Therefore, the calculation of the risk for offshore installations, i.e. platforms and wind turbines, has been performed for 2011 and 2020 based on the traffic databases for 2011 and 2020. The traffic database for 2011 has been composed from the AIS data for 2011. The traffic database for 2020 is determined from the database for 2011 taking into account the changes in shipping, the free areas of the wind farms for 2020 and the new traffic separation schemes.

4.2 Input for platform risk computations

4.2.1 Input for platform collision risk

A set of platforms with the geographic position and the dimensions is input for the calculations. For this purpose the Bonn Agreement Secretariat prepared a database with the offshore platforms but most of the countries also sent information separately. All datasets obtained were combined and as many platforms as possible were identified.

The following steps were executed for achieving the offshore platforms in 2011 that are included in the calculations.

Subsea structures

The subsea structures have not been used for the analyses.

Decommissioned platforms

Decommissioned platforms were not taken into account in the analyses. However, the information was useful to check completeness of the data with nautical charts.

The Dutch platform P14-A (NL88) was not in use according to the dataset but this platform has actually been removed.

Future platforms

The proposed and future platforms have not been taken into account for the 2011 analyses.

Dimensions of platforms

The dimensions have been based on the available information. For some countries there was information about the weight of the substructure and the topside. This information has been combined with the available information about the dimensions. For the different types of platforms, different fits for the trend lines were used given an indication of the length and the width of the platforms.

Information that was not used

Platforms without coordinates have not been used. A file with minimal information on offshore installations was obtained from Denmark. There were 9 platforms that could not be connected with the file from the Bonn Agreement Secretariat. These have not been taken into account.

Platform database for 2011

The above activities have resulted in a platform file for 2011 with 633 platforms above sea level for which the collision risk has been assessed. The numbers per country are given in Table 4-1.

Table 4-1 Number of platforms

Denmark	57
Germany	3
Ireland	2
Netherlands	148
Norwegian	108
United Kingdom	315
Grand Total	**633**

Platform dataset for calculation of risk for 2020

From the data achieved it is not clear which ones will be decommissioned by 2020. Therefore the same platforms are used for the 2011 and 2020 computations.

Spillage

The probability of a spill of bunker oil and/or cargo oil is calculated for the ships that collide with a platform. However, the collision can also cause a spillage at the side of the platform. The cases are described in 0.

4.2.2 Input for spills from platforms

The probability of a spill from the ship that collides with a platform is modelled in the standard collision risk computation. However, the collision can also result in a spillage on the platform side. If the kinetic energy of the colliding ship is high the platform will be damaged and this can result in a spillage. The probability and volume of the spillage of oil depends on the type of the platform. For fixed platforms the probability and the volume of a spill will be small due to the safety measures. In the case of an FPSO (Floating, Production, Storage and Offloading), when the floating storage unit is involved in a collision, this can result in larger spills.

Furthermore spills can occur on platforms during normal operations. Also for this scenario the probability and the volume of the spill depend strongly on the type of a platform (FPSO, oil or gas) and the number and type of the wells (High Pressure and High Temperature or normal).

Additional characteristics of the platforms are required for the assessment of the spill from the platforms. These additional characteristics (number and type of wells, size of FPSO) were taken from online national databases.

4.3 Input for the wind farm risk computations

In most cases the areas of the wind farms are given. However this is not sufficient for a risk calculation because the risk depends strongly of the number of wind turbines. Therefore the project collected the geographical positions of all wind turbines within the existing wind farms in 2011.

The number of offshore wind farms will increase enormously in the coming years. Therefore the project estimated the wind farms that are expected to be built before 2020. This was based upon information in the OSPAR Offshore Wind farm Database, planning applications or proposals and areas where a grid connection was planned before 2020. However it was very hard to predict the exact number of wind farms that would be built by 2020 as this relies on so many variables such as investment, government policy and other infrastructure developments, therefore this is likely to be a overestimation.

The positions of the wind turbines for these wind farms were collected where available. Where only the number of wind turbines was known, the wind farm area was populated with the number of planned wind turbines. The wind farms for 2011 and 2020 included in the analysis are shown in Figures 4-1 and 4-2.

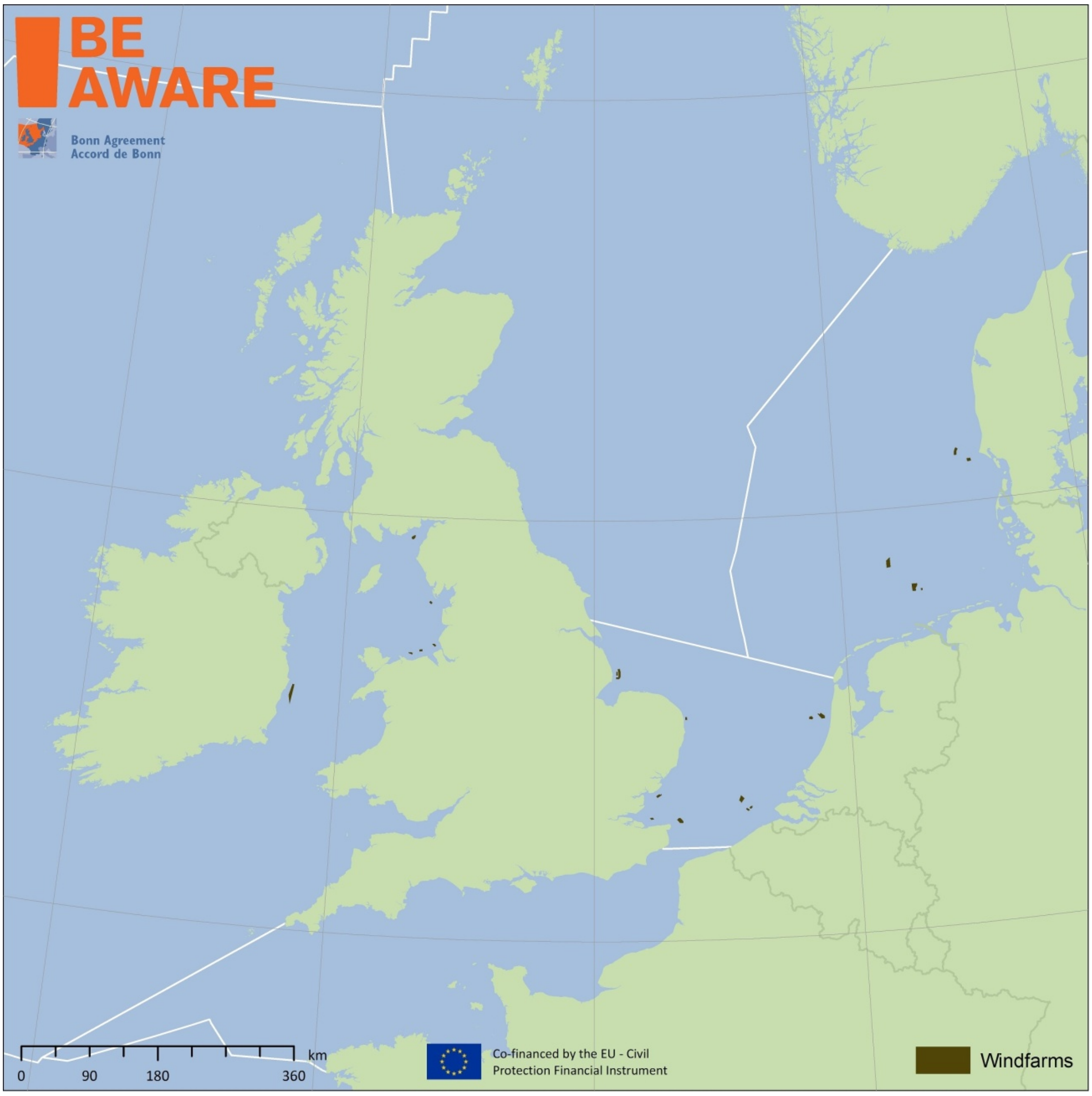

Figure 4-1 Location of the wind farms included for 2011 risk computations

From the wind turbine data delivered, the input files for 2011 and 2020 were created. The input file for 2011 contains 1010 wind turbines spread over 24 wind farms and the input file for 2020 contains 11703 wind turbines spread over 143 offshore wind farms.

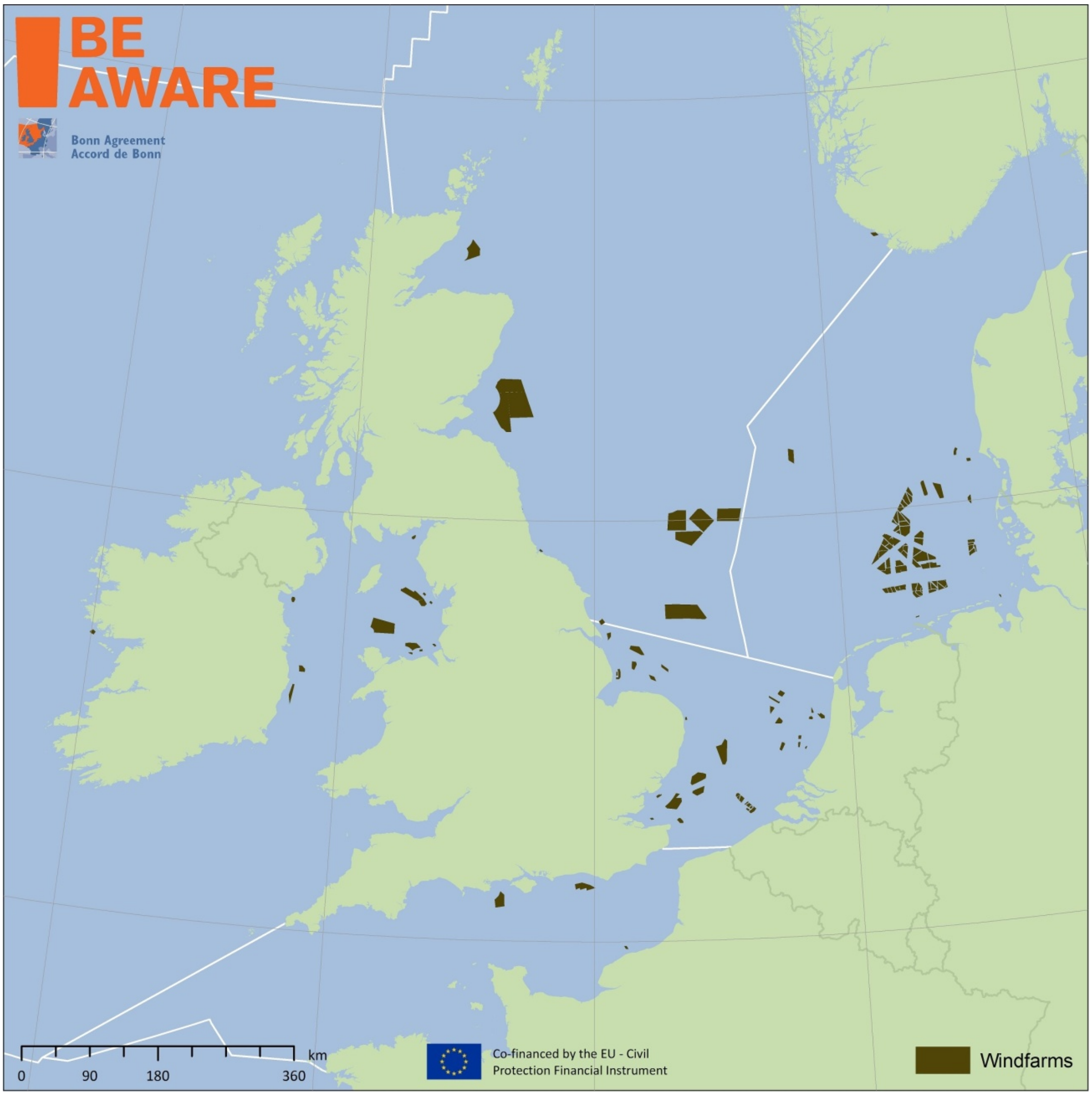

Figure 4-2 **Location of the wind farms included for 2020 risk computations**

5. Platform collisions risk for 2011 based on AIS

5.1 Introduction

In the BE-AWARE project the platform collision risk is computed using a traffic database that has been developed from AIS data. However, MARIN also made a calculation of the platform collision risk using AIS data directly in the computation for comparison.

