NAVIGATIONAL RISK – JAMMERLAND BUGT WIND FARM

Navigational Risk Assessment Jammerland Bugt Offshore Wind Farm

Orbicon A/S

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Assessment of the navigational risk associated with establishment of the Omø Syd Offshore Wind Farm

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Contents

Nomenclature

AIS	Automatic Identification System
EIA	Environmental impact assessment
HAZID	Hazard Identification
IMO	International Maritime Organization
IWRAP	IALA Waterway Risk Assessment Programme

1 SUMMARY

Jammerland Bugt Offshore Wind Farm is a project subject to pre-investigations under the "open-door" arrangement issued by Danish Energy Agency dated march 2014. The scope of the present report is to assess the navigational risk associated with establishment of the Jammerland Bugt Offshore Wind Farm

The overall approach for this navigational risk assessment follows IMO's (international Maritime Organization) guidelines for evaluation of navigational safety assessment. A stepwise approach is adopted meaning that results are presented after each step and evaluated together with the Danish Maritime Authority (Søfartsstyrelsen) whether or not the next step needs to be executed.

Step 1: A frequency analysis based on ship traffic and proposed offshore wind farm layout is executed and results are presented to the Danish Maritime Authority.

Step 2: If the Danish Maritime Authority does not find it possible to conclude from the results of the frequency analysis that the navigational risks will be acceptable, a consequence analysis must be executed and combined with the frequency results. The navigational risk assessment will then be updated with the resulting risk derived by combining the frequency and the consequence analyses.

Step 3: If the Danish Maritime Authority cannot approve the estimated risk, possible risk reducing measures have to be identified, analyzed and adopted if considered feasible. This risk reduction process must continue until the risk reaches an acceptable level. Otherwise it has to be concluded that the project will not be feasible when required to be associated with an acceptable ship collision risk.

For the present Jammerland Bugt Offshore Wind Farm it is judged that Step 1 is sufficient for the risk assessment. This implies that only a frequency analysis is carried out for the present study. The ship traffic around the proposed area for the Jammerland Bugt Offshore Wind Farm is established based on available AIS data and used as the basis for the navigational risk assessment. The HAZID report concludes that the hazards related to navigational risk are all related to the risk of ships colliding with a turbine or ship-ship collision due to the presence of the Offshore Wind Farm. A wind farm layout consisting of 80 turbines of 3MW (240 MW total) has been used as the worst case scenario (this is a scenario that is expected to produce the largest navigational risk) for this evaluation.

The frequency analysis gives a return period for ship-wind turbine collisions of 111700 years for powered collisions (i.e., typical human error), and 5873 years for drifting collisions (i.e., typical technical errors). The combined return period for powered and drifting collision is thus estimated to 5580 years. The largest contribution to the calculated collision return period is from ship traffic on the north and south going route H west of the wind farm. The risk of ship-ship collision and grounding around the offshore wind farm under existing conditions has been compared to the imposed traffic change due to the wind farm and is evaluated to be insignificant.

Based on these evaluations it is judged not to be necessary to perform a consequence analysis (Step 2) and, hence, neither to perform a detailed evaluation of risk reducing measures (Step 3). The conclusions from the frequency analysis (Step 1) indicate that the occurrence of ship-turbine collisions will be low and hence the increase in navigational risk due to establishment of the Jammerland Bugt Offshore Wind Farm is acceptable.

The impact on the navigational risk during the installation and decommissioning phases has not been evaluated since there are still too many unknown parameters to complete this analysis. The risk assessment for the installation and decommissioning would normally be part of the scope of work for the appointed contractor.

2 INTRODUCTION

On February 22 2012 European Energy A/S applied for a permit for feasibility studies and preparation of an EIA for the establishment of an offshore wind farm at Jammerland Bugt. The permit was given by Energistyrelsen on March 3 2014. In connection with the feasibility studies a navigational risk analysis shall be carried out.

DNV GL has been contracted to perform a navigational safety analysis in connection with the preparation of the environmental impact assessment (EIA) for the Jammerland Bugt Offshore Wind Farm.

2.1 Objectives

The objective of the present navigational risk assessment is to evaluate how and to what extent the ship traffic in the area will be influenced by the Jammerland Bugt Offshore Wind Farm and to identify and estimate any associated increase in the navigational risk in the region near the wind farm.

3 PROJECT DESCRIPTION

Jammerland Bugt Offshore Wind Farm is a near shore farm. The entire survey area is shown in figure 3.1. Refer to appendix A for a navigational chart.

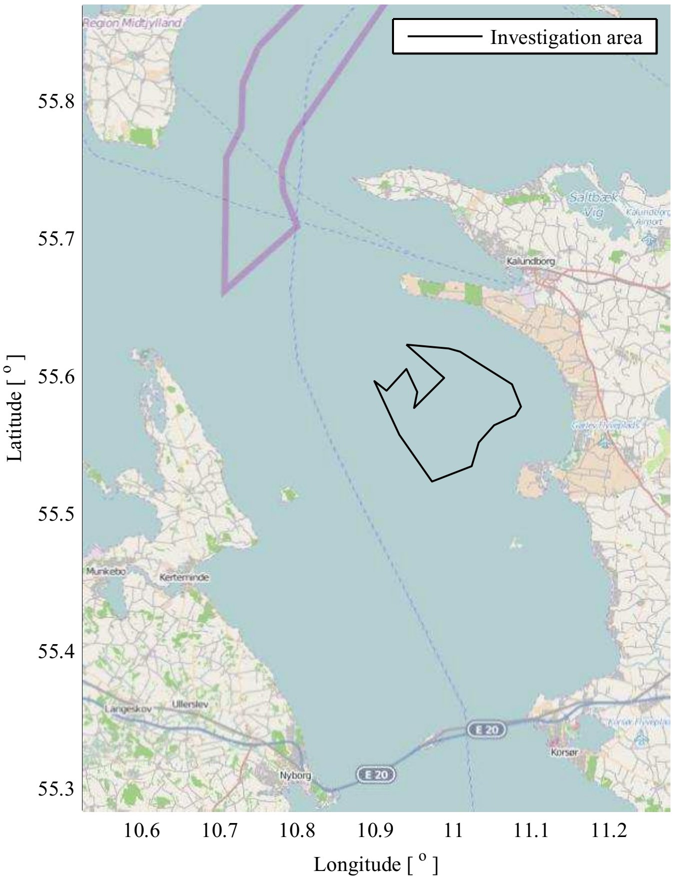


Figure 3.1

3.1 Installations offshore

Jammerland Bugt Offshore Wind Farm will be located within an approximate 69 km^2 survey area, which covers an area, situated between the Great Belt bridge and Kalundborg. Water depths in the area vary between 4 and 20 m. The offshore wind farm will possibly be established with a maximum capacity of 240 MW and will possibly take op the whole survey area.

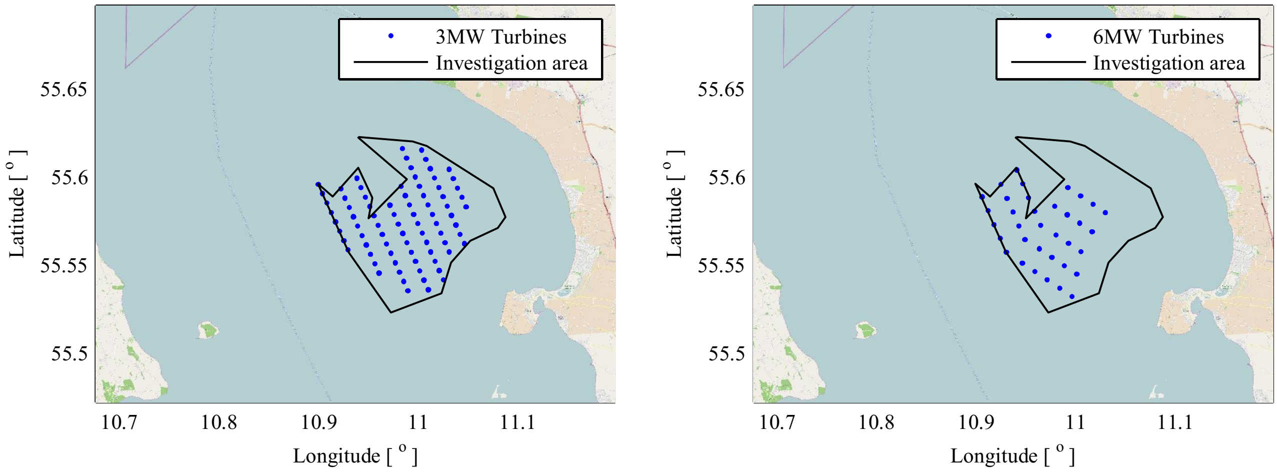
Turbine capacity	Rotor diameter	Total height	Hub height	Max number
3MW	112 m	150 m	94 m	80 pcs
6MW	154 m	199 m	112 m	35 pcs

Table 3.1: Specifications of possible turbines

The power will be exported directly to land thus no offshore substation will be needed.

3.2 Wind farm layout

The possible positions for the 80 3MW and 35 6MW turbines are shown in appendix C.1-C.2. The turbine layout is shown in figure 3.2.



(a) 3MW turbine layout

(b) 8MW turbine layout

Figure 3.2: Turbine layouts

4 BACKGROUND

The navigational risk assessment presented in the present report is part of the total EIA (Environmental Impact Assesment) for the Jammerland Bugt Offshore Wind Farm project.

The overall approach for this navigational risk assessment follows IMO's (international Maritime Organization) guidelines for evaluation of navigational safety assessment. A stepwise approach is adopted meaning that results are presented after each step and evaluated together with the Danish Maritime Authority (Søfartsstyrelsen) whether or not the next step needs to be executed.

Step 1	A frequency analysis based on ship traffic and proposed offshore wind farm layout is executed and results are presented to the Danish Maritime Authority.
Step 2	If the Danish Maritime Authority does not find it possible to conclude from the results of the frequency analysis that the navigational risks will be acceptable, a consequence analysis must be completed and combined with the frequency results. The navigational risk assessment will then be updated with the resulting risk derived by combining the frequency and the consequence analyses.
Step 3	If the Danish Maritime Authority cannot approve the estimated risk, possible risk reducing measures have to be identified, analyzed and adopted if considered feasible. This risk reduction process must continue until the risk reaches an acceptable level. Otherwise it must be concluded that the project will not be feasible when required to be associated with an acceptable ship collision risk.

The basis for the evaluation covered in Step 1 (The frequency analysis) is described in the following subsections. The objective of Step 1 is to estimate the frequency of ship collisions with the wind turbines and this is performed based on a worst case layout of the offshore wind farm. The results are initially used to assess if the risk associated with collisions can be concluded acceptable without quantifying the consequences of these collisions. This would be the case if the frequencies are so low that the associated risks would be acceptable even with the most conservative assessment of the consequences. If this is not the case Step 2 (The consequence analysis) has to be carried out.

4.1 Method

The following describes the method for performing Step 1, - the frequency analysis. The frequency analysis is based on acknowledged mathematical models typically used for such analyses and with input based on historical (statistical) data. The applied calculation tool IWRAP MKII is a part of the IALA Recommendation [IALA O-134] on risk management.

4.1.1 Analysis tool

The IWRAP MKII software calculates the probability of collision or grounding for a vessel operating on a specified route. The applied model for calculating the frequency of grounding or collision accident involves the use of a so-called causation probability that is multiplied onto a theoretically obtained number of grounding or collision candidates. The causation factor models the probability of the officer on the watch not reacting in time given that he is on collision course with another vessel (or – alternatively – on grounding course), refer to Engberg [2010] for detailed theoretical model description.

A description of the ship traffic constitutes the central input for a navigational risk assessment. Automatic Identification System (AIS) data provides a detailed geographic and temporal description of the ship traffic in a region and has been used as the primary data basis. Because the predominant part of the ship traffic is following navigational routes – which can be more or less well defined – the modelling of the ship traffic and the associated models of the risk of collisions and groundings usually adopts a route based description of the traffic.

The ship traffic description based on AIS is thus subsequently used as basis for definition of the routes in the probabilistic model in IWRAP MKII.

4.1.2 Risk scenarios

Installation of an offshore wind farm will introduce obstacles that the ship traffic has to avoid. If not successful in doing this a collision to a wind turbine will be the result. However, the deviations required of the ship traffic to avoid the wind turbines may also increase the potential for ship-ship collisions. A navigational risk analysis shall therefore cover the following four risk contributions:

- Ship-turbine collision risk for powered vessels (i.e., typically human error).
- Ship-turbine collision risk for drifting vessels (e.g., vessel with technical error).
- Changes in ship-ship collision risk due to increased traffic density around the offshore wind farm area.
- Changes in ship grounding risk due to changed traffic pattern around the offshore wind farm area.