In 2010 the Dutch set of AIS data was used for the calculation of the risk for the Dutch platforms (Tak, 2010). For the BE-AWARE project AIS data has been provided for the complete Bonn Agreement area at a time step of approximately 6 minutes. Therefore the risk calculations have been performed with time steps of 6 minutes. At each time step the last received AIS message of a ship was used and it was assumed that the ship will remain on course and speed during the next 6 minutes. This is modelled by a link with a length of 0.1 times Speed over Ground with an intensity of 1 movement. The collision risk for all platforms was calculated by totalling the risk of all ships and all time steps.

The reason for doing this analysis is that some ships make a large contribution to the collision risk (Tak, 2010), such as:

- Safety vessels operating in the vicinity of the platform;
- Vessels moored or at anchor destined for the platform or a neighbouring platform;

It is really necessary to distinguish these types of vessels in order to provide a realistic collision risk for each platform.

Table 5-1 Sets of platforms used for the calculations.

Input file with platforms	Number of platforms	Country	Area for calculation
Platform2012.dat	148	Netherlands	NorthSea
Platforms_DU_DK_NO.dat	179	Denmark, Germany, Norwegian	NorthSea
Platform_UK.dat	315	UK	NorthSea
Platform_NW_UK.dat	3	UK	NW UK
Platform_UK_IrishSea.dat	17	UK	UK Irish Sea
Platform_Ireland.dat	2	Ireland	S Ireland

Table 5-1 contains the sets of platforms that are used in the calculations. For each set of platforms an area defined as a polygon is defined. Only ships (AIS-targets) located in the area specified can cause a collision with a platform. It is really necessary to use this information to exclude the vessels in the port areas or restricted water. These ships cannot drift to the platforms. The first three sets of platforms in Table 5-1 comprise the North Sea area. For the other sets new areas were defined. The areas are shown in Figure 5-1. Platform_UK.dat contains all platforms of the UK, thus including the platforms NW_UK and in the Irish Sea.

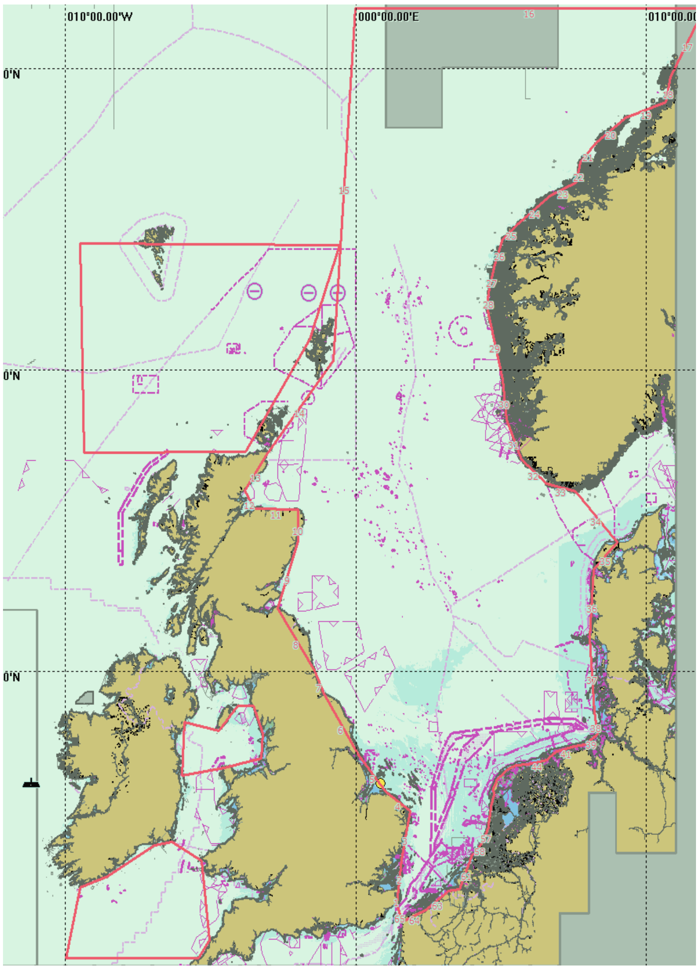

Figure 5-1 Sea areas used in the calculations.

5.2 Investigations

The results of earlier research showed that some platforms had very high risk especially in a number of ship type and size classes. The causes of some unexpected contributions have been analysed and are described briefly:

Unknown vessels:

Not all MMSI numbers could be linked to a ship in the Lloyds shipping database. These ships were processed as unknown ships in (Tak, 2010), of which the ship type was based on the type code from the AIS message. The length (from position of the antenna) was used to determine the size of the ship. This is not the best approach in all cases because in some cases the unknown vessel was not a vessel but the transponder of a platform. It is clear that such a MMSI-number delivers a very huge drifting and ramming risk, while in reality the risk is zero.

This could be solved by starting with the process of creating a good link between the MMSI number and the ship type and size.

Ships at anchor or moored

A second group that had a large impact on the results of [Tak, 2010] were ships with navigation state “moored” or “at anchor”. These ships were handled in the following way:

1. It is assumed that ships moored are securely fastened to the platform. Therefore they are skipped in the calculations.
2. Ships at anchor in the vicinity of platforms have a certain threat, because the anchor can start crabbing or the anchor chain can break. Thereafter the ship starts drifting but only for a short period because the crew will start the engine and shortly thereafter the ship will be under control. The probability of an anchor failure is taken from the SAMSON casualty rates. The drifting time can be given as input and is set to 1 hour which is much shorter than the maximum 24 hours (or less in case of successful anchoring or repairing) for drifting in case of an engine failure used in other calculations.

Safety vessels and supply vessels

The contribution to the risk by safety vessels and supply vessels remains relatively high. This follows directly from the AIS data and can be understood when analysing plots of AIS positions. Presumably the ramming risk is overestimated because these vessels know exactly where the platforms are. But these ships can also have engine failures after which the ship starts drifting. Theoretically these vessels can be operated in such a way that they will drift away from a platform after an engine failure. It is uncertain whether the crew will always follow this strategy.

However, it can be assumed that the calculated risk is overestimated for this group of vessels. This is one of the reasons for keeping the results for safety vessels / tugs separate from the other results.

Conclusion

The investigations of the results all require a high quality link between the MMSI number and the corresponding shipping characteristics.

5.3 Impact of AIS coverage

The accuracy of the drifting and ramming risk calculated directly from the AIS targets depends strongly on the completeness of the AIS targets. Thus in areas with a complete coverage of AIS, the accuracy of the risk calculation based on AIS will be higher than the calculation based on a modelled traffic database as is done in SAMSON because the real ship movements are used. However, in areas where the coverage of AIS is poor, the risk calculation based on AIS directly delivers an underestimation of the risk. The level of underestimation depends on the level of the percentage of AIS messages that is received. From experience we know that the AIS coverage in the middle of the North Sea is less than along the coast, while for example many Norwegian platforms are located in that area. AIS reception can be improved by installing AIS base stations on these platforms. This will improve the AIS coverage in these areas and subsequently the accuracy of the risk calculations will increase.

5.4 Results of the calculations

Before the data could be analysed imperfections have been deleted from the dataset. In the analysis a comparison is made between calculation results obtained with the SAMSON model and results based on AIS. Because the AIS coverage seems to be really good in the Dutch sector of the North Sea, the results of the two ways of calculation for the Dutch platforms are compared with each other. The risk totalled over all Dutch platforms is given Table 5-2.

In the result with AIS a distinction is made for the ship type. This is necessary because work vessels, supply and safety vessels around platforms are mostly movements in service of the platform. These movements are not described in the traffic database of SAMSON with merchant vessels. The risk of the platform by work vessels, supply and safety vessels can be determined with the database for non-route-bound ships, but this database does not describe the real activity close to a platform. For this reason only the risk by route-bound ships (R-ships) is compared. The last row of Table 5-2 contains the factor between the results of the two models. It shows that the SAMSON results for drifting are a little lower than based on AIS, while the total SAMSON ramming risk is two times higher. Furthermore the table shows that the ramming and drifting risk by work vessels and supply/safety vessels, thus platform dedicated vessels, is much higher than by passing route-bound ships.

Table 5-2 Total collision risk for Dutch platforms

Model calculation	Drifting per ship type				Ramming per ship type				Grand Total
	R-ship	Work	Supply / safety	Total	R-ship	Work	Supply / safety	Total	
AIS	0.0496	0.0269	0.0683	0.1448	0.0521	0.0350	0.1955	0.2827	0.4275
SAMSON	0.0438				0.1033				
SAMSON/AIS	0.88				1.98				

A geographical display of the results is most suitable for comparing the results of both calculations in more detail because the difference is due to traffic which varies enormously over the area. This geographical analysis is included in the Annex. This Annex also contains the above comparison for the UK and for Norway, German and Denmark.

From the comparisons (see also the Annex) the following can be concluded. There are differences for each platform because the modelled traffic database can never describe the reality of the shipping movements. It is expected that globally the risk calculation of AIS will be qualitatively better than the calculation based on the traffic database. The following conclusions can be drawn:

- The differences for drifting are relatively smaller than for ramming, because the ramming risk is more sensitive to the passing distance of ships;
- The relative difference between AIS and SAMSON is larger in areas with little traffic because in these areas the risk is more built up by outliers, thus movements that are not described precisely in the traffic database;
- When platforms are located close to a traffic lane, the ramming risk based on the traffic database is higher. This means that in reality ships pass the platforms at a larger distance than is modelled in SAMSON;
- Not visible in the figures is that the results for the four periods of three months exhibit fluctuations. This is due to the varying number of ship movements and tracks of these ships. The relative variation is smaller when the risk increases. Thus small risk values are less accurate than large risk values.
- The ramming risk is considerably higher than the drifting risk in the southern part of the area, while the opposite is the case in the northern part. This is because the platforms in the northern part are located in areas with low traffic density where ships pass the platform on relatively larger distances.

5.5 Collision risk for platforms summarized per country

The collision probabilities are summarized per country in Table 5-3. The totals per country divided by the number of platforms delivers the average probability per platform per country, presented in

Table 5-4. The average probabilities are compared and coloured per item to show the highest risk. It shows that the Dutch platforms have relatively high probabilities for route-bound traffic because they are located close to the traffic routes. The platforms in Irish waters have relatively the highest probabilities for fishing and the Danish platforms have relatively the highest probabilities for work vessels and safety and supply vessels.

Table 5-3 Total collision risk per year for offshore platforms per country

Sector	number of platforms	Drifting collision					Ramming collision					Total
		R-bound	fishing	Work	safety& supply	Total drifting	R-bound	fishing	work	safety& supply	Total ramming	
Germany	3	0.0001	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0001	0.0003
Denmark	65	0.0072	0.0028	0.0863	0.2528	0.3491	0.0014	0.0003	0.1389	0.3700	0.5106	0.8596
United Kingdom	314	0.0295	0.0069	0.1481	0.3039	0.4884	0.0229	0.0010	0.1711	0.6633	0.8582	1.3467
Norway	108	0.0043	0.0007	0.0442	0.0818	0.1310	0.0094	0.0001	0.1234	0.3366	0.4695	0.6005
Ireland	2	0.0000	0.0002	0.0001	0.0026	0.0029	0.0000	0.0001	0.0000	0.0057	0.0059	0.0088
Netherlands	147	0.0411	0.0086	0.0269	0.0683	0.1448	0.0490	0.0031	0.0350	0.1955	0.2827	0.4275
Grand Total	639	**0.0822**	**0.0192**	**0.3057**	**0.7094**	**1.1165**	**0.0827**	**0.0046**	**0.4685**	**1.5711**	**2.1269**	**3.2434**

Table 5-4 Average collision risk per offshore platforms for each country

Sector	number of plat-forms	Drifting collision					Ramming collision					Total
		R-bound	fishing	work	safety& supply	Total drifting	R-bound	fishing	work	safety& supply	Total ramming	
Germany	3	0.000039	0.000013	0.000011	0.000006	0.000070	0.000018	0.000015	0.000001	0.000001	0.000035	0.000104
Denmark	65	0.000111	0.000043	0.001328	0.003889	0.005370	0.000021	0.000004	0.002138	0.005692	0.007855	0.013225
United Kingdom	314	0.000094	0.000022	0.000472	0.000968	0.001555	0.000073	0.000003	0.000545	0.002112	0.002733	0.004289
Norway	108	0.000039	0.000007	0.000410	0.000757	0.001213	0.000087	0.000001	0.001143	0.003117	0.004347	0.005560
Ireland	2	0.000017	0.000089	0.000053	0.001306	0.001465	0.000001	0.000043	0.000023	0.002863	0.002931	0.004396
Netherlands	147	0.000279	0.000058	0.000183	0.000465	0.000985	0.000334	0.000021	0.000238	0.001330	0.001923	0.002908
Grand Total	639	0.000129	0.000030	0.000478	0.001110	0.001747	0.000129	0.000007	0.000733	0.002459	0.003329	0.005076

6. Collision risk for platforms and wind farms with the BE-AWARE traffic databases

The method described in the former Chapter is the most accurate one because when using AIS data the true trajectory of each individual ship is modelled. However, this method cannot be used for estimating the risk for a future layout because the flow of traffic changes over the years. Especially in the next decades the traffic flows will change due to the construction of many offshore wind farms. These wind farms are quite space consuming and shipping traffic will be guided around the wind farms. Thus shipping tracks will deviate from the present ones.

The other approach is to construct a traffic database for the future layout and use this for calculating the collision risk for offshore installations. For this approach the BE-AWARE traffic database for 2020 has been used. The BE-AWARE traffic database for 2020 is constructed from the BE-AWARE traffic database of 2011. In 2011 there were 1010 wind turbines built offshore spread over 24 wind farms. Most of these wind farms were located in areas near the coast with low shipping densities. The expectation for 2020 is that 11703 wind turbines have been built spread over 143 offshore wind farms. These wind farms consume a considerable area at sea through which ships cannot sail. The route links through these wind farms have been removed as well as the traffic routed through the links surrounding the wind farms. Furthermore the new scheme of TSSs in the Dutch sea area is included in the 2020 database. This traffic database is used for the calculation of the collision risk for offshore installations, being platforms and wind turbines, in 2020.

6.1 Collision risk for oil and gas platforms

For the calculation of the collision risk for oil and gas platforms the same platforms have been used as in the AIS-based analysis. It should be noted that it is assumed that the same platforms will be operational in the Bonn Agreement area in 2020.

The calculated collision risks for the platforms with the traffic databases of 2011 and 2020 are presented in Table 6-1 and Table 6-2. The risk is given for drifting and ramming collisions and per country. Comparing Table 6-1 with Table 5-3 shows the difference in the approach of Chapter 5 and the approach of this Chapter. The movements of safety vessels, supply vessels, work vessels and fishing vessels operating near a platform are not included in the BE-AWARE traffic database. This means that the risks caused by these ships are not included in Table 6-1. The ships that are included in the BE-AWARE traffic database are the route-bound ships (also indicated with R-ships or R-bound). The risk presented in the column “R-bound” of Table 5-3 corresponds to the risk presented in Table 6-1.

Table 6-1 Ship-platform collisions per year based on the traffic database of 2011

Country	Totals			Average per platform		
	Drifting collision	**Ramming collision**	**Total**	**Drifting collision**	**Ramming collision**	**Total**
Germany	0.0003	0.0001	0.0004	0.000102	0.000019	0.000121
Denmark	0.0116	0.0023	0.0138	0.000178	0.000035	0.000213
United Kingdom	0.0441	0.0355	0.0796	0.000140	0.000113	0.000253
Norway	0.0047	0.0055	0.0101	0.000050	0.000058	0.000108
Netherlands	0.0442	0.0382	0.0824	0.000300	0.000260	0.000560
Grand Total	**0.1048**	**0.0815**	**0.1863**	**0.000168**	**0.000131**	**0.000299**

This result is comparable to the result in Table 5-3. The comparison is made in Table 6-3, see below.

This result is also visualised in the next Figure.

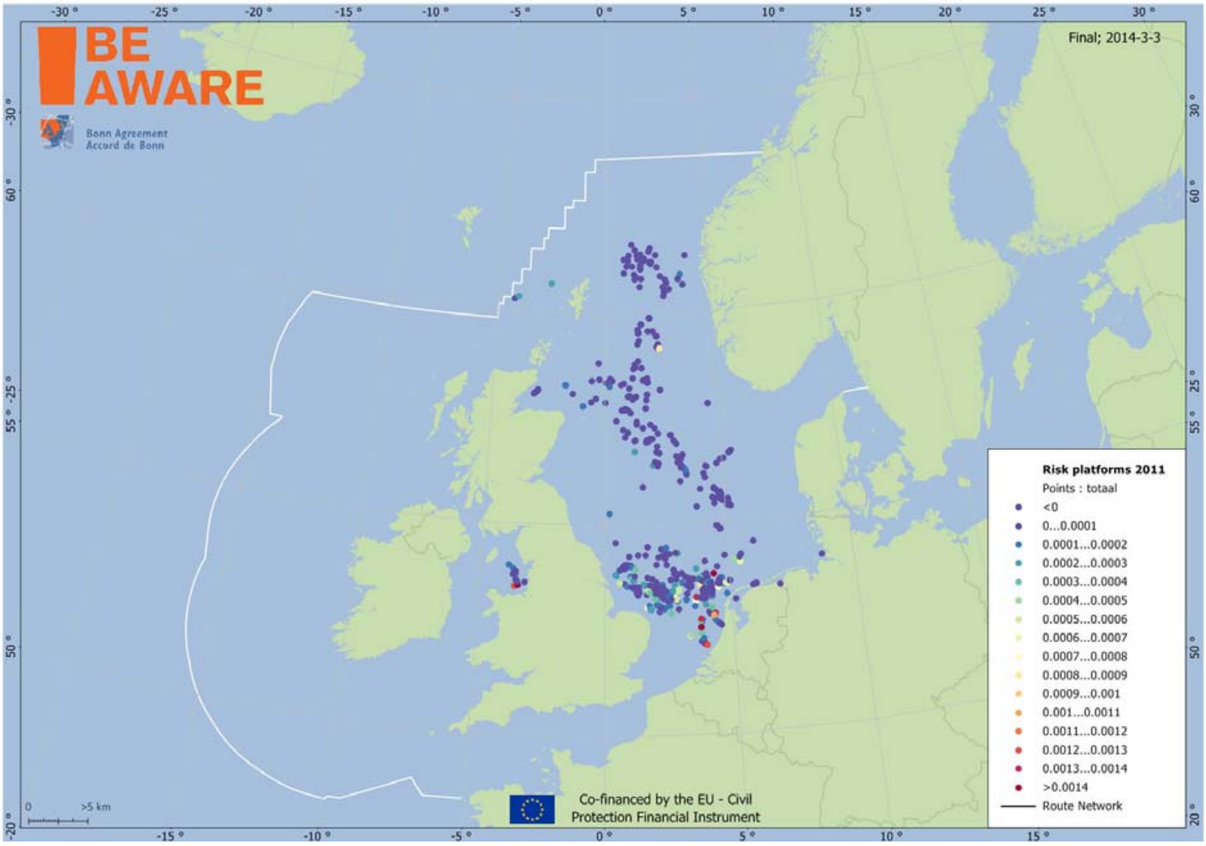

Figure 6-1 **The probability of ship-platform collisions for 2011**

The results of the computations for 2020 are shown in the next table.

Table 6-2 **Ship-platform collisions per year based on the traffic database of 2020**

Country	Totals			Average per platform		
	Drifting collision	**Ramming collision**	**Total**	**Drifting collision**	**Ramming collision**	**Total**
Germany	0.0009	0.0002	0.0011	0.000305	0.000052	0.000356
Denmark	0.0119	0.0025	0.0144	0.000183	0.000039	0.000222
United Kingdom	0.0455	0.0369	0.0824	0.000144	0.000117	0.000262
Norway	0.0046	0.0042	0.0088	0.000049	0.000044	0.000093
Netherlands	0.0488	0.0715	0.1203	0.000332	0.000487	0.000818
Grand Total	**0.1117**	**0.1153**	**0.2270**	**0.000179**	**0.000185**	**0.000364**

This result is visualised in the next Figure:

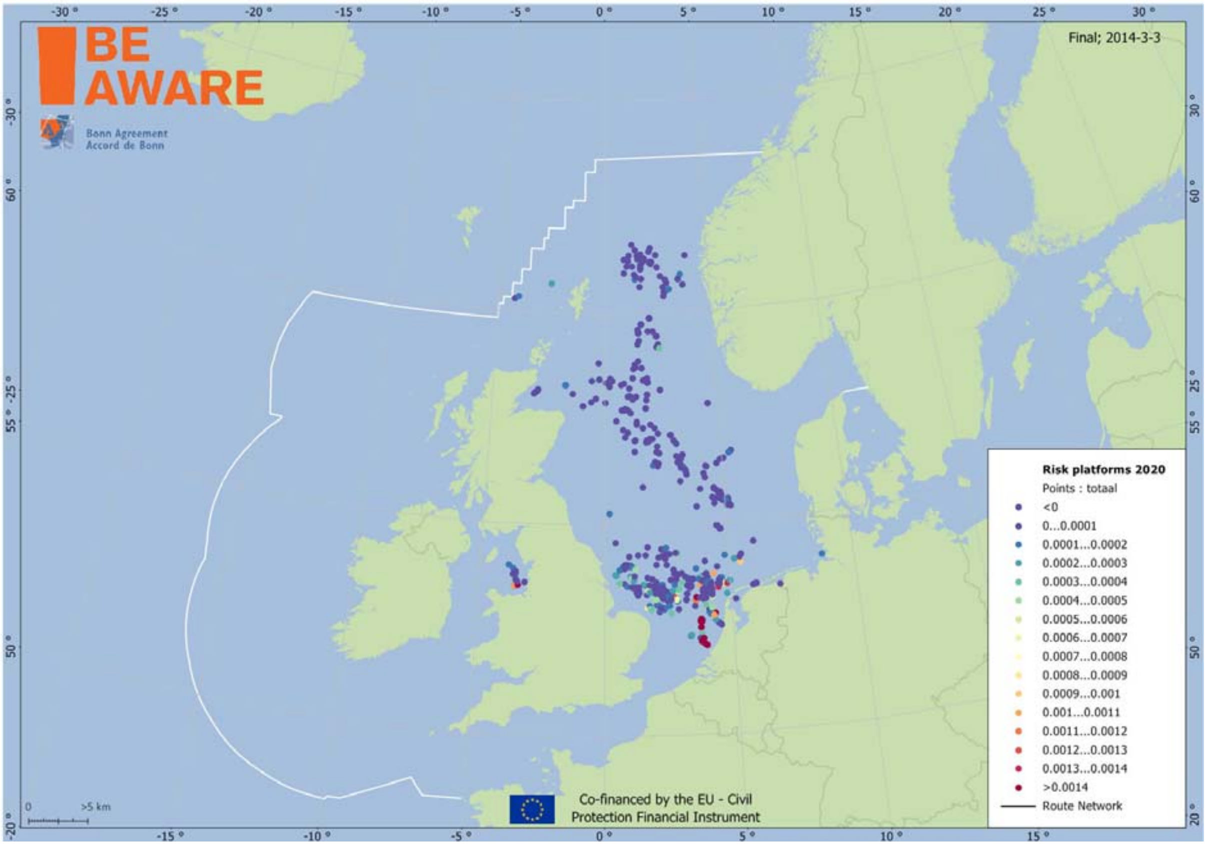

Figure 6-2 The probability of ship-platform collisions for 2020

The results for 2011 are compared with the collision probabilities given in Chapter 5, thus directly based on AIS. Table 6-3 contains this comparison. It contains the factor (the collision risk calculated with the traffic database of 2011) based on AIS of Table 6-1) / (the collision risk calculated directly from the AIS messages of Table 5-3).