The frequency analysis shall determine how often the above-mentioned three scenarios are expected to occur when the offshore wind farm has been introduced and based on this it can initially be judged if the risk associated with such collisions is readily acceptable. If not, the likely consequences of the collisions have to be determined to establish the fully detailed risk picture.

4.2 Worst case assumptions

As described in section 3.1 either 3MW or 6MW turbines are to be installed. Since the final layout of the turbines in the offshore wind farm is not known at present, the navigational risk assessment is performed such that it will represent a worst case for all possible turbine layouts i.e. both with regards to turbine size and location of the turbines within the offshore wind farm area.

The collision frequency analysis is based on a layout of wind turbines that, in the context of navigational risk, is considered as the worst case scenario. The chosen worst case scenario is 80 3MW turbines since this will result in the highest risk of collision. It is noted that a layout with 35 6MW turbines would take up approximately the same area, but the lower number of turbines would present fewer obstacles to the ship traffic which would lead to a reduced potential of ship collisions. The 80 3MW turbines are in the worst case scenario distributed over the entire offshore wind farm area since this represents the case where the existing ship traffic will be disturbed the most.

The diameter of the tower at the water surface, which is relevant for the ship-turbine collision is assumed to be 10 meters.

4.3 Before and after

The ship traffic before and after the construction of the wind farm will be modeled in order to compare the impact of the offshore wind farm on the navigational risk. It is assumed that some traffic routes will change and furthermore fishing and leisure vessels will change patterns. Ship-ship collision and grounding of ships will thus be modeled in cases predicting before (i.e. existing conditions) and after construction of the wind farm.

Scenario	Existing routes	Relocated routes	Turbines included
1 (Before)	x		
2 (After)	x	x	x

Table 4.1: Calculated scenarios

5 EXISTING CONDITIONS

In the context of navigational risk the relevant existing conditions are constituted by the ship traffic in the area. The existing ship traffic in the vicinity of the offshore wind farm area is shown in figure 5.1. The figure is based on AIS data collected in the period from October 1 2013 to September 30 2014 and hence represents the existing conditions undisturbed by the presence of an offshore wind farm. The collection of ship traffic data and subsequent modifications in order to use it for the frequency analysis is described in the following subsections.

5.1 Ship traffic based on AIS data

This subsection describes the ship traffic used as input for the frequency analysis. The ship traffic is determined from regional AIS data collected for twelve months. The AIS data handled in the analysis is within the following geographic bounds:

	56°13.335′ N	
008°49.836′ E		014°34.969′ E
	54°22.917′ N	

Table 5.1: Geographic bounds of AIS

The mapped AIS data and its extents are shown in figure 5.1

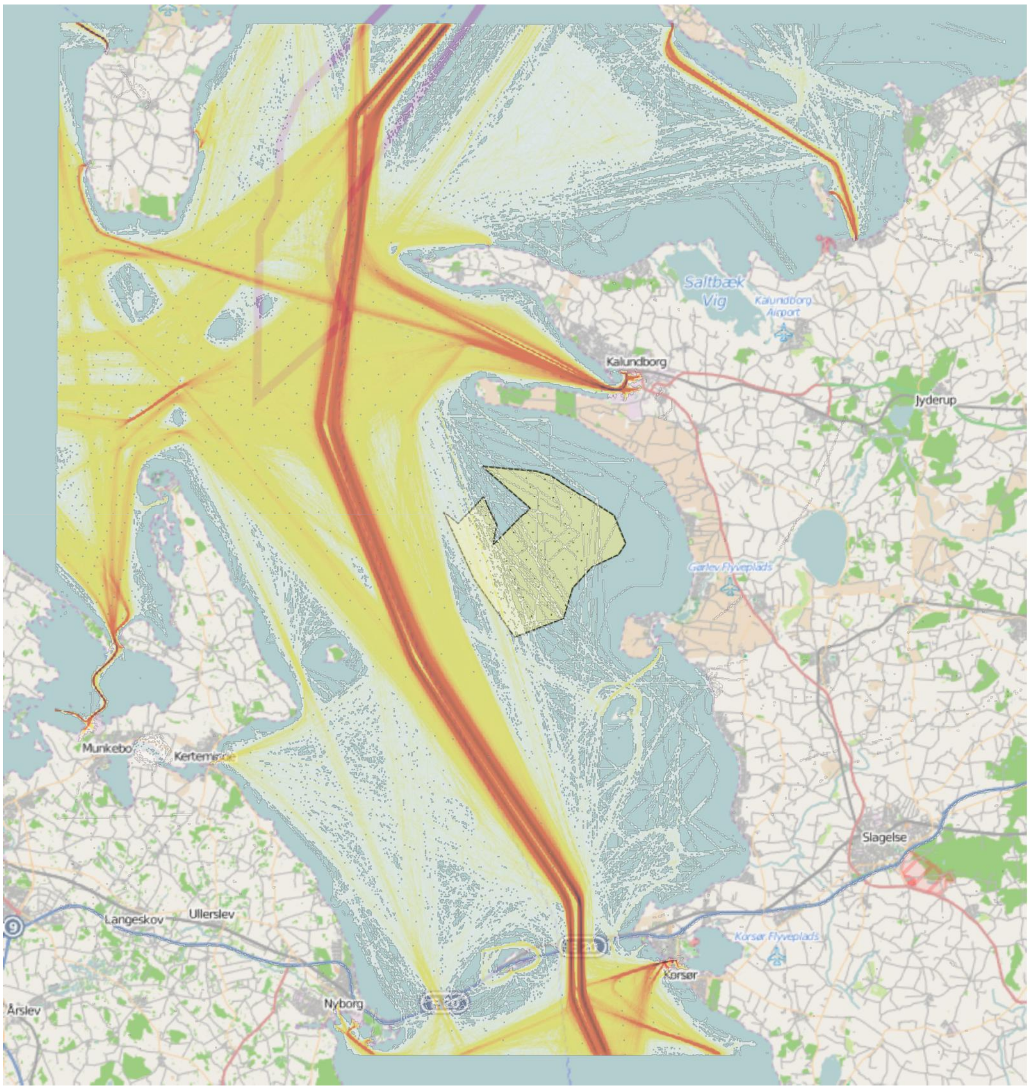


Figure 5.1: Ship traffic density based on AIS data from October 1 2013 to September 30 2014. The turbine area is shown for information only

5.2 Analysis of AIS data

The AIS data consists basically of successive position reports from each individual vessel that are within the selected geographic area. The first step in the analysis is to separate the position reports for each vessel, arrange them chronologically and combine them in sequence to form tracks that describe their passage within the area. These tracks form the basis for the subsequent analysis. The first result of the analysis is the density of tracks that is shown in figure 5.1.

Of main regard for the wind farm the traffic density is dominated by the densely trafficked corridor, route H, that is passing through Great Belt.

The traffic modelling is approximated by poly-linear center-lines – the route – and a probabilistic description of the traffic distribution transverse to this ideal center line. Based on successive definition of routes and association of the AIS tracks to these routes, a set of routes have been found necessary and relevant in order to model the ship traffic considered in the present study which is of particular concern to the proposed Jammerland Bugt Offshore Wind Farm.

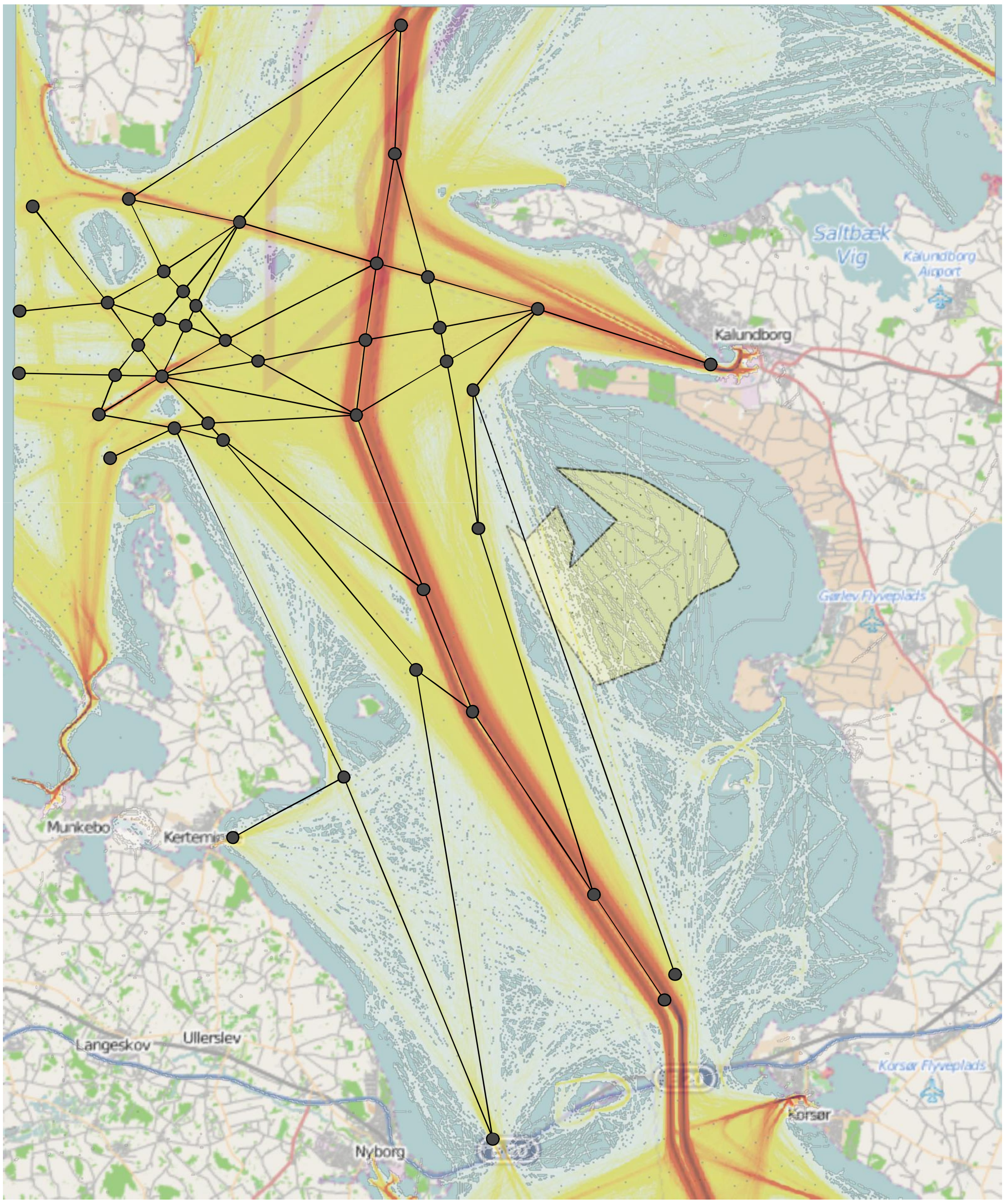


Figure 5.2: Ship traffic routes and AIS data, refer appendix D for route and waypoint numbers. Turbine area shown for information only

Based on the AIS and associated routes in figure 5.2 (refer appendix D for waypoint and route details), it is evident that ship traffic on some routes are passing through the site or in close proximity, and will thus adapt to the presence of the proposed Jammerland Bugt Offshore Wind Farm.. It is noted that LEG_39 is passing directly through the proposed Jammerland Bugt Offshore Wind Farm. Hence, the traffic pattern after the offshore wind farm has been established will change. Section 6 deals with the anticipated reaction of the ship traffic due to the presence of the wind farm i.e. the traffic will tend to stay outside the wind farm and at a reasonable distance.

The association of routes does not necessarily utilize all the observed tracks in the AIS database. However all tracks has been evaluated and the ones found important for the present analysis has been included.

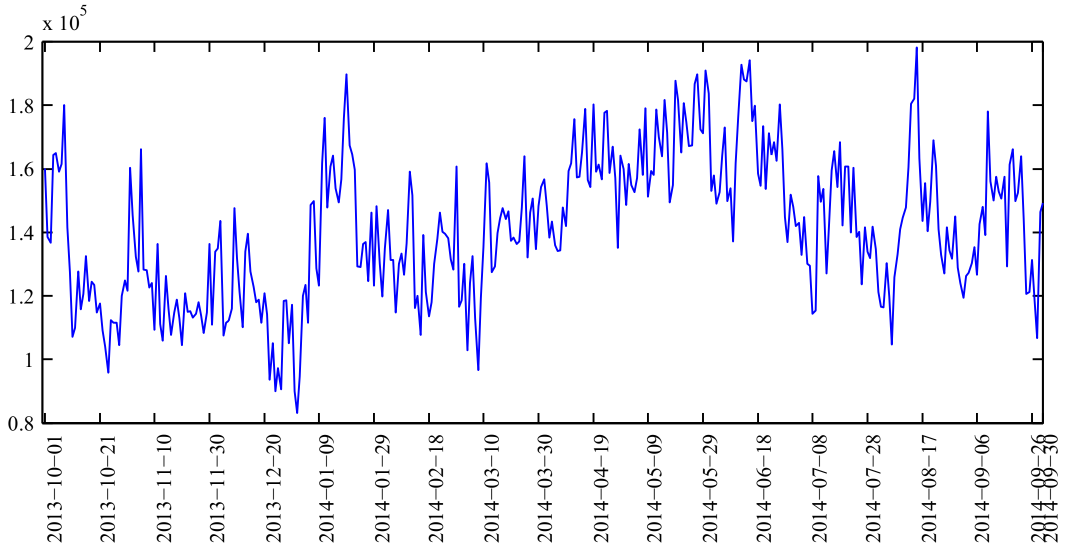


Figure 5.3: Variation of number of AIS records per day for the survey period

5.3 Ship classification

The ships are classified according to information contained in AIS signal message 5 (see ITU-R-1371-5 section 3.3 "Ship static and voyage related data" and section 3.3.2 "Type of ship"). Based on the identifier number contained in message 5 the following ship types are categorized as follows:

	Ship type					
	Fishing ship	Pleasure boat	Support ship	Passenger ship	General cargo ship	Oil Products tanker
Type Of Ship And Cargo	30	37	31-35 50-59	40-49 60-69	70-79	80-89

* All tankers are placed into the category "Oil Products tanker"
* All cargo ships are placed into the category "General cargo ships"
* Passenger ships which travels faster than 30 knots are placed in the category "High speed ferry"
* If AIS is class B and not "Fishing ship" then "Pleasure boat"

Table 5.2: Ship classification according to AIS identifier number

5.4 Modeling of traffic distribution across routes

The ship traffic as identified through the AIS data has been associated with ideal – or generic – routes described in terms of the ideal centerlines. In order to calculate the risk of collisions to the offshore wind farm structures it is required that the deviation of the ship traffic from these ideal centerlines is described by a probabilistic model.

In some cases the description of the deviations can be extracted from the observed deviations – i.e., via the spread of the observed traffic density. But, in other cases, the establishment of the proposed offshore wind farm will impose changes to the navigational pattern to ensure a safe passing distance to the offshore wind farm structures. In these cases the spread and distribution type of the traffic has to be assumed on the basis of the presently observed spread combined with the proximity and restriction that the offshore wind farm structures is considered to constitute to the ship traffic.

The transverse distribution is composed of a number of superposed probability distributions (normal and uniform) which are fitted to the recorded AIS data. A graphic overview of the fitted distributions are shown in figure 5.4.

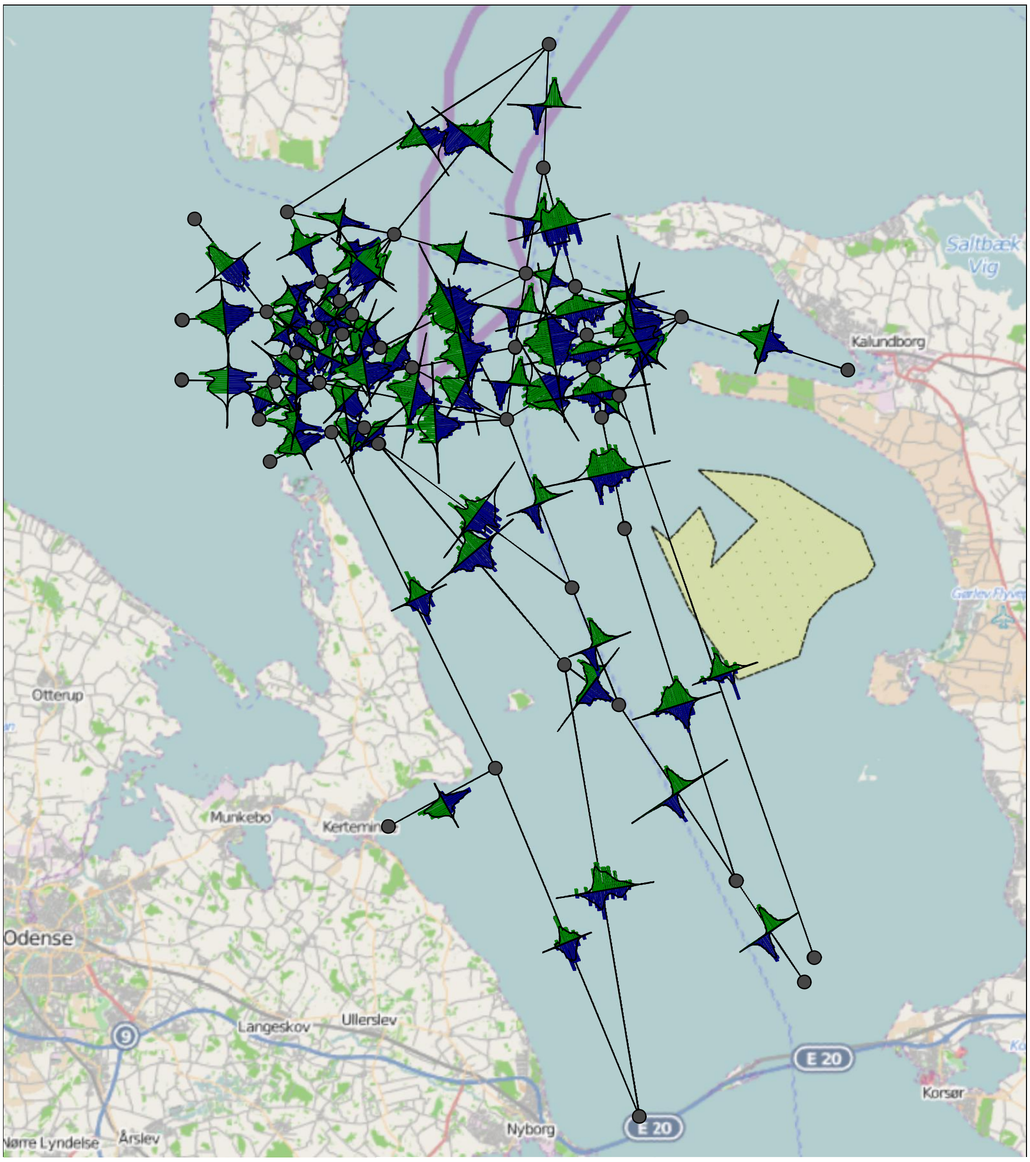


Figure 5.4: Defined routes and distributions. Turbine area shown for information only

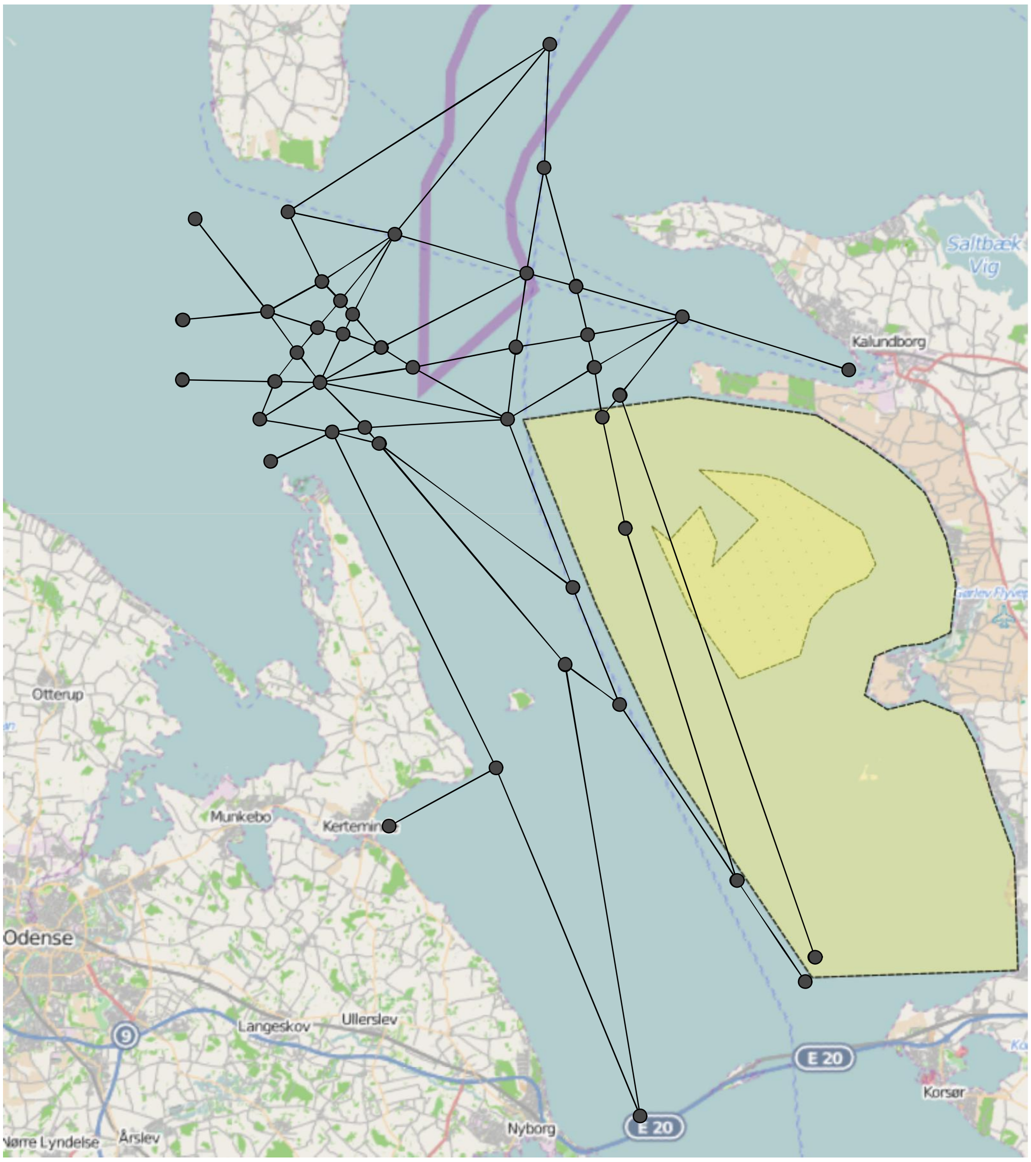


Figure 5.5: Leisure traffic modeled in the yellow area. Turbine area shown for information only

5.5 Traffic areas

By traffic area is understood that traffic that do not follow ordinary routes. The area traffic is composed of leisure crafts and fishing vessels. These vessels will cross the routes at which the line traffic operates at random angles. The number of collisions between the area traffic and the line traffic is calculated by assuming that the area traffic crosses the route the line traffic operates on at eight different directions.

The traffic areas is included to predict the ship-ship collision frequencies and does not influence the ship grounding or ship-turbine collision results.

Since the traffic is not based on AIS statistics it is thus defined manually in terms of size, number and some parameters determining how the traffic is assumed to behave during a year.

5.5.1 Leisure traffic

The leisure vessels will usually travel in patterns that are more irregular than that of the merchant ship traffic. As mentioned in the HAZID report DNV GL [2014] these traveling patterns are not well described in the route structure that is used for the merchant traffic, and a different more diffuse modeling of this ship traffic is required for use in a frequency analysis.

It is evaluated that approximately 500 leisure vessels are present in Jammerland Bugt during a year.

Length [m]	Number of ships [per year]	Number of days [per ship per year]	Visits [per day]	Movement time [hours per visit]	Stationary time [hours per visit]
15 m	500	20	1	8	0

Table 5.3: Assumed leisure traffic

The leisure vessels are included in the model as a “traffic area”. In these areas the vessels will cross the routes at which the line traffic operates at random angels. The number of collisions between the area traffic and the line traffic is calculated by assuming that the area traffic crosses the route the line traffic operates on, at eight different directions.

It is evaluated that the traffic on route H will be unaffected by the presence of the farm and the anticipated response of the leisure vessels. The leisure traffic area is thus modeled as an traffic area extending from Zealand and towards the boundary of route H in Great Belt see figure 5.5.

5.5.2 Fishing traffic

As during the HAZID DNV GL [2014] it was estimated that approximately 45 fishing vessels at the size of around 12m are not covered by AIS. The assumed fishing traffic is shown in table 5.4 (note that size and number of ships has been taken as 20 m and 100 respectively). It is assumed that these vessels are present in the same area as shown in figure 5.5.