Table 6-3 Comparison of calculated collision risk of the two approaches

Country	Calculated risk for 2011 based on traffic database of 2011 divided by the risk based directly on AIS		
	drifting	Ramming	total
Germany	2.60	1.04	2.11
Denmark	1.61	1.64	1.62
United Kingdom	1.50	1.55	1.52
Norway	1.09	0.58	0.74
Netherlands	1.08	0.78	0.91
Grand Total	1.28	0.98	1.13

Within this comparison **only the R-bound ships** are taken from Table 5-3, because only these ships are included in the traffic database. Table 5-3 shows that most collisions with platforms are caused by work, supply and safety vessels. Those vessels operate in service of the platforms. Because of the size of these vessels combined with their speed, collisions by these ships will seldom result in a spillage of oil. For this reason it is acceptable that these collisions are not included in the collision risk results in Table 6-1 and Table 6-2.

In general the results based on the database are slightly higher compared to the results based on AIS, see also the above table. As these analyses are complex it is difficult to give one reason for the differences found. A few effects that certainly contribute are:

- Bad coverage of AIS;
- Behaviour of the traffic close to a platform.

6.2 Collision risk for wind turbines

As described in section 4.3, from the wind turbine data delivered, the input files for 2011 and 2020 were created. The input file for 2011 contains 1010 wind turbines spread over 24 wind farms and the input file for 2020 contains 11703 wind turbines spread over 143 offshore wind farms.

The calculated collision risk for the wind turbines with the traffic databases of 2011 and 2020 are presented in Table 6-4. The risk is given for drifting and ramming collisions and **per country**. The total collision risk increases enormously in 2020 because of the growth from 1010 wind turbines in 2011 to 11703 wind turbines in 2020. When looking at the average risk per wind turbine, the average drifting risk decreases while the average ramming risk increases. The reason is that the outer wind turbines in 2020 are built closer to the passing traffic. The sensitivity of the risk to the passing distance is much larger for ramming than for drifting,

Table 6-4 Ship-wind turbines collisions per year based on the traffic database for 2011 and 2020

Year	Wind turbines	Totals			Average per wind turbine		
		Drifting collision	**Ramming collision**	**Total**	**Drifting collision**	**Ramming collision**	**Total**
2011	1010	0.1730	0.0207	0.1937	0.000171	0.000021	0.000192
2020	11703	1.4957	0.4067	1.9024	0.000128	0.000035	0.000163

The results for 2011 more or less compare with the results for collisions with platforms (wind turbines: 0.1937, platforms: 0.1863. For 2020 the risk for collisions with platforms only increases slightly, whereas the probability for collisions with wind turbines almost increases with a factor 10.

In the next figure an overview is given of the probability contribution of the various wind farms on the 2011 result.

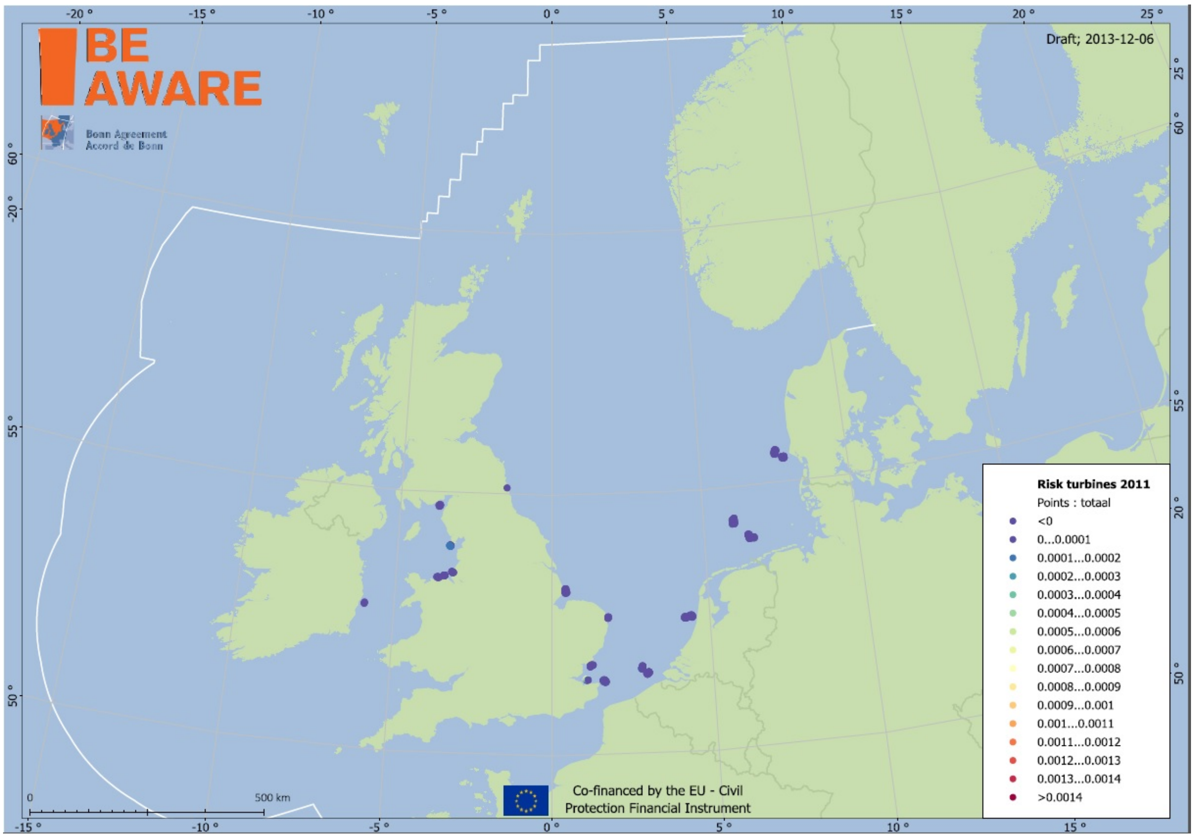

Figure 6-3 **Results for the wind farm calculations for 2011**

Figure 6-4 **Details of the wind farm calculations offshore Belgium**

In the next two figures the results for 2020 are presented in a similar way.