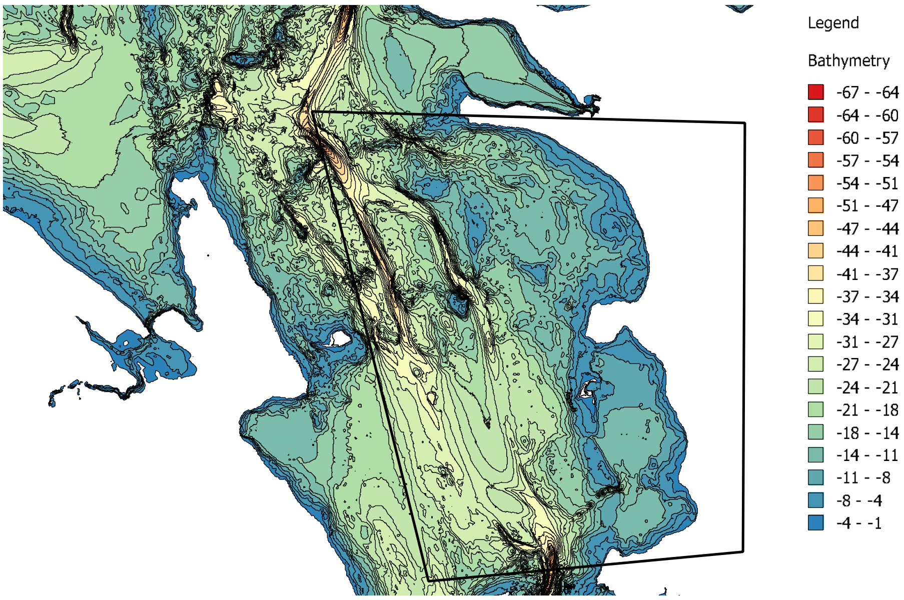
Length [m]	Number of ships [per year]	Number of days [per ship per year]	Visits [per day]	Movement time [hours per visit]	Stationary time [hours per visit]
20	100	100	1	6	2

Table 5.4: Assumed fishing traffic

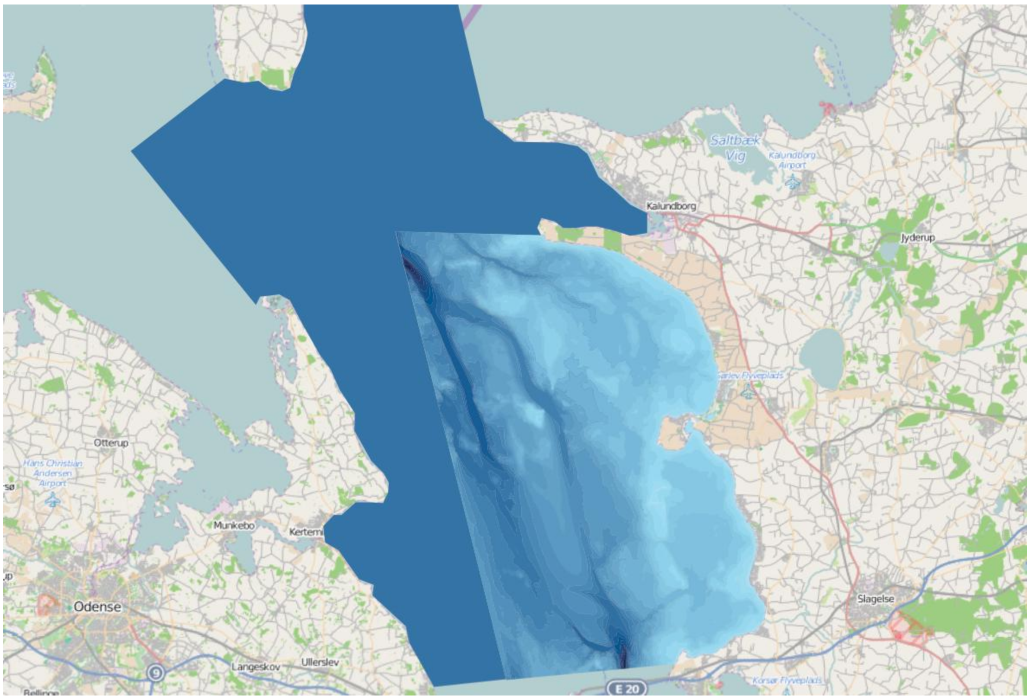
5.6 Modeling of grounds

The grounds in the area are as shown in figure 5.6a. The wind farm will be located at water depths ranging between 10 to 4m in the bay of Jammerland Bugt. The wind farm will be partly shielded by the grounds "Lysegrunde" (Southbound traffic on route H) and "Elefantgrunde" (Northbound traffic on route H).

The grounds inside the marked area in figure 5.6a have been included in the model.



(a) Grounds inside highlighted area used in analysis



(b) Bathymetry imported into analysis. The darker surrounding area defines a water depth enabling emergency anchoring for ships outside the detailed bathymetry area

Figure 5.6

6 REVISED CONDITIONS

The presence of the offshore wind farm under investigation is assumed to result in that some of the ship traffic will relocate to avoid passing through the offshore wind farm. The routes used to model these components of the ship traffic in the frequency analysis will be adjusted accordingly based on the assumed future behavior of this traffic i.e. how the traffic will tend to relocate.

In the analysis it is assumed that ship traffic will not travel through the farm. The proposed revisions to these routes are discussed in the following.

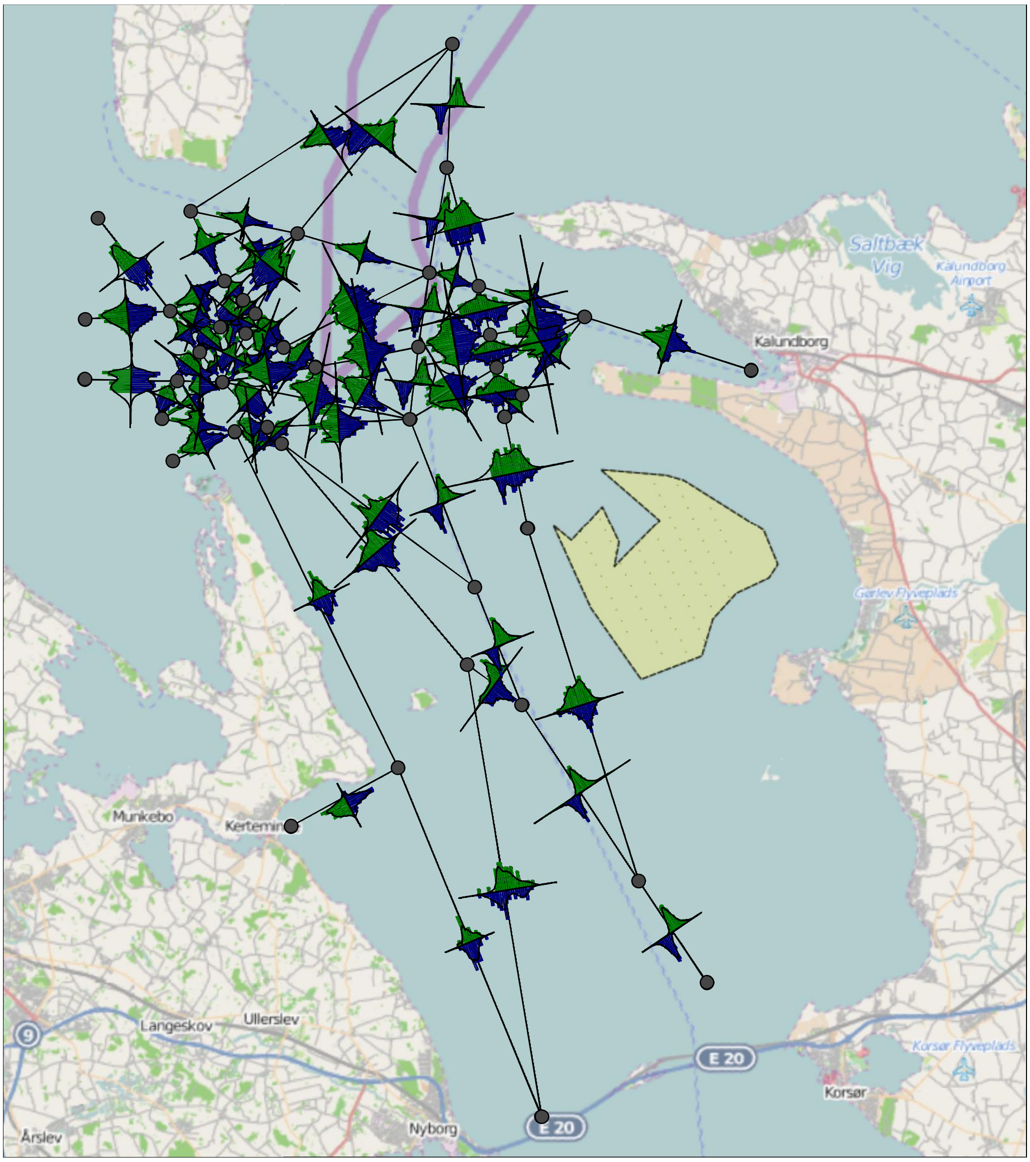


Figure 6.1: Revised routes due to wind farm.

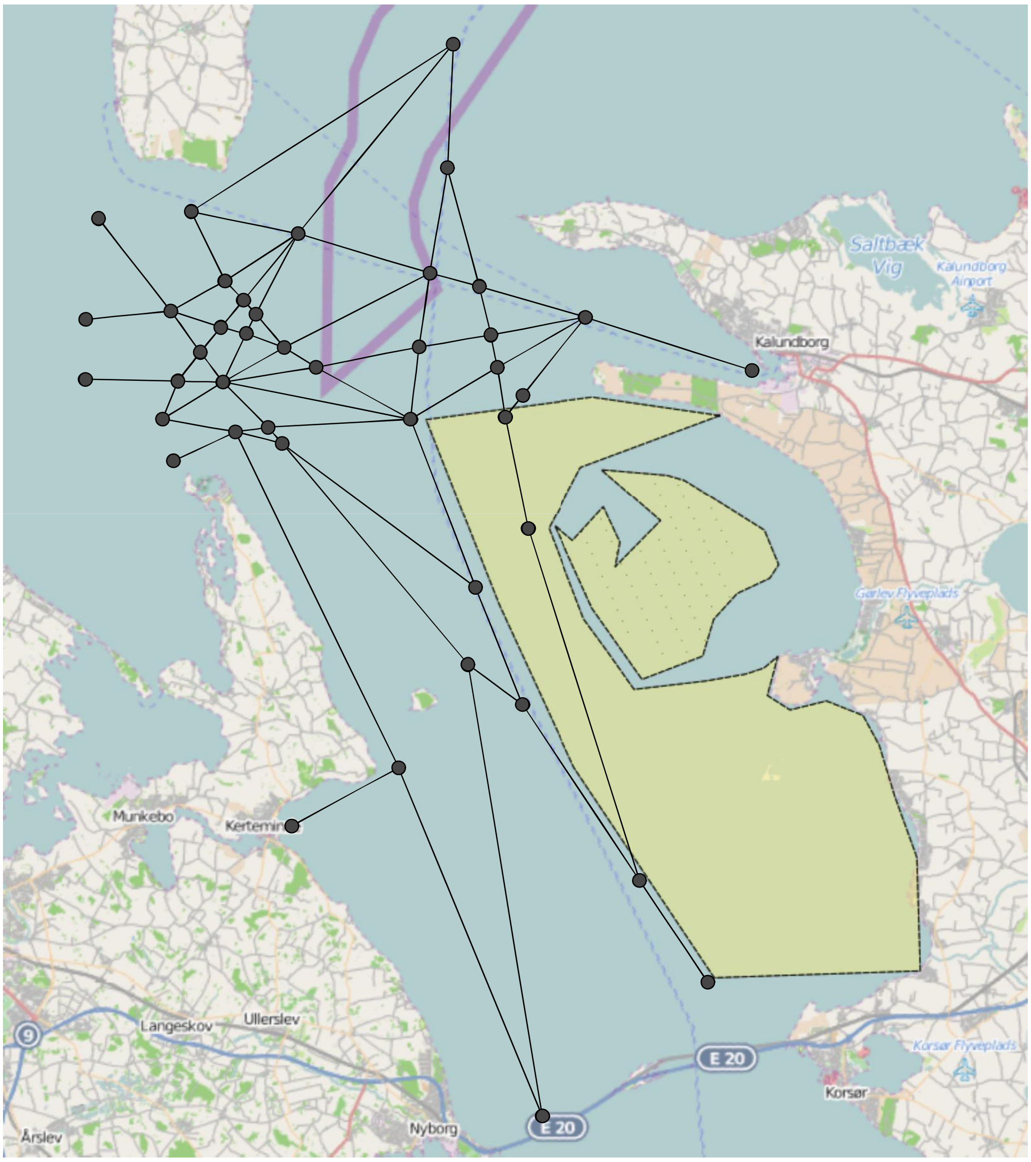


Figure 6.2: Revised traffic area due to windfarm

6.1 Revised modeling of traffic distribution across routes

As mentioned in section 5.2 the traffic on LEG_39 is passing straight through the wind farm area . It is predicted that the traffic will respond as in the following:

LEG 39	Traffic is mainly consisting of support vessels to and from Kalundborg Harbour. It is evaluated that this traffic will follow route 2 in the future thus increasing probability of ship-ship collisions on the route.

Refer to appendix D for route information.

6.2 Leisure traffic

As discussed in the HAZID DNV GL [2014] the wind conditions inside the wind farm is not ideal for sailing purposes, leisure vessels will likely tend to stay out of the wind farm area. The revised traffic area is shown in figure 6.2.

6.3 Fishing traffic

As discussed in the HAZID DNV GL [2014] the foundations of the turbines will create an artificial reef which can give beneficial conditions for certain types of fish. It is thus not expected that the fishing pattern will be different from the one described in section 5.5.2. The vessels are however conservatively (with regard to ship-ship collision) assumed to be in the same area as the leisure traffic discussed above.

7 IMPACT ASSESMENT DURING INSTALLATION PHASE

The present report focuses on the operation phase. Key parameters necessary for performing a thorough risk assessment of the installation phase (installation technique, type of installation vessels and transport route of components from onshore fabrication facility to the offshore site etc) will be chosen by the contractor. Hence the risk assessment for the installation phase cannot be carried out before the necessary decisions have been taken by the appointed contractor. The risk assessment would normally be part of the scope of work for the appointed contractor. Furthermore the choice of foundation type for the turbines and the amount of turbines to be installed (80 3MW or 35 6MW) will also influence the duration of the installation and hence also the risk assessment. It is assumed that a "safety zone" will be laid out during the installation work in order to protect the installation vessels, the personnel and the installed assets from collision with incoming vessels.

8 IMPACT ASSESMENT DURING OPERATION

8.1 Hazard identification

In the HAZID report DNV GL [2014] hazards for the operation phase have been identified. The majority of the identified hazards relate to the risk that ships in the area will collide with a turbine

8.2 Collision and grounding frequencies

8.2.1 Ship-turbine collision

The ship-turbine collision frequencies are calculated for the two scenarios below:

- Collision from drifting vessels
- Collision from powered vessels

The frequency results are derived based on the worst case scenario defined in section 4.2 which is evaluated to constitute the largest risk of ship collision. The ship routes and traffic are as defined in section 6 and reflects the presence of of the Jammerland Bugt Offshore Wind Farm. It is noted that the calculated collision frequencies cover all cases of collision, i.e. both minor collisions as well as severe collisions where repair of ship is needed.

The accumulated results are presented in table 8.1

	Powered collision	Drifting collision	Sum
All routes & all vesseltypes	111700 years	5873 years	5580 years

Table 8.1: Collision return period in years

From table 8.1 it is seen that the total return period for collisions is estimated to 5580 years without any risk reducing measures implemented. The cumulative collision frequencies for powered and drifting vessels distributed on ship routes are shown in figure 8.1.

This is under the assumption that the traffic will relocate to avoid passing through the wind farm as discussed in section 6.

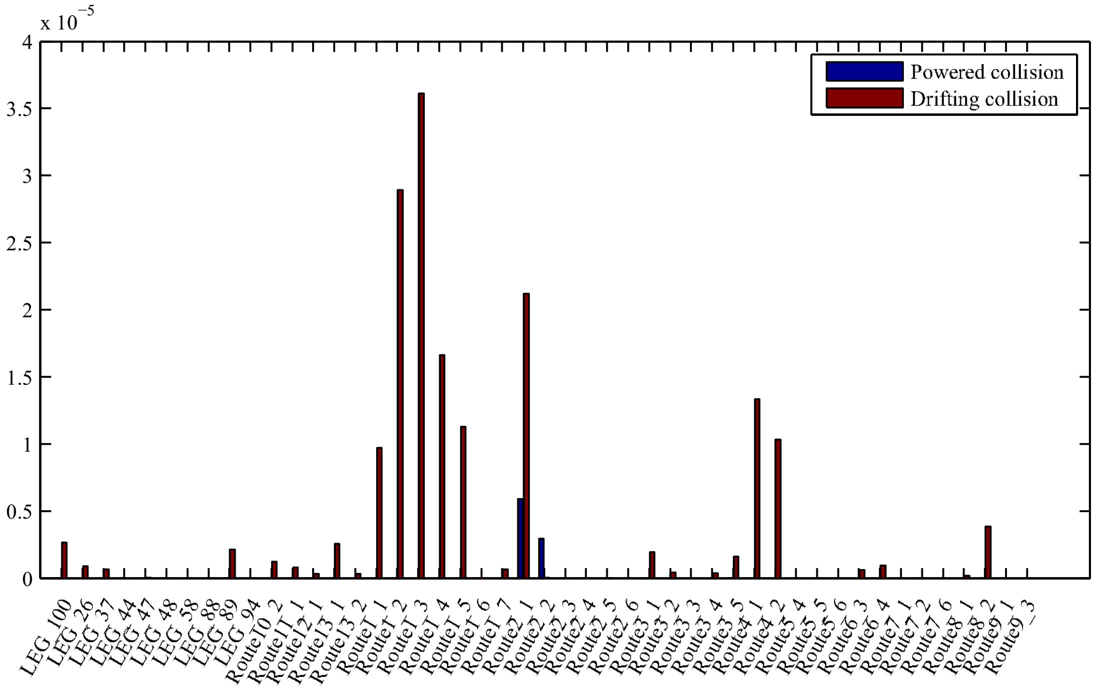


Figure 8.1: Collision frequencies for powered and drifting vessels distributed on ship routes

8.2.2 Ship-ship collision and grounding

In order to evaluate the change in navigational risk in the area a before and after scenario has been established as discussed in section 4.3. The accumulated results are presented in table 8.2.

	Grounding incidents	Ship-ship collision incidents
Before	21.62 years	11.09 years
After	21.62 years	11 years

Table 8.2: Impact on navigational risk due to presence of wind farm. Return period in years.

Detailed results distributed on ship routes are shown in appendix F.

8.3 Total impact

From the hazard identification process, refer section 8.1, it is determined that the main risk is posed by ship-turbine collision, ship-ship and grounding incidents.

This risk is evaluated by performing a frequency analysis with results provided in table 8.3.

	Phase	Impact
Ship-turbine collision	Operation	Return period 5580 years
Ship-ship collision	Operation	Return period 21.62 years before and 21.62 years after
Grounding	Operation	Return period 11.09 years before and 11 years after

Table 8.3: Total impact

Based on results shown in table 8.3 it was not deemed necessary to perform a consequence analysis or to perform a detailed evaluation of risk reducing measures. The conclusions from the frequency analysis alone indicate that the occurrence of ship-turbine collisions, ship-ship and grounding incidents will be low and hence the increase in navigational risk due to establishment of the Jammerland Bugt Offshore Wind Farm is acceptable.

9 IMPACT ASSESSMENT DURING DECOMMISSION

Risk of collision during the decommissioning phase has not been evaluated in present report. This should be the responsibility of the appointed contractor taking care of the decommissioning and should not be evaluated in detail before the offshore wind farm is close to the end of the defined service life.

10 MITIGATION MEASURES

It is not found necessary to implement mitigation measures in addition to the usual precausions that by default are required for offshore installations, refer conclusion in section 8.3. These default requirements include that; turbine foundations must be painted yellow, turbine foundations must have identification signs that are illuminated, and the offshore wind farm must have light marking. These measures have already been taken into account in the risk assessment since the risk calculation models have been calibrated against observed collisions and these have happened under usual conditions and thus under the precautions normally required. Additional mitigation measures are as previously stated not included in the risk assessment.

11 CONCLUSION

The impact of the Jammerland Bugt Offshore Wind Farm on the navigational risk is evaluated based on hazards identified in a HAZID and a subsequent calculation of collision frequencies. The risk assessment is performed on this basis.

In the HAZID report DNV GL [2014] the majority of identified hazards for the operation phase relate to the risk that ships in the area will collide with a turbine.

A frequency analysis is performed to evaluate the likelihood of ship-turbine collision. An offshore wind farm layout consisting of 80 turbines of 3MW distributed over the entire offshore wind farm area is used as worst-case scenario for the assessment. The ship traffic is established based on AIS data and routes have been adjusted where necessary to reflect the reaction of the ship traffic to the presence of the offshore wind farm.

The frequency analysis gives a return period for ship-wind turbine collisions of 111700 years for powered collisions (i.e., typical human error), and 5873 years for drifting collisions (i.e., typical technical errors). The combined return period for powered and drifting collision is thus estimated to 5580 years.

The change in ship-ship collision risk and the increase of grounding incidents has been found to be insignificant.

Based on these evaluations it is not deemed necessary to perform a consequence analysis (Step 2) or to perform a detailed evaluation of risk reducing measures (Step 3). The conclusions from the frequency analysis alone (Step 1) indicate that the occurrence of ship-turbine collisions will be low and hence the increase in navigational risk due to establishment of the Jammerland Bugt Offshore Wind Farm is acceptable.

The impact on the navigational risk during the installation and decommissioning phases has not been evaluated since too many parameters are unknown. The risk assessment for the installation and decommissioning would normally be part of the scope of work for the appointed contractor.

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A Navigational chart

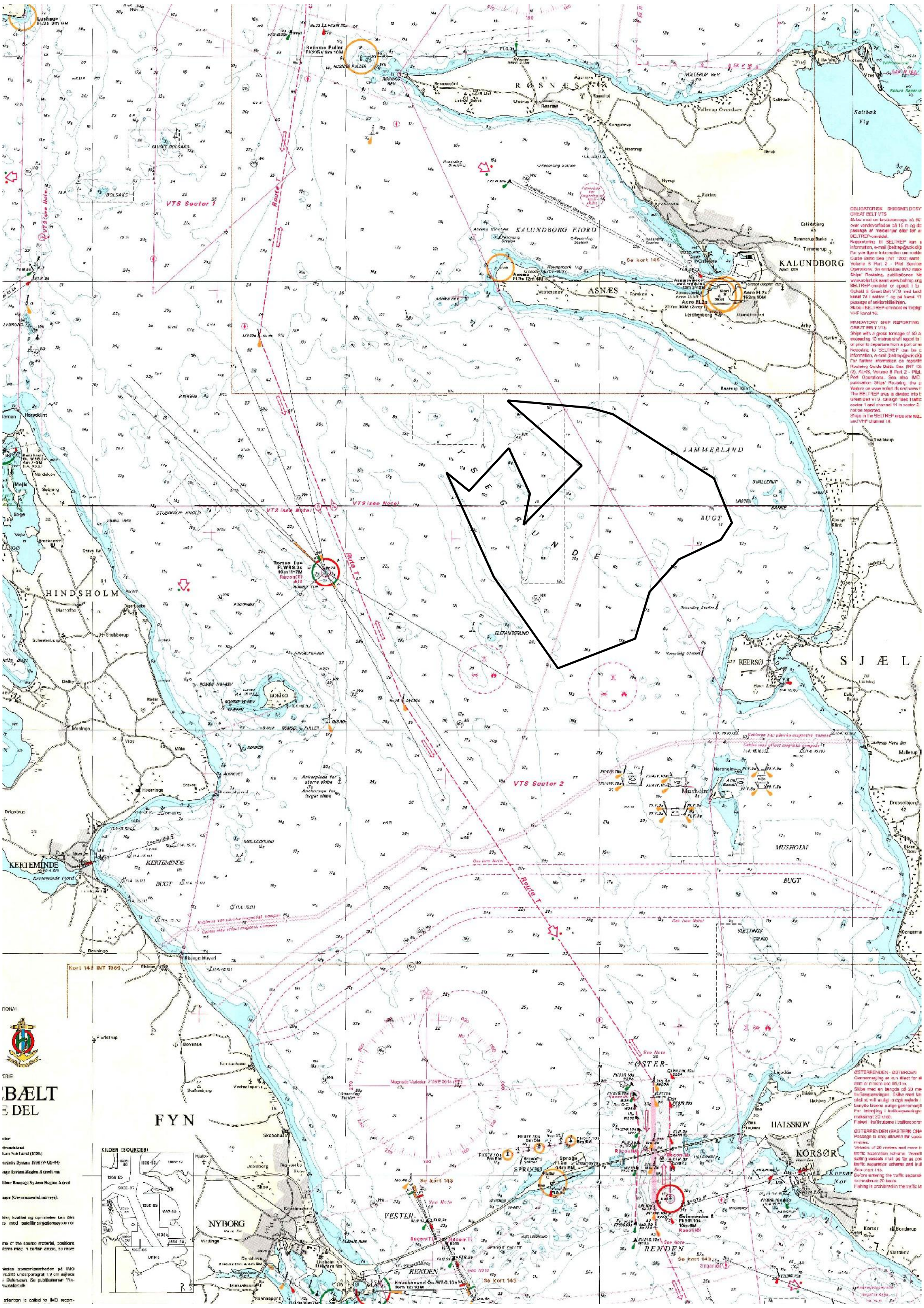


Figure A.1

B Probabilistic model assumptions

Already in 1974 Fujii and Mizuki [1974] and also MacDuff [1974] initiated more systematic and risk based approaches for grounding and collision analysis. MacDuff studied grounding and collision accidents in the Dover Strait and calculated a theoretical probability of both the grounding and the collision event. This probability was calculated by assuming all vessels to be randomly distributed in the navigational channel. MacDuff denoted the thus obtained probability the geometric probability, since this probability was entirely based on a geometric distribution of ships that were "navigating blind". By comparing to the observed number of grounding and collision it was found that the geometric probability predicted too many events and a correction factor P_c was introduced to account for the difference. The correction factor was denoted the causation probability and it models the vessels and the officer of the watch's ability to perform evasive manoeuvres in the event of a potential critical situation.