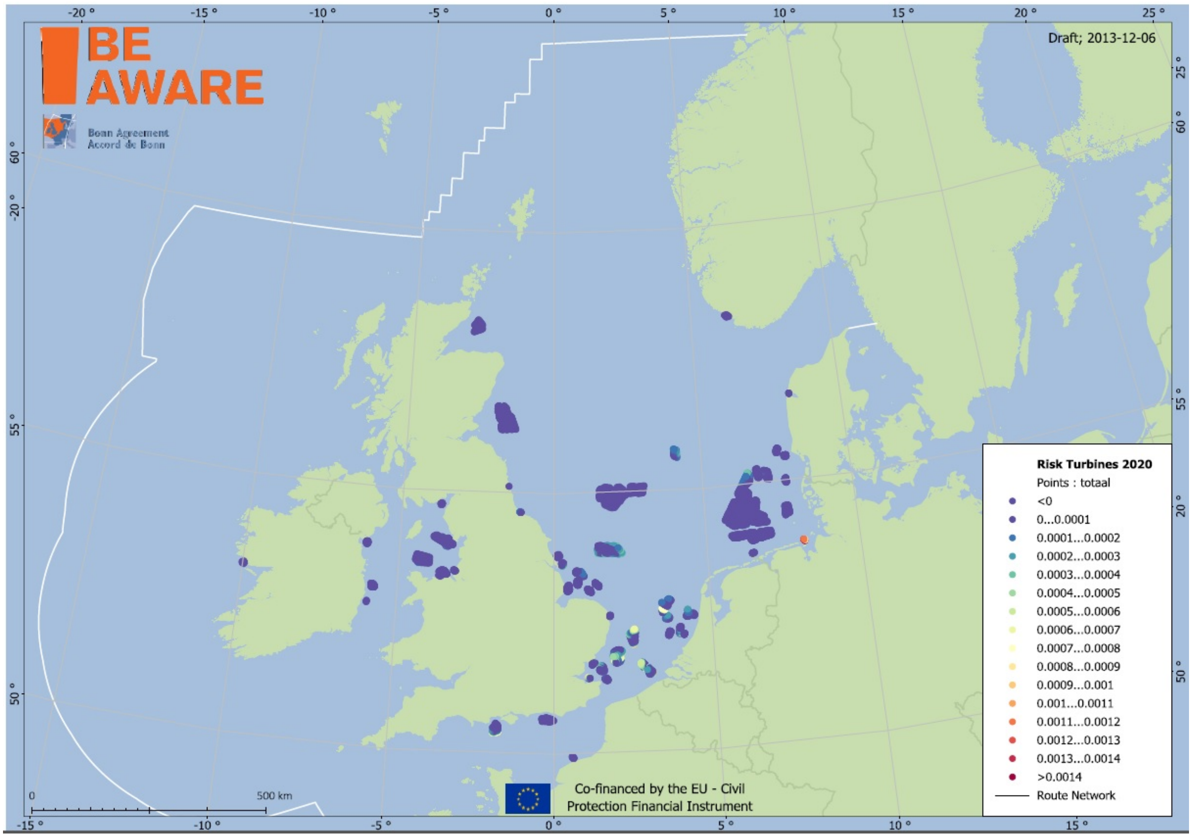

Figure 6-5 Results for the wind farm calculations for 2020

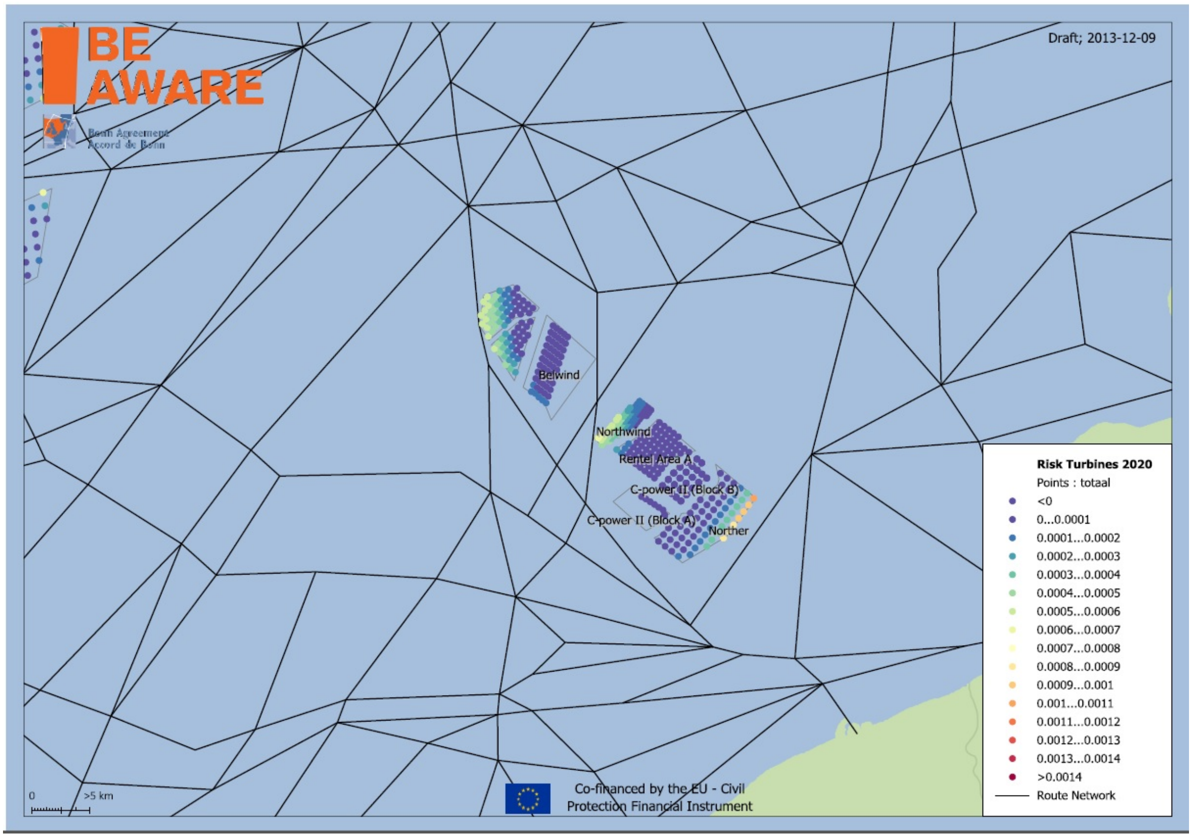

Figure 6-6 Details of the wind farm calculations offshore Belgium for 2020

The above picture shows that turbines close to a traffic link give a relatively large contribution to the overall probability on a collision compared to the turbines inside a wind farm.

6.3 Spills from ships after a collision with an offshore installation

A probability of a spillage of oil can only occur when the collision energy is sufficient to penetrate the hull. If the penetration is on the location of a fuel tank or a cargo tank and the tank is loaded, the bunker oil or cargo oil is spilt. The probabilities of a spillage of oil, thus bunker oil plus cargo oil, after a collision with an offshore installation are given in Table 6-5 and Table 6-6.

Table 6-5 Oil spill probabilities from ships colliding with an offshore installation in 2011

Type of incident	**No spill**	**Spill size in tonnes**								**Total only of spills**
		0-1 t	**1-15**	**15-300**	**300-5000**	**5000-15000**	**15000-50000**	**50000-150000**	**>150000**	
ship_platform	0.1722	0.0000	0.0000	0.0012	0.0048	0.0079	0.0001	0.0000	0.0000	0.0141
ship_wind turbine	0.1873	0.0000	0.0000	0.0010	0.0032	0.0021	0.0002	0.0000	0.0000	0.0064
Grand Total	0.3595	0.0000	0.0000	0.0022	0.0080	0.0100	0.0003	0.0000	0.0000	0.0205

Table 6-6 Oil spill probabilities from ships colliding with an offshore installations in 2020

Type of incident	**No spill**	**Spill size in tonnes**								**Total only of spills**
		0-1 t	**1-15**	**15-300**	**300-5000**	**5000-15000**	**15000-50000**	**50000-150000**	**>150000**	
ship_platform	0.2090	0.0000	0.0000	0.0011	0.0068	0.0098	0.0002	0.0000	0.0000	0.0180
ship_wind turbine	1.8381	0.0000	0.0000	0.0047	0.0332	0.0246	0.0018	0.0000	0.0000	0.0643
Grand Total	2.0471	0.0000	0.0000	0.0058	0.0401	0.0345	0.0020	0.0000	0.0000	0.0823

7. Spills from oil platforms

7.1 Spills from an oil platform after being hit by a ship

The result of the collision risk per platform and per wind turbine for ramming and for drifting are computed for each wind force class in Beaufort. The wind force is used to determine the drifting speed and herewith the kinetic energy of the drifting ship. The kinetic energy for ramming is much higher because the ship is sailing on average with 90% of the service speed. The collision speed is slightly lower due to last minute actions (course change) of the colliding ship. It is assumed that the collision speed is reduced to 85% of the sailing speed. The kinetic energy is used to determine if the hull or double hull of the ship will be penetrated and bunker or cargo oil flows out.

The kinetic energy is also used to assess the probability that the collision against a platform results in a spillage from the platform itself. A platform can resist a collision by a ship with kinetic energy up to 50 MJ without serious damage to the construction of the platform. These collisions will not result in a spillage from the platform. Because high energy collisions occur very seldom, no historical data is available.

Table 7-1 shows the distribution of the collision energy of colliding ships for 2011 based on AIS, thus including platform dedicated traffic. The last column of Table 7-1 is used within the ship-platform collision assessment which indicates what size of spill is expected from the platform in case the collision energy is within the range of column 1 and 2.

Table 7-1 Assumed size of spill from the platform when collided by a ship from AIS

collision energy in MJ		platform collisions per year			platform collisions per year			Spill size in tonnes
from	To	Drifting	ramming	total	drifting	ramming	Grand Total	
0	1	0.139	0.001	0.140	12.4%	0.1%	4.3%	none
1	3	0.239	0.063	0.302	21.3%	2.9%	9.2%	none
3	5	0.271	0.001	0.272	24.1%	0.1%	8.3%	none
5	10	0.263	0.123	0.387	23.5%	5.7%	11.8%	none
10	15	0.085	0.002	0.087	7.6%	0.1%	2.7%	none
15	50	0.078	1.679	1.758	7.0%	78.2%	53.8%	none
50	100	0.031	0.148	0.179	2.8%	6.9%	5.5%	1-15
100	200	0.015	0.003	0.018	1.3%	0.2%	0.6%	15-300
200	…	0.001	0.126	0.127	0.1%	5.9%	3.9%	300-500
Grand Total		1.123	1.123	2.147	3.270	100.0%	100.0%	100.0%

An FPSO platform is considered differently. An FPSO is a double hull tanker. Thus the outflow probabilities of a double hull tanker that is hit by another ship can be used for the assessment of the spill from the ship – platform (FPSO) collision.
The above result is based on the collision risk analysis on the basis of AIS. However, in this project we use the risk values as computed with the BE-AWARE traffic models for 2011 and 2020, the probabilities of platform collisions are presented in Table 5-1. A similar analysis has been made on the results obtained for these models to compute the collision energy and the spillage. So the drift speed is computed for each wind class and the resulting collision energy is computed. With this energy the spillage is determined. The results of these calculations are presented in

Table 7-2.

Table 7-2 Oil spills from the platform after being collided

Year	Type of incident	Spill size in tonnes								Total only of spills
		0-1	1-15	15-300	300-5000	5000-15000	15000-50000	50000-150000	>150000	
2011	Ship platform collision	0.0000	0.0124	0.0060	0.0708	0.0000	0.0000	0.0000		0.0891
	FPSO spills by collision	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	0.0005
2020	Ship platform collision	0.0000	0.0149	0.0085	0.1054	0.0000	0.0000	0.0000	0.0000	0.1289
	FPSO spills by collision	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0003

The results of these calculations are presented in Chapter 8.1 together with the results of spills by operations on the platforms.

8. Spills from offshore oil installations due to daily operations and blow outs

This Chapter deals with spillage from the offshore oil installations due to events on board of the installation, thus not caused by a colliding ship. This part is completely composed by using the spill and leakage frequencies published by others. Contract partners of BE-AWARE have provided supported in this task by delivering, translating and analysing relevant documents.

The SINTEF Offshore Blowout Database contains information on 573 offshore blowouts/well releases that have occurred world-wide since 1955 and overall exposure data from the US Gulf of Mexico, Outer Continental Shelf and the North Sea. The blowouts and well releases are categorized in several parameters, emphasising blowout causes.

This database is the main source used by others to derive frequencies for different type of incidents. The Scandpower report “Blowout and well release frequencies” contains frequencies of blowouts and leakage probabilities of various types of operations for the platforms in the North Sea area.

The International Association of Oil & Gas Producers recommends in (OGP, 2010) the analysis of Scandpower of the SINTEF’s blow-out database for the risk assessment of well operations in the North Sea and in other offshore areas where the equipment is of North Sea Standard. The frequencies of (Scandpower, 2011) have been applied to platforms and wells within the BE-AWARE study area.

In Scandpower, a distinction is made between oil wells and gas wells and between Normal wells and High Pressure and High Temperature (HPHT) wells. The frequencies for oil wells presented in Table 8-1 have been applied to the wells in the BE-AWARE study area. Hereto the oil wells were counted for each platform. Table 8-2 contains the platforms, FPSOs and wells for each country. The substance spilt by oil platforms is crude oil and the spills by condensate platforms are categorized as gas oil spills. There are 19 HPHT platforms, all located in the United Kingdom sector.

Table 8-1 Blow-out frequencies for oil wells

Operation	frequency per unit			frequency per well per year		
	type of well		unit	operations/per year	type of well	
	Normal	HPHT			Normal	HPHT
Production drilling	2.62E-05	1.62E-04	per well	1.0	2.62E-05	1.62E-04
Completion	8.40E-05	8.40E-05	per operation	0.13	1.09E-05	1.09E-05
Wireline	4.00E-06	4.00E-06	per operation	0.5	2.00E-06	2.00E-06
Coiled tubing	8.40E-05	8.40E-05	per operation	0.04	3.36E-06	3.36E-06
Snubbing	1.30E-04	1.30E-04	per operation	0.05	6.50E-06	6.50E-06
Workover	1.40E-05	1.40E-05	per well per year	0.1	1.40E-06	1.40E-06
Producing wells	1.50E-05	1.50E-05	per well per year	1	1.50E-05	1.50E-05
Totals per well/year					6.54E-05	2.01E-04

A short description of the offshore operations in the above table is given below:

Production drilling: the drilling of production wells;

Completion: is the process of making a well ready for production (or injection). This principally involves preparing the bottom of the hole to the required specifications, running in the production tubing and its associated down hole tools as well as perforating and stimulating as required. Sometimes, the process of running in and cementing the casing is also included.

Wireline: a cabling technology used to lower equipment or measurement devices into the well for the purposes of well intervention, reservoir evaluation, and pipe recovery;

Coiled tubing: metal piping, normally 1" to 3.25" in diameter, used for interventions in oil and gas wells (activity is comparable to wireline);

Snubbing: heavy well intervention performed on oil and gas wells, snubbing can be performed with the well still under pressure (not killed);

Workover: complex, difficult and expensive types of wellwork, they are only performed if the completion of a well is terminally unsuitable for the job at hand. The production tubing may have become damaged (due to corrosion) or downhole components may have broken down.

Producing wells: wells producing oil or gas.