Using an approach similar to MacDuff [1974], Fujii and Mizuki [1974] introduced a probability of mismanoeuvres on the basis of grounding statistics for several Japanese straits. For the considered straits the probability was found to be in the range from 0.6E-4 to 1E-3.

The IWRAP default values for human failure which have been applied are shown in the top of table B.1. The values are mainly rooted in the observations from Fujii and Mizuki [1998]. The assumed machine failure relevant parameters are reflected in the bottom of table B.1.

Human failure relevant parameters

Ship-ship collision incidents	Causation factors
Merging	1.3E-4
Crossing	1.3E-4
Bend	1.3E-4
Headon	0.5E-4
Overtaking	1.1E-4
Area moving	0.5E-4
Area stationary	0.5E-4
Ship grounding incidents	
Grounding - forget to turn	1.6E-4
Ship-turbine collision incidents	
Collision - forget to turn	1.6E-4
Ship type specific reductions	Causation reduction factors
Passenger ships	20
Fast ferries	20

Machine failure relevant parameters

Drift speed	1 knot(s)
Probability of successful anchoring	0.98
Probability of self-repair	$p(t) = \begin{cases} 0 & t \leq 0.25 \\ \frac{1}{1.5(t-0.25)+1} & t > 0.25 \end{cases}$
Blackout frequencies	
RoRo and passenger ships	0,1 per year
Other vessels	1,75 per year

Probabilty of drift direction

N	NE	E	SE	S	SW	W	NW
9.1%	18.2%	18.2%	18.2%	9.1%	9.1%	9.1%	9.1%

Table B.1

C Turbine coordinates

C.1 Turbine coordinates 3MW

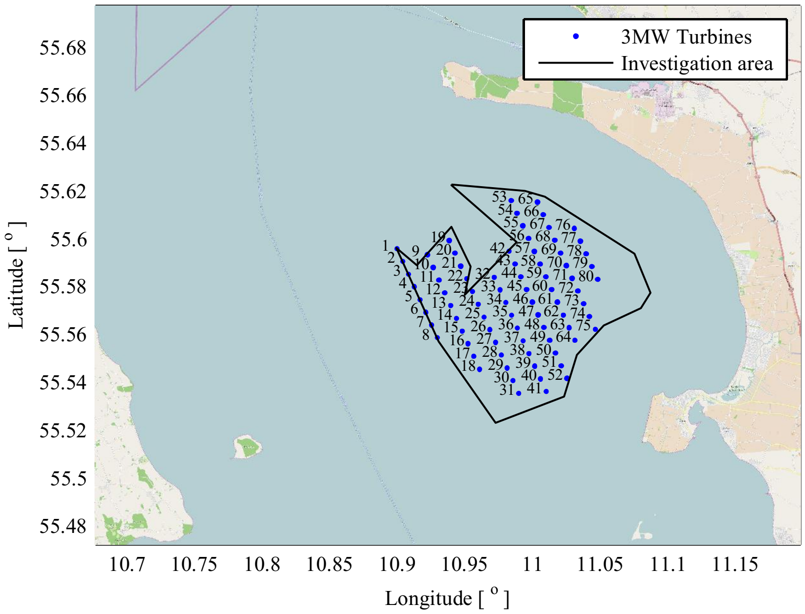


Figure C.1: 3MW turbine layout

	Longitude [°]	Latitude [°]
1	55.5957	10.8999
2	55.5903	10.9042
3	55.5850	10.9084
4	55.5797	10.9127
5	55.5744	10.9170
6	55.5691	10.9213
7	55.5638	10.9255
8	55.5585	10.9298
9	55.5932	10.9223
10	55.5879	10.9266
11	55.5825	10.9309
12	55.5772	10.9352
13	55.5719	10.9394
14	55.5666	10.9437
15	55.5613	10.9480
16	55.5560	10.9522
17	55.5507	10.9565
18	55.5454	10.9608
19	55.5990	10.9385
20	55.5937	10.9428
21	55.5884	10.9471
22	55.5831	10.9514
23	55.5778	10.9556
24	55.5725	10.9599
25	55.5672	10.9642
26	55.5619	10.9685

27	55.5565	10.9727
28	55.5512	10.9770
29	55.5459	10.9813
30	55.5406	10.9855
31	55.5353	10.9898
32	55.5838	10.9717
33	55.5785	10.9760
34	55.5732	10.9803
35	55.5679	10.9846
36	55.5625	10.9888
37	55.5572	10.9931
38	55.5519	10.9974
39	55.5466	11.0017
40	55.5413	11.0059
41	55.5360	11.0102
42	55.5946	10.9828
43	55.5893	10.9871
44	55.5840	10.9914
45	55.5787	10.9956
46	55.5734	10.9999
47	55.5680	11.0042
48	55.5627	11.0085
49	55.5574	11.0127
50	55.5521	11.0170
51	55.5468	11.0213
52	55.5415	11.0255
53	55.6158	10.9843
54	55.6105	10.9885
55	55.6052	10.9928
56	55.5999	10.9971
57	55.5946	11.0014
58	55.5892	11.0057
59	55.5839	11.0099
60	55.5786	11.0142
61	55.5733	11.0185
62	55.5680	11.0228
63	55.5627	11.0270
64	55.5574	11.0313
65	55.6152	11.0036
66	55.6099	11.0079
67	55.6045	11.0122
68	55.5992	11.0165
69	55.5939	11.0208
70	55.5886	11.0250
71	55.5833	11.0293
72	55.5780	11.0336
73	55.5727	11.0379
74	55.5673	11.0421
75	55.5620	11.0464
76	55.6041	11.0310
77	55.5988	11.0353
78	55.5935	11.0396
79	55.5882	11.0439
80	55.5829	11.0482

C.2 Turbine coordinates 8MW

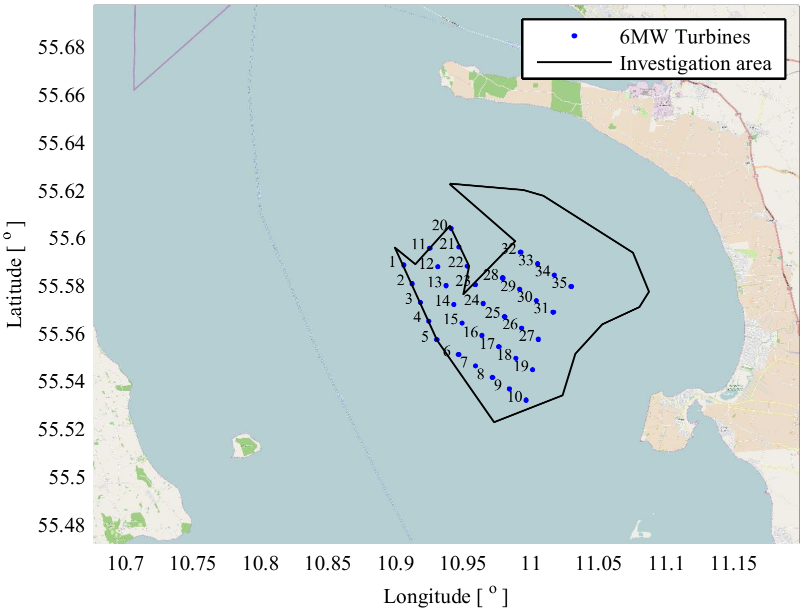


Figure C.2: 8MW turbine layout

	Longitude [°]	Latitude [°]
1	55.5885	10.9061
2	55.5807	10.9121
3	55.5729	10.9182
4	55.5651	10.9243
5	55.5572	10.9304
6	55.5511	10.9464
7	55.5463	10.9589
8	55.5415	10.9714
9	55.5368	10.9839
10	55.5320	10.9964
11	55.5956	10.9252
12	55.5877	10.9312
13	55.5799	10.9371
14	55.5721	10.9431
15	55.5642	10.9491
16	55.5591	10.9637
17	55.5543	10.9762
18	55.5496	10.9887
19	55.5448	11.0012
20	55.6038	10.9409
21	55.5960	10.9469
22	55.5881	10.9528
23	55.5803	10.9588
24	55.5725	10.9648
25	55.5669	10.9805
26	55.5622	10.9929
27	55.5574	11.0055
28	55.5831	10.9790
29	55.5784	10.9915

30	55.5736	11.0040
31	55.5689	11.0165
32	55.5938	10.9923
33	55.5891	11.0048
34	55.5843	11.0174
35	55.5796	11.0299

D Waypoint coordinates and route definitions

D.1 Before scenario

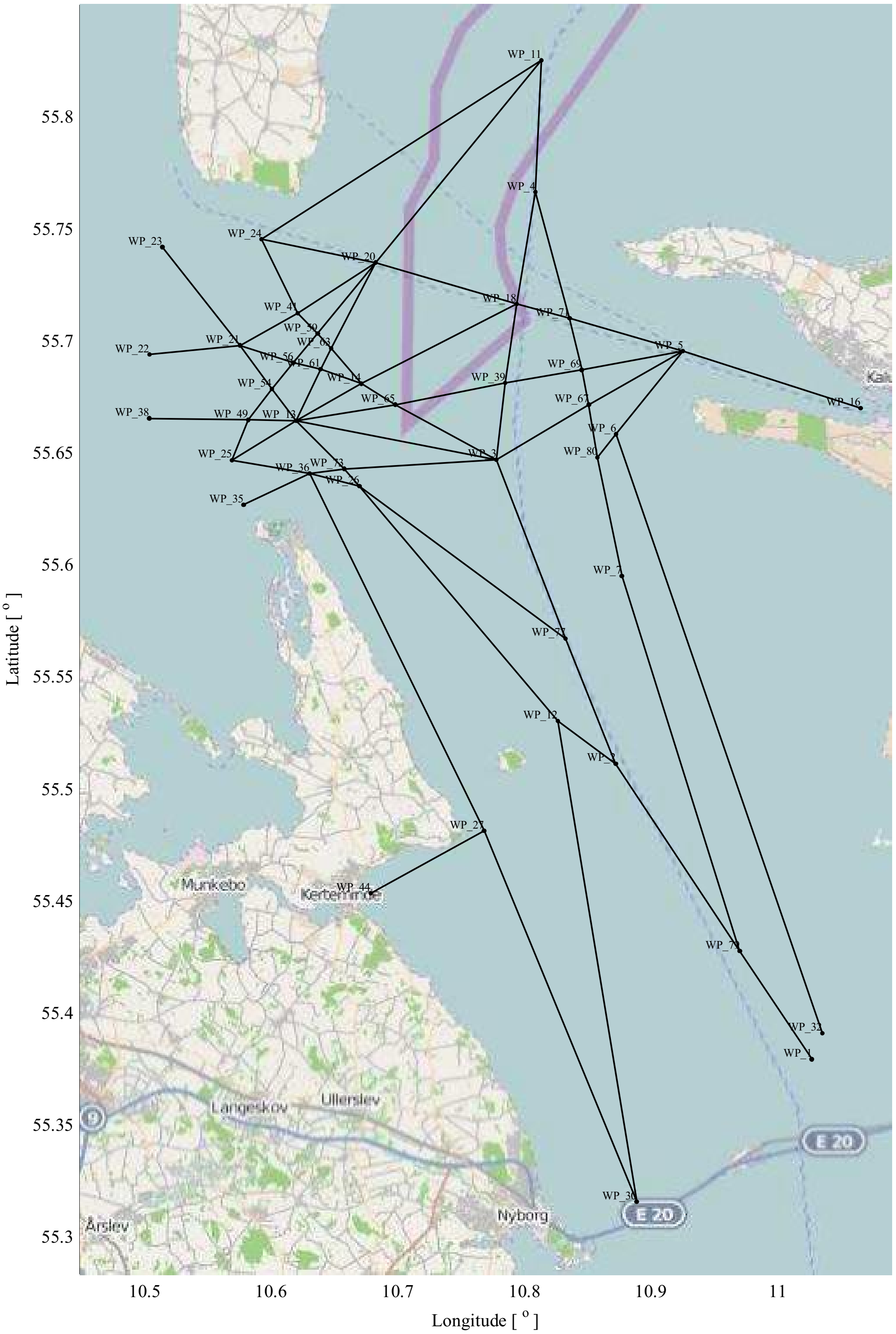


Figure D.1: Waypoints

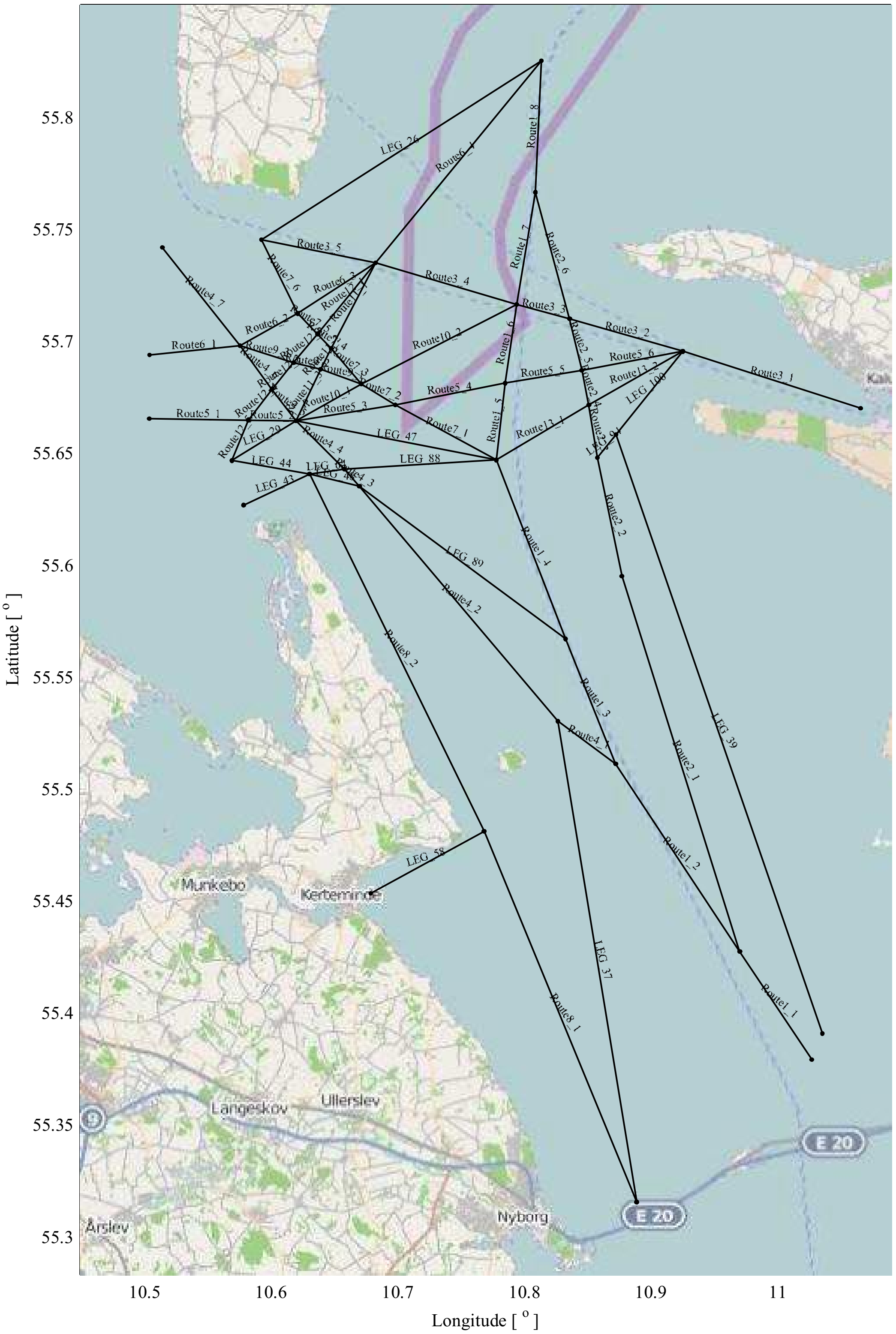


Figure D.2: Routes

	Longitude [°]	Latitude [°]
WP_1	55.3790116	11.0268745
WP_2	55.5110472	10.8720783
WP_3	55.6466894	10.7777749
WP_4	55.7662346	10.8087271
WP_5	55.6952133	10.9250447
WP_6	55.6581	10.87245
WP_7	55.5948298	10.8769562
WP_11	55.8249612	10.8134492
WP_12	55.5301075	10.826311
WP_13	55.6641095	10.619741
WP_14	55.680661	10.6712726
WP_16	55.6697327	11.0653986
WP_18	55.7161723	10.7939184
WP_20	55.73473	10.682579
WP_21	55.6977609	10.5753952
WP_22	55.6936529	10.503981
WP_23	55.741629	10.5142355
WP_24	55.7451473	10.592407
WP_25	55.6464571	10.5690843
WP_26	55.6350107	10.6697632
WP_27	55.4810222	10.7682034
WP_30	55.3153869	10.8886594
WP_32	55.3907073	11.0352388
WP_35	55.6265248	10.5783318
WP_36	55.6404922	10.6303024
WP_38	55.6651256	10.503796
WP_39	55.6809733	10.7848513
WP_41	55.7121223	10.6211043
WP_44	55.4531946	10.6786207
WP_49	55.6644841	10.5818386
WP_54	55.6782552	10.6005113
WP_56	55.6901189	10.6177054
WP_59	55.7030396	10.6367814
WP_61	55.6871876	10.639094
WP_63	55.696499	10.64731
WP_65	55.6712729	10.6980188
WP_67	55.6712934	10.8509287
WP_69	55.6867601	10.8453729
WP_71	55.7098291	10.8356352
WP_73	55.6426665	10.657681
WP_77	55.5668341	10.8325086
WP_79	55.4273249	10.9700781
WP_80	55.6477178	10.8576159