Table 8-2 Number of platforms, FPSOs and wells per country in 2011 and 2020

Country	**All platforms**	**for oil and condensate platforms only**		
		FPSO's	**Normal wells**	**HPHT wells**
Denmark	57	2	219	
Germany	3			
Ireland	2			
Netherlands	148		76	
Norway	108	6	757	
United Kingdom	315	16	273	19
Grand Total	**633**	**24**	**1325**	**19**

Besides the blow-out, leakage can occur within the process. For the leakage of wells the same operations are distinguished as for blow-outs.

Table 8-3 Leakage of oil wells

Operation	frequency per unit			frequency per well per year		
	type of well		Unit	operations/per year	type of well	
	Normal	HPHT			Normal	HPHT
Production drilling	5.18E-04	3.21E-03	per well	1.0	5.18E-04	3.21E-03
Completion	2.90E-04	2.90E-04	per operation	0.13	3.77E-05	3.77E-05
Wireline	1.30E-05	1.30E-05	per operation	0.5	6.50E-06	6.50E-06
Coiled tubing	1.40E-04	1.40E-04	per operation	0.04	5.60E-06	5.60E-06
Snubbing	1.10E-04	1.10E-04	per operation	0.05	5.50E-06	5.50E-06
Workover	4.20E-04	4.20E-04	per well per year	0.1	4.20E-05	4.20E-05
Producing wells	1.85E-05	1.85E-05	per well per year	1	1.85E-05	1.85E-05
Totals per well/year					6.34E-04	3.33E-03

Furthermore leakage can occur in the pipelines for the transport to onshore, internal pipelines and risers. These leakages are not included because not enough data was available to include it. In general the expected size of these kinds of spills is small.

Further included are:

- the spill frequency of 5.7E-4 per installation per year;
- the spill frequency of 1.05E-3 from the storage tank in case the oil produced is transported via an FPSO (Floating Production Storage and Offloading);
- leakage frequency of 2.0E-3 per shipment from the FPSO.

Not only the frequency but also the amount of oil spilt is important in modelling the consequences of the oil spills. For each type of oil spill incident, the spill size distribution has been assessed. The distribution of the spill size distribution for each incident, presented in Table 8-4, is taken from (Petroleumstilssybet, 2010).

Table 8-4 Spill size distribution

Spill size in ton		Blow out	Leakage						loading/ unloading
from	to		Well	Pipeline	Internal pipes	Risers	process	storage tanks	
1	1,000	0.1	0.98	0.44	0.52	0.99	1	0.095	0.99075
1,000	2,000	0.1	0.02	0.23	0.21	0.01	0	0.095	0.00075
2,000	20,000	0.61	0	0.33	0.26	0	0	0.76	0.00835
20,000	100,000	0.09	0	0	0.01	0	0	0.05	0.0001
100,000	….	0.1	0	0	0	0	0	0	0.00005
Sum		1	1	1	1	1	1	1	1

The spill size distribution of Table 8-4 does not correspond with the spill size classes distinguished in BE-AWARE. Therefore Table 8-4 is converted to Table 8-5 containing the spill size classes from BE-AWARE. The spill size distribution for the blow-out incident of HPHT wells is added. Because the outflow speed from HPHT wells is much higher than for normal wells the spill will be much more than for normal wells. By lack of data this size distribution had to be assumed. Based on expert opinions the spill size distribution for normal wells is used but the classes are shifted two steps. The conversion has resulted in the spill size distribution of Table 8-5 that is used in the assessment of the oil spills from operations on board of platforms.

Table 8-5 Spill size distribution applied for the calculation of the spills in size classes

Spill size in ton		Blow-out		Leakage			Loading/ unloading
from	to	Normal wells	HPHT wells	Well	Process	Storage tanks	
1	15	0.039	0.000	0.384	0.392	0.037	0.695
15	300	0.043	0.000	0.425	0.434	0.041	0.200
300	5,000	0.360	0.039	0.191	0.174	0.414	0.100
5,000	15,000	0.291	0.043	0.000	0.000	0.363	0.004
15,000	50,000	0.127	0.360	0.000	0.000	0.123	0.001
50,000	150,000	0.071	0.291	0.000	0.000	0.022	0.000
150,000	…	0.068	0.266	0.000	0.000	0.000	0.000
Sum		1	1	1	1	1	1

The spill frequency per spill size class is determined for each oil installation, based on the type of the platform and the number of wells. Results of this Chapter only relate to the spills from the oil installations themselves

The spill frequency per spill size class is determined for each oil installation, based on the type of the installation and the number of wells. These results are given in Table 8-6. The result for 2020 is the same as for 2011 because the set of platforms is not changed.

Table 8-6 Oil spill frequency per year by daily operation

Type of incident	**Spill size in tonnes**								**Total only of spills**
	0-1 t	**1-15**	**15-300**	**300-5000**	**5000-15000**	**15000-50000**	**50000-150000**	**>150000**	
2011 and 2012	0.0000	0.9337	0.6005	0.3114	0.0353	0.0157	0.0078	0.0069	1.9112

8.1 Total spills from oil installations

The results of all calculations are collected for 2011 in Table 8-7 and for 2020 in Table 8-8. The probabilities are summarized over all oil installations.

Table 8-7 Oil spill frequency per year by offshore installations in 2011

Type of incident	No spill	Spill size in tonnes								Total only of spills
		0-1 t	1-15	15-300	300-5000	5000-15000	15000-50000	50000-150000	>150000	
ship_platform	0.1722	0.0000	0.0000	0.0012	0.0048	0.0079	0.0001	0.0000	0.0000	0.0141
platform spills by collision	-	0.0000	0.0124	0.0060	0.0708	0.0000	0.0000	0.0000		0.0891
FPSO spills by collision	-	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	0.0005
platform operation spills	-	0.0000	0.9337	0.6005	0.3114	0.0353	0.0157	0.0078	0.0069	1.9112
ship_wind turbine	0.1873	0.0000	0.0000	0.0010	0.0032	0.0021	0.0002	0.0000	0.0000	0.0064
Grand Total	**0.3595**	**0.0000**	**0.9460**	**0.6087**	**0.3902**	**0.0456**	**0.0161**	**0.0078**	**0.0069**	2.0213

Table 8-8 Oil spill frequency per year by offshore installations in 2020

Type of incident	No spill	Spill size in tonnes								Total only of spills
		0-1 t	1-15	15-300	300-5000	5000-15000	15000-50000	50000-150000	>150000	
ship_platform	0.2090	0.0000	0.0000	0.0011	0.0068	0.0098	0.0002	0.0000	0.0000	0.0180
platform spills by collision	-	0.0000	0.0149	0.0085	0.1054	0.0000	0.0000	0.0000	0.0000	0.1289
FPSO spills by collision	-	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0003
platform operation spills	-	0.0000	0.9337	0.6005	0.3114	0.0353	0.0157	0.0078	0.0069	1.9112
ship_wind turbine	1.8381	0.0000	0.0000	0.0047	0.0332	0.0246	0.0018	0.0000	0.0000	0.0643
Grand Total	**2.0471**	**0.0000**	**0.9486**	**0.6149**	**0.4569**	**0.0699**	**0.0178**	**0.0078**	**0.0069**	2.1227

The spills resulting from operations on oil installations have been calculated for 2011, however as it is difficult to predict where installations may be decommissioned or installed, the spills by operations on installations in 2020 were kept on the same level as for 2011.

The growth in number of wind turbines from 1010 in 2011 to 11703 in 2020 has an impact on the traffic flows because the wind farm areas are blocked for shipping. The growth causes an increase not only in the number of incidents and spills involving wind turbines but also has an impact on the number of collisions with platforms due to changes to the routes.

Table 8-9 is derived from Table 8-7 and Table 8-8. For each spill size class a representative spill is taken. The frequency within a spill size class, multiplied with the representative spill size delivers the average amount of tonnes spilt per year. The results for 2020 are divided by those for 2011 in the last two columns of Table 8-9. It shows that the number of ship-wind turbine spills is more than 10 times higher in 2020 than in 2011. Then the average amount spilt per year is about 3 times the amount spilt by ship-platform collisions, while it was 1/3 in 2011.

The ship-platform collision risk grows by 27% (factor 1.27) and the tonnes spilt from the platform by the collisions by 49%. The change is caused by the changes in the traffic flows. The predicted 3420 tonnes of spills per year for oil installation operation spills is not the amount of oil that is yearly spilt. Ninety percent of the amount predicted would be in fact delivered by spills from events that occur less than once in 70 or 145 years, e.g. infrequent blow-out events as the oil spilt in these types of events can be very large.

Table 8-9 Predicted Frequency and volume of spills (per year) for 2011 and 2020

	2011		2020		2020/2011	
	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tonnes
ship_platform	0.0141	78	0.0180	99	1.27	1.27
platform spills by collision	0.0891	85	0.1289	127	1.45	1.49
FPSO spills by collision	0.0005	6	0.0003	4	0.62	0.71
platform operation spills	1.9112	3420	1.9112	3420	1.00	1.00
ship_turbine	0.0064	26	0.0643	303	10.01	11.51
Grand Total	2.0213	3616	2.1227	3954	1.05	1.09

The results in the above tables have been used to compute the exceedance probability of a spill size. This result is shown in the next figure:

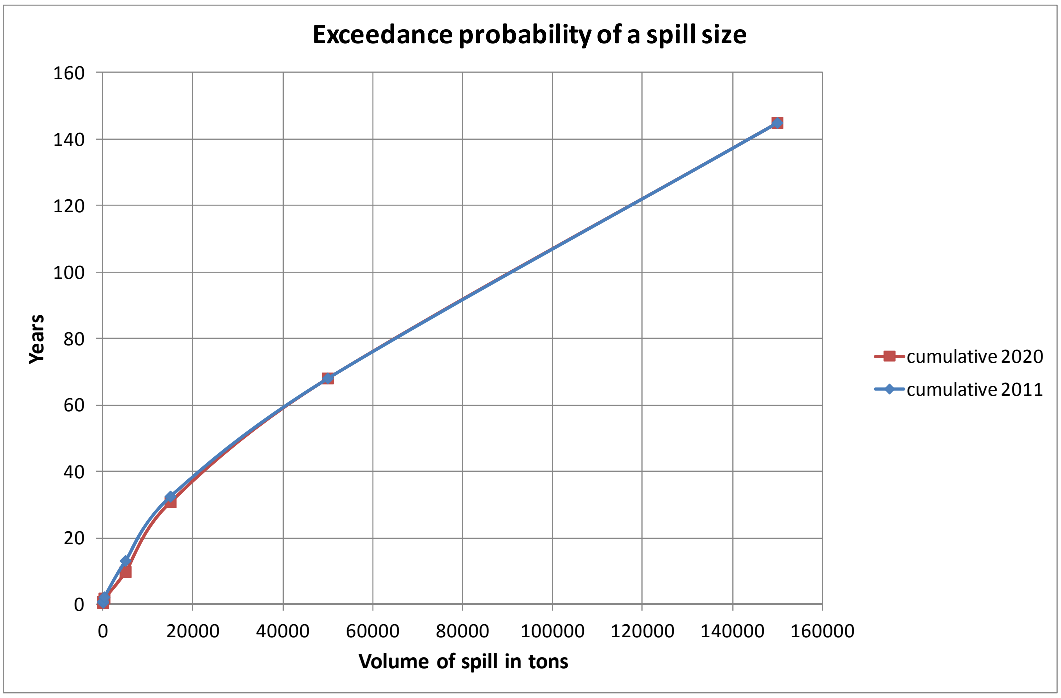

Figure 8-1 Exceedance probability of a spill with a certain size

This figure shows that a spill larger than 40,000 tonnes can be expected once in 60 years. A spill size larger than 90,000 tonnes is expected once in 100 years.

Mitigating measures to reduce the outflow of oil

The BE-AWARE methodology takes into consideration existing risk reducing measures. However, possible response measures will only be addressed in a second phase (BE-AWARE II) where the outflow of oil will be modelled. Therefore, recent advancements in technology, particularly for blow-out accidents, such as subsea capping and dispersant application equipment are not taken into consideration in this report.

9. Summary and Conclusion

In this study three possible scenarios that lead to the spillages of oil from accidents involving offshore installations have been considered:

- Spillage from the ship due to damage as a result of a collision/contact between a ship and an offshore installation, this can be platforms or wind turbines or other structures *(ship – platform or ship turbine)*;
- Spillage from the offshore installation due to damage as a result of a collision/contact between a ship and an offshore installation *(platform or FPSO spills by collision)*;
- Spillage from the offshore installation due to events on board of the installation that lead to damage that results in a spillage of oil *(platform operation spills)*.

Table 9-1 contains the spill frequencies and the tonnes spilt per year for 2011 and 2020. In the last column the increase from 2011 to 2020 is indicated. It shows that the number of ship-wind turbine spills is more than 10 times higher in 2020 than in 2011. The number of ship-platform collisions grows by 27% (factor 1.27) and the tonnes spilt from the platform by the collisions by 49%. The change is caused by the changes in traffic flows.

Table 9-1 Frequency and volume of spills for 2011 and 2020

	2011		2020		2020/2011	
	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tonnes
ship_platform	0.0141	78	0.0180	99	1.27	1.27
platform spills by collision	0.0893	86	0.1290	127	1.44	1.49
FPSO spills by collision	0.0004	5	0.0003	4	0.69	0.78
platform operation spills	1.9112	3420	1.9112	3420	1.00	1.00
ship_turbine	0.0064	26	0.0643	303	10.01	11.51
Grand Total	2.0215	3615	2.1228	3954	1.05	1.09

The predicted 3420 tonnes spills per year for platforms operation spills is not the amount of oil that is yearly spilt. Ninety percent of the amount predicted would be in fact delivered by spills from events that occur less than once in 70 or 145 years, e.g. infrequent blow-out events. The oil spilt in these types of events can be very large.

The results of this study have been used to compute the exceedance probability of a spill size. This result is shown in the next figure:

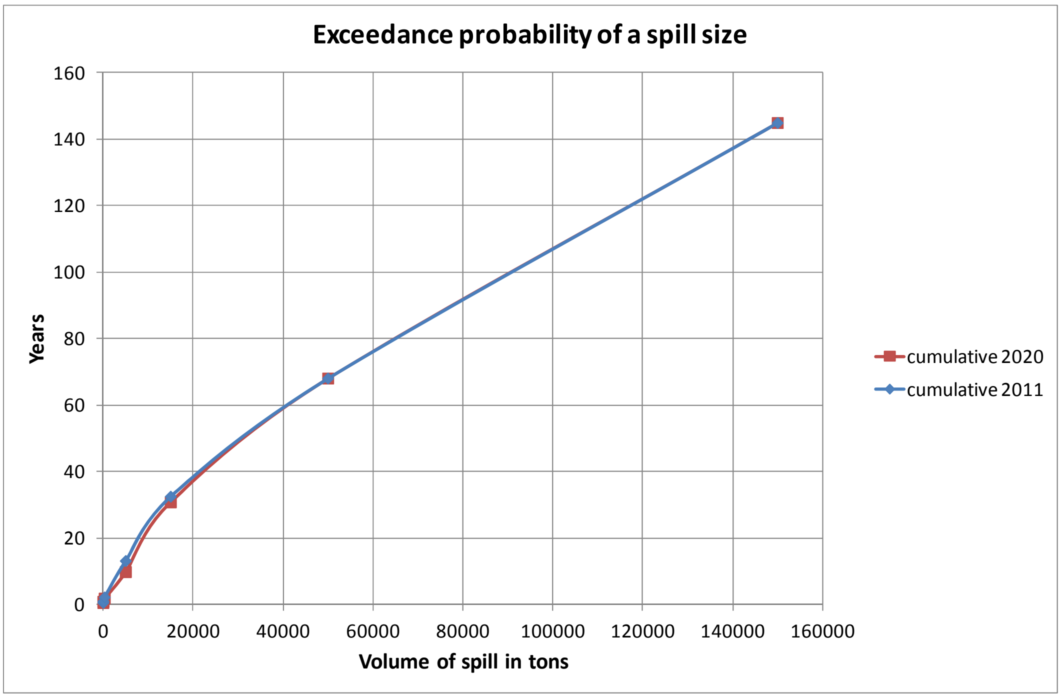

Figure 9-1 Exceedance probability of a spill with a certain size

This figure shows that a spill larger than 40,000 ton can be expected once in 60 years. A spill size larger than 90,000 tonnes is expected once in 100 years.

Mitigating measures to reduce the outflow of oil

The BE-AWARE methodology takes into consideration existing risk reducing measures however possible response measures will only be addressed in a second phase (BE-AWARE II) where the outflow of oil will be modelled. Therefore recent advancements in technology, particularly for blow-out accidents such as subsea capping and dispersant application equipment are not taken into consideration in this report.

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(OGP, 2010)	International Association of Oil & Gas Producers, Risk Assessment Data Directory, Report No. 434 -2 March 2010
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(Petroleumstilsynet, 2010)	Frekvenser for akutte utslipp fra petroleumsvirksomheten

Glossary of Definitions and Abbreviations

FPSO	Floating Production Storage and Offloading, a tanker is used as production facility
HPHT	High Pressure High Temperature well
N-ship	A non-route-bound ship. This ship mostly has a mission at sea, such as fishing vessels, supply vessels, working vessels and pleasure crafts.
NEEZ	Netherlands Exclusive Economic Zone
Probability	The probability (or number per year) is generally given with a large number of digits. This does not necessarily mean that the accuracy is very large, but the larger number of digits is used to make comparison possible between different items, also when the absolute values are small.
QRA	Quantitative Risk Assessment
R-ship	A route-bound ship. It is a merchant ship sailing along the shortest route from one port to another.
SAMSON	Safety Assessment Model for Shipping and Offshore on the North Sea
TSS	Traffic Separation Scheme
Exceedance probability	Probability that an event of specified magnitude will be equalled or exceeded in any defined period of time, on average

Annex

Detailed geographical comparison between SAMSON/AIS results and (normal) SAMSON database results.

A geographical display of the results is most suitable for comparing the results of both calculations in more detail because the difference is due to traffic which varies enormously over the area. Therefore Figure 0-1 and Figure 0-2 with respectively the drifting risk and ramming risk in the southern part of the Dutch North Sea are provided. The numbers in the figure near the platforms have the following meaning. The first number is the risk calculated based on AIS and the second number after the "-" is the risk calculated with SAMSON based on the traffic database. The "-" is located on the position of the platform. Not all results are plotted because overlapping values are omitted. The risk is presented in expected number of collisions in million years. Thus the notation "1049-816" in Figure 0-1 means that based on AIS 1049 drifting contacts are expected in one million years (thus about once in 950 years) and 816 drifting contacts are expected in one million year based on the traffic database (thus once in 1225 years). Figure 0-3 and Figure 0-4 show the same type of data but than for the northern part of the Dutch North Sea. The platform P14-A has the highest ramming risk of 9236 based on AIS in Figure 0-2. This risk value is wrong because platform P14-A has been removed in 2008, but was by mistake still included in the platform file. Now ships can freely cross the former safety zone around P14-A.

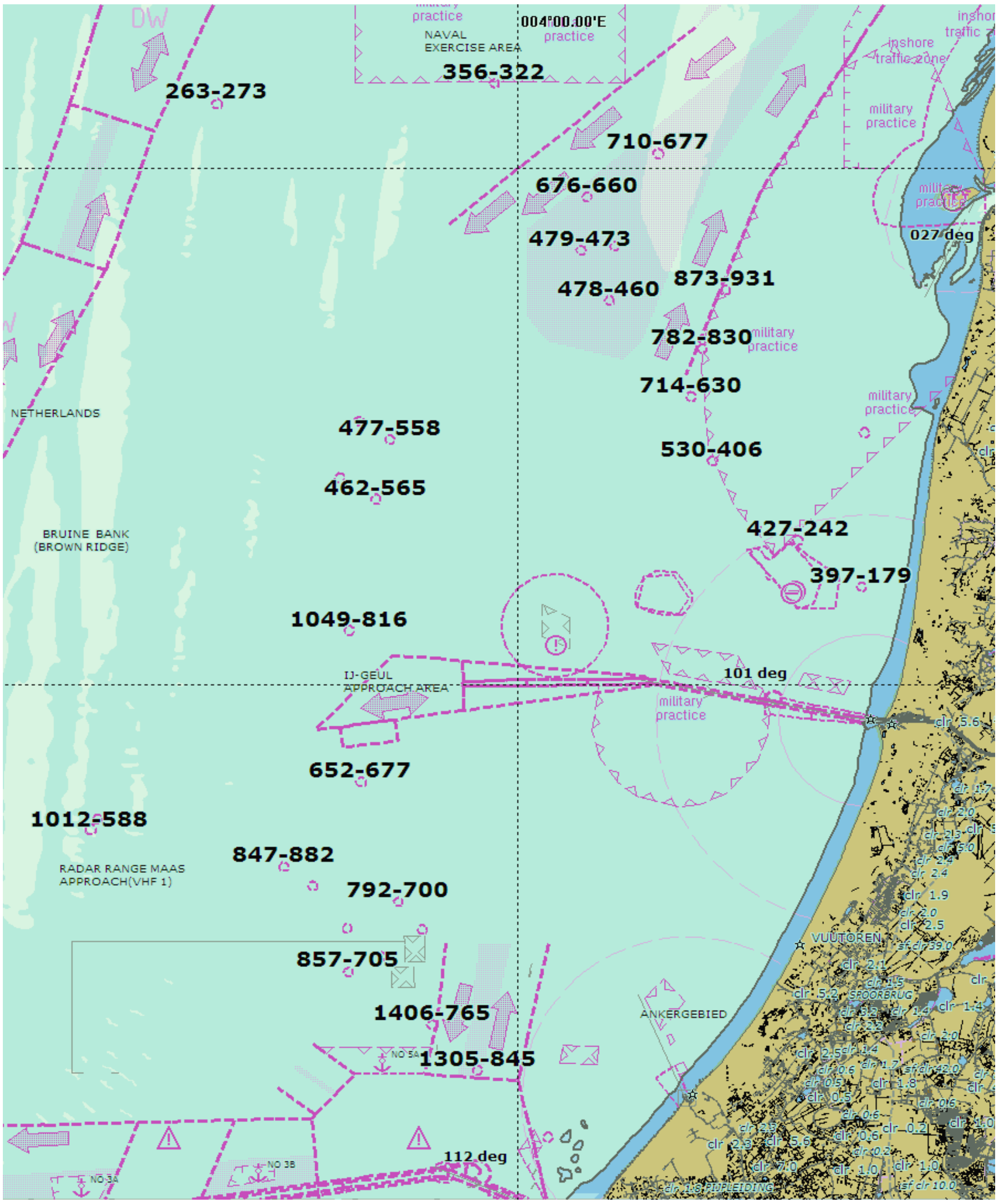

Figure 0-1 Drifting risk for southern Dutch platform per million year AIS-SAMSON

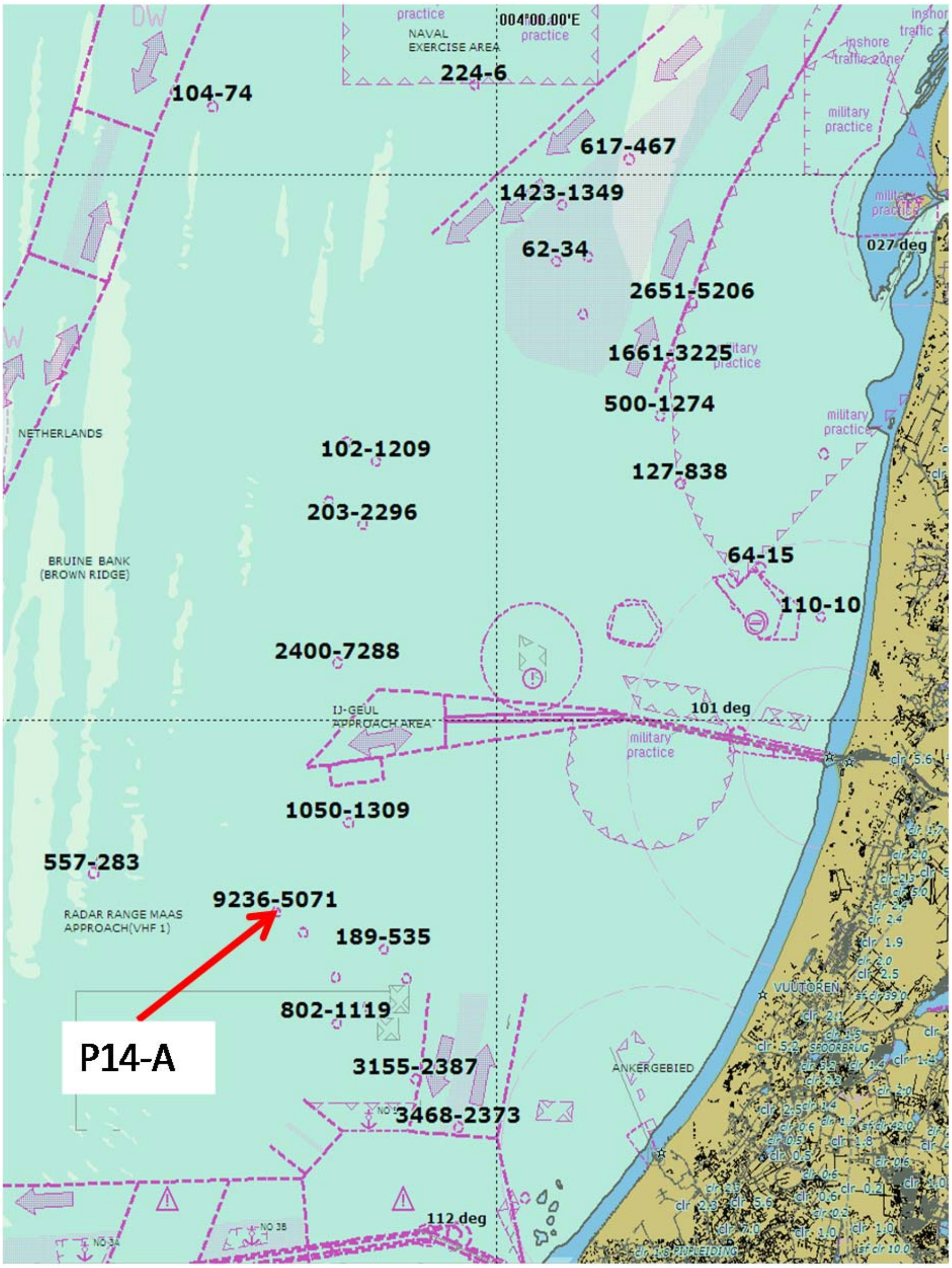

Figure 0-2 Ramming risk for southern Dutch platform per million year AIS-SAMSON

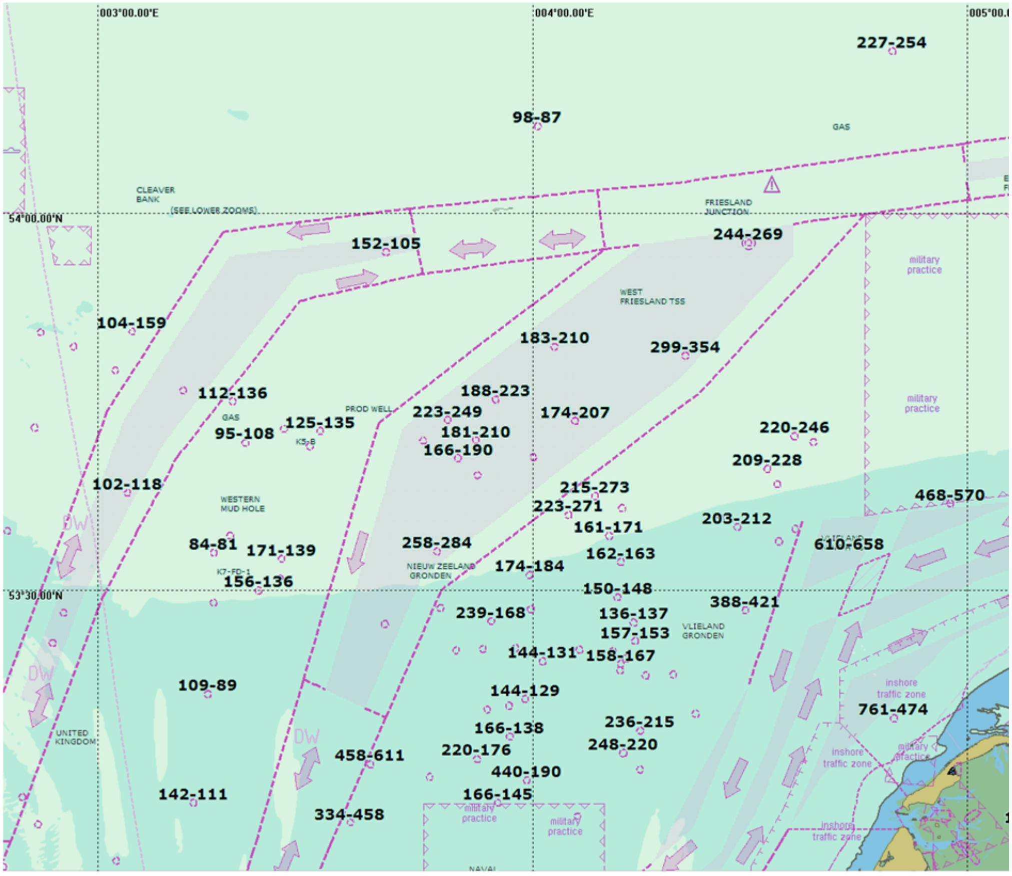

Figure 0-3 Drifting risk for northern Dutch platforms per million year AIS-SAMSON

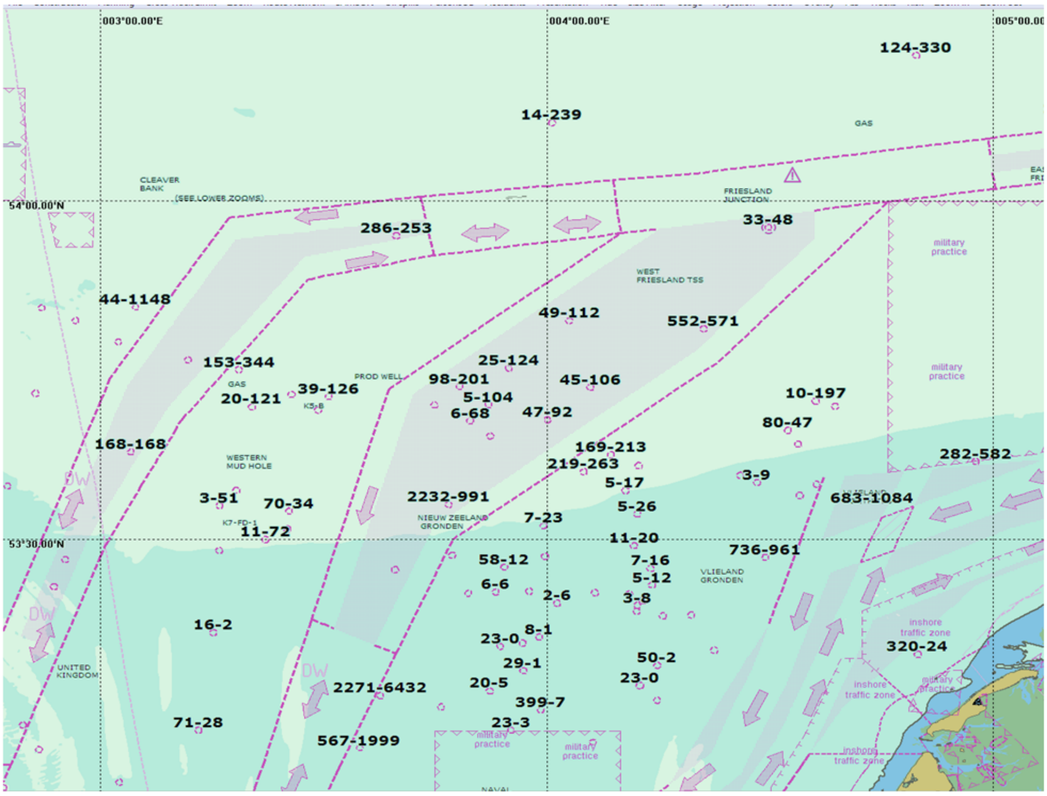

Figure 0-4 Ramming risk for northern Dutch platforms per million year AIS-SAMSON

Of course there are differences for each platform because the modelled traffic database can never describe the reality of the shipping movements. It is expected that globally the risk calculation of AIS will be qualitatively better than the calculation based on the traffic database. The following conclusions can be drawn:

- The differences for drifting are relatively smaller than for ramming because the ramming risk is more sensitive to the passing distance of ships;
- The relative difference between AIS and SAMSON is larger in areas with little traffic because in these areas the risk is more built up by outliers, thus movements that are not described precisely in the traffic database;
- Where platforms are located close to traffic lanes, the ramming risk based on the traffic database is higher. This means that ships pass the platforms at a larger distance in reality than is modelled in SAMSON;
- Not visible in the figures is that the results for the four periods of three months exhibit fluctuations. This is due to the varying number of ship movements and tracks of these ships. The relative variation is decreasing when the risk increases. Thus small risk values are less accurate than large risk values.
- The ramming risk is considerably higher than the drifting risk in the southern part, while the opposite is the case in the northern part. This is because the platforms in the northern part are located in areas with low traffic density.

A comparison for the other areas considered in the computations is shown below.

Table 0-1 Total collision risk for offshore platforms of Norwegian + German + Denmark

Model calculation	Drifting per ship type				Ramming per ship type				Grand Total
	R-ship	Work	Supply / safety	Total	R-ship	Work	Supply / safety	Total	
AIS	0.0152	0.1306	0.3346	0.4803	0.0112	0.2624	0.7066	0.9802	1.4605
SAMSON	0.0178				0.0538				
SAMSON/ AIS	1.13				4.79				

Table 0-2 Total collision risk for offshore platforms of UK

Model calculation	Drifting per ship type				Ramming per ship type				Grand Total
	R-ship	Work	Supply / safety	Total	R-ship	Work	Supply / safety	Total	
AIS	0.0366	0.1482	0.3065	0.4913	0.0240	0.1711	0.6690	0.8641	0.0366
SAMSON	0.0411				0.0772				
SAMSON/ AIS	1.12				0.59				