D.2 After scenario

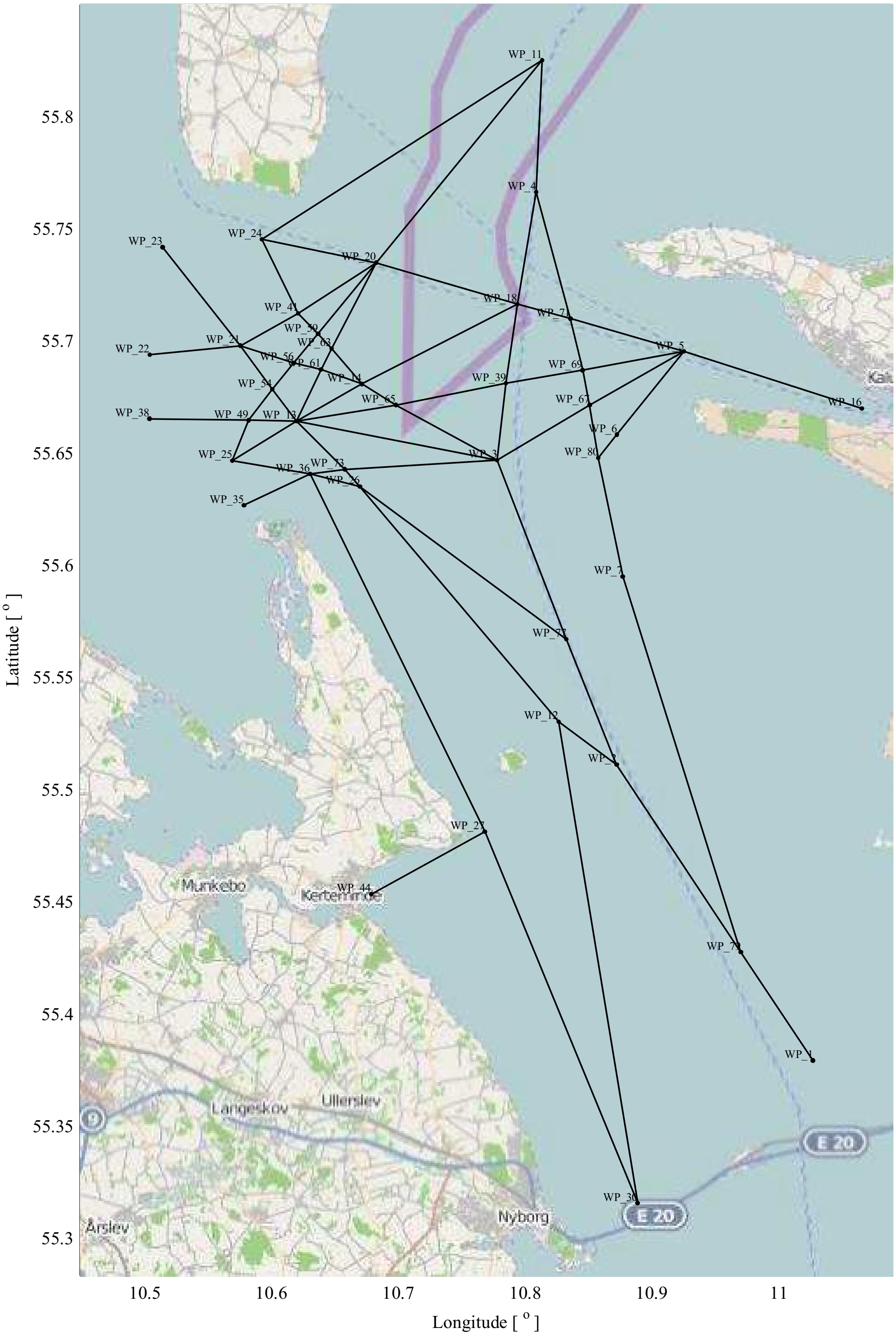


Figure D.3: Waypoints

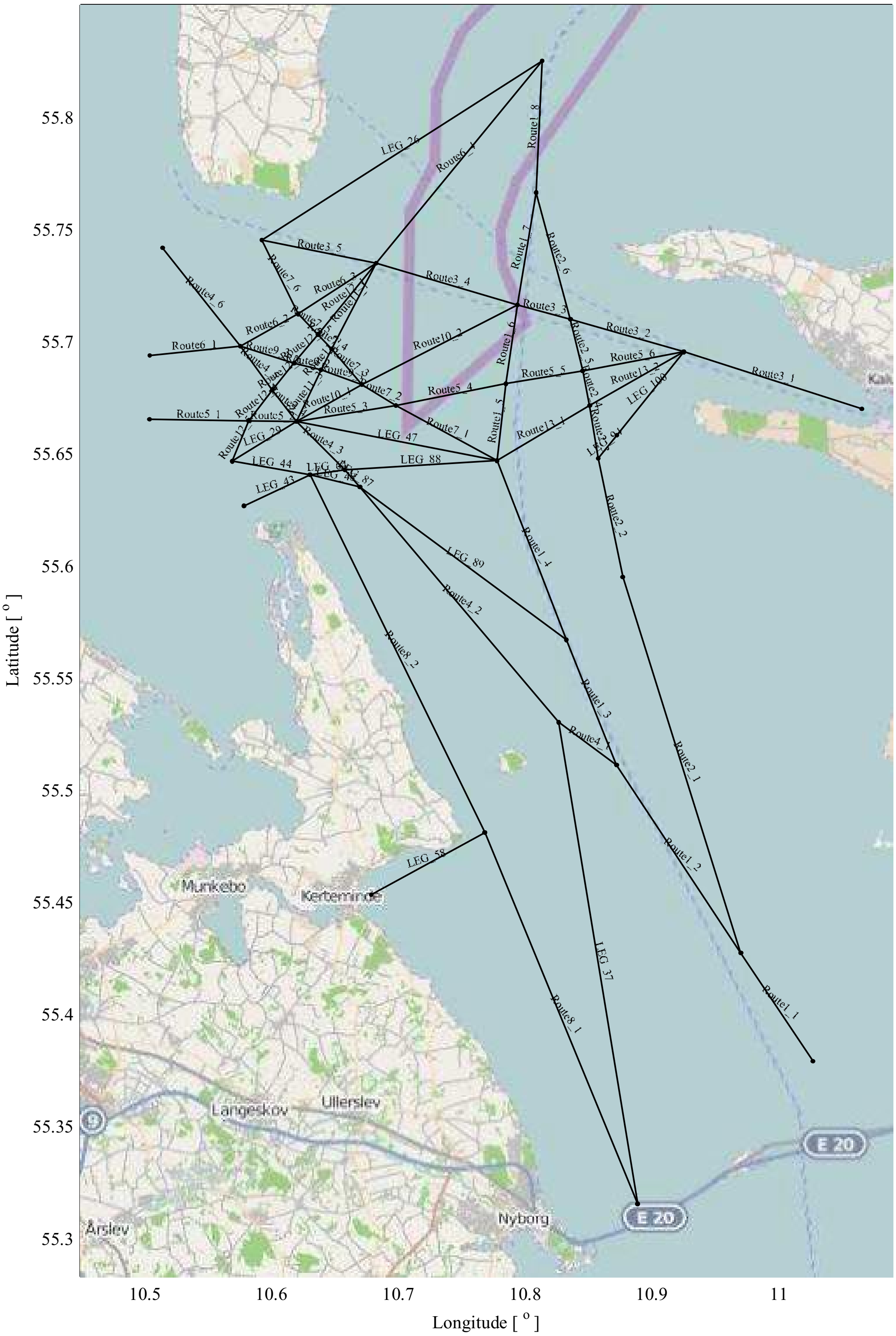


Figure D.4: Routes

	Longitude [°]	Latitude [°]
WP_1	55.3790116	11.0268745
WP_2	55.5110472	10.8720783
WP_3	55.6466894	10.7777749
WP_4	55.7662346	10.8087271
WP_5	55.6952133	10.9250447
WP_6	55.6581	10.87245
WP_7	55.5948298	10.8769562
WP_11	55.8249612	10.8134492
WP_12	55.5301075	10.826311
WP_13	55.6641095	10.619741
WP_14	55.680661	10.6712726
WP_16	55.6697327	11.0653986
WP_18	55.7161723	10.7939184
WP_20	55.73473	10.682579
WP_21	55.6977609	10.5753952
WP_22	55.6936529	10.503981
WP_23	55.741629	10.5142355
WP_24	55.7451473	10.592407
WP_25	55.6464571	10.5690843
WP_26	55.6350107	10.6697632
WP_27	55.4810222	10.7682034
WP_30	55.3153869	10.8886594
WP_35	55.6265248	10.5783318
WP_36	55.6404922	10.6303024
WP_38	55.6651256	10.503796
WP_39	55.6809733	10.7848513
WP_41	55.7121223	10.6211043
WP_44	55.4531946	10.6786207
WP_49	55.6644841	10.5818386
WP_54	55.6782552	10.6005113
WP_56	55.6901189	10.6177054
WP_59	55.7030396	10.6367814
WP_61	55.6871876	10.639094
WP_63	55.696499	10.64731
WP_65	55.6712729	10.6980188
WP_67	55.6712934	10.8509287
WP_69	55.6867601	10.8453729
WP_71	55.7098291	10.8356352
WP_73	55.6426665	10.657681
WP_77	55.5668341	10.8325086
WP_79	55.4273249	10.9700781
WP_80	55.6477178	10.8576159

E Traffic on routes

E.1 Before scenario

Traffic distribution

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Sum
LEG_100	0	17	23	0	0	77	148	265
LEG_26	1	26	162	0	1	12	11	213
LEG_29	3	251	407	12	2	237	36	948
LEG_37	6	0	0	1	1	28	10	46
LEG_39	5	1	18	2	1	21	20	68
LEG_43	0	0	45	0	2	585	76	708
LEG_44	0	0	40	0	0	19	10	69
LEG_47	0	66	155	3	2	46	17	289
LEG_48	0	0	21	0	1	132	17	171
LEG_58	21	0	1	1	10	23	23	79
LEG_64	0	0	2	0	0	240	4	246
LEG_88	0	0	0	0	0	147	1	148
LEG_89	0	3	38	0	0	29	9	79
LEG_94	0	14	16	0	0	62	114	206
Route10_1	2	132	194	8	0	54	12	402
Route10_2	3	149	197	8	0	61	12	430
Route11_1	0	1	89	0	0	18	3	111
Route11_2	0	0	87	0	0	28	0	115
Route11_3	0	0	80	0	0	31	0	111
Route12_1	0	0	93	0	0	25	3	121
Route12_2	0	0	68	0	0	22	7	97
Route12_3	0	0	41	0	0	21	7	69
Route12_4	0	0	39	0	1	24	6	70
Route12_5	0	0	31	0	2	18	5	56
Route13_1	0	99	62	0	0	133	35	329
Route13_2	0	40	29	0	0	76	12	157
Route1_1	9	3557	5145	876	21	512	493	10613
Route1_2	26	3554	5036	886	21	471	475	10469
Route1_3	20	3470	4568	870	12	248	331	9519
Route1_4	1	3482	4561	870	16	235	309	9474
Route1_5	1	3078	3957	815	10	163	242	8266
Route1_6	9	3200	4273	883	15	192	289	8861
Route1_7	8	3344	4338	861	19	195	270	9035
Route1_8	9	4019	4989	904	21	240	353	10535
Route2_1	5	81	358	1	10	107	49	611
Route2_2	5	47	226	4	6	99	41	428
Route2_3	6	9	177	5	6	26	53	282
Route2_4	7	7	186	6	7	30	36	279
Route2_5	7	16	207	6	8	33	37	314
Route2_6	4	588	513	54	5	125	76	1365
Route3_1	0	760	370	945	0	1444	496	4015
Route3_2	0	38	25	918	0	72	19	1072
Route3_3	0	26	8	880	0	41	10	965
Route3_4	0	26	7	900	0	20	10	963
Route3_5	0	117	132	909	0	22	26	1206
Route4_1	0	6	147	0	0	178	99	430
Route4_2	0	6	171	1	0	193	100	471
Route4_3	0	7	137	0	3	197	63	407
Route4_4	0	7	127	0	1	170	23	328
Route4_5	0	7	54	0	3	70	13	147
Route4_6	0	8	51	0	4	78	10	151
Route4_7	0	5	44	0	2	33	10	94
Route5_1	0	69	88	0	0	106	15	278
Route5_2	0	79	102	0	1	111	16	309
Route5_3	0	143	112	5	1	136	17	414
Route5_4	0	71	23	0	0	182	14	290
Route5_5	0	61	38	0	0	322	61	482
Route5_6	0	175	93	0	0	431	131	830
Route6_1	0	14	264	0	3	117	22	420
Route6_2	0	2	120	0	3	119	12	256
Route6_3	0	0	147	0	0	116	8	271
Route6_4	0	36	451	0	1	22	18	528
Route7_1	0	71	174	1	1	18	20	285
Route7_2	0	78	187	1	1	18	37	322
Route7_3	0	33	47	1	1	18	17	117
Route7_4	0	48	35	0	1	11	15	110
Route7_5	0	47	26	0	1	11	14	99
Route7_6	0	50	48	0	1	13	18	130
Route8_1	3	0	1	0	1	33	1	39
Route8_2	1	0	2	0	2	37	4	46
Route9_1	0	14	104	0	0	7	17	142
Route9_2	0	17	92	0	0	11	23	143
Route9_3	0	13	124	1	0	9	26	173

Table E.1: Northbound traffic

Traffic distribution

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Sum
LEG_100	0	27	31	0	0	103	169	330
LEG_26	0	11	132	1	2	20	10	176
LEG_29	3	279	464	12	1	255	88	1102
LEG_37	11	0	1	1	1	39	12	65
LEG_39	3	0	2	0	2	26	12	45
LEG_43	0	0	62	0	2	569	30	663
LEG_44	1	0	63	3	2	29	17	115
LEG_47	0	105	174	4	1	64	13	361
LEG_48	0	0	19	0	0	150	2	171
LEG_58	11	0	2	0	4	23	2	42
LEG_64	0	0	1	0	0	360	3	364
LEG_88	0	1	1	0	0	181	1	184
LEG_89	0	0	80	0	1	13	12	106
LEG_94	0	7	17	0	0	56	114	194
Route10_1	3	174	242	6	2	106	16	549
Route10_2	3	157	241	5	2	54	8	470
Route11_1	1	0	48	0	0	8	2	59
Route11_2	0	0	92	0	0	41	1	134
Route11_3	0	0	77	0	0	41	2	120
Route12_1	0	2	136	0	0	39	9	186
Route12_2	0	1	77	0	0	8	11	97
Route12_3	0	0	38	0	0	10	10	58
Route12_4	0	0	39	0	0	14	10	63
Route12_5	0	0	32	0	1	19	6	58
Route13_1	0	73	47	1	0	153	27	301
Route13_2	0	39	31	0	0	57	24	151
Route1_1	17	1974	3931	860	31	538	468	7819
Route1_2	31	1960	3904	858	28	495	443	7719
Route1_3	37	1930	3603	853	22	243	318	7006
Route1_4	16	1921	3509	860	19	188	310	6823
Route1_5	18	1428	2863	795	17	106	220	5447
Route1_6	18	1535	3026	859	20	130	248	5836
Route1_7	21	1699	3127	859	23	124	243	6096
Route1_8	20	2322	3429	874	21	168	289	7123
Route2_1	0	14	23	1	2	35	12	87
Route2_2	3	32	47	2	2	80	25	191
Route2_3	8	2	24	2	1	13	24	74
Route2_4	11	1	19	2	1	12	21	67
Route2_5	12	1	25	2	1	16	22	79
Route2_6	6	23	43	1	0	16	25	114
Route3_1	0	763	405	950	0	1504	531	4153
Route3_2	0	91	51	912	0	122	62	1238
Route3_3	0	48	14	899	0	49	20	1030
Route3_4	0	28	5	906	0	21	8	968
Route3_5	0	96	111	905	0	26	20	1158
Route4_1	1	12	167	0	5	214	85	484
Route4_2	0	13	263	0	5	250	141	672
Route4_3	1	10	223	0	5	227	89	555
Route4_4	1	8	193	0	6	179	77	464
Route4_5	0	1	72	0	4	72	18	167
Route4_6	0	2	70	0	4	78	15	169
Route4_7	0	2	67	0	2	31	21	123
Route5_1	1	48	91	0	5	109	10	264
Route5_2	1	64	117	0	5	114	15	316
Route5_3	0	69	21	1	0	123	6	220
Route5_4	0	55	25	1	0	182	12	275
Route5_5	0	38	48	1	0	340	77	504
Route5_6	0	117	90	3	0	447	110	767
Route6_1	0	3	278	1	1	105	21	409
Route6_2	0	1	140	0	1	98	10	250
Route6_3	0	1	112	0	1	99	11	224
Route6_4	0	42	481	0	2	38	20	583
Route7_1	0	35	71	0	0	9	3	118
Route7_2	0	56	145	0	0	20	25	246
Route7_3	0	40	68	0	0	12	24	144
Route7_4	0	43	40	0	0	11	22	116
Route7_5	0	42	37	0	0	11	19	109
Route7_6	0	49	42	0	1	12	20	124
Route8_1	2	0	0	0	0	34	4	40
Route8_2	5	0	0	2	7	39	13	66
Route9_1	0	13	47	0	0	5	10	75
Route9_2	0	6	96	0	0	9	23	134
Route9_3	0	6	95	0	0	13	23	137

Table E.2: Southbound traffic

E.2 After scenario

Traffic distribution

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Sum
LEG_100	0	17	23	0	0	77	148	265
LEG_26	1	26	162	0	1	12	11	213
LEG_29	3	251	407	12	2	237	36	948
LEG_37	6	0	0	1	1	28	10	46
LEG_43	0	0	45	0	2	585	76	708
LEG_44	0	0	40	0	0	19	10	69
LEG_47	0	66	155	3	2	46	17	289
LEG_48	0	0	21	0	1	132	17	171
LEG_58	21	0	1	1	10	23	23	79
LEG_64	0	0	2	0	0	240	4	246
LEG_87	0	7	137	0	3	197	63	407
LEG_88	0	0	0	0	0	147	1	148
LEG_89	0	3	38	0	0	29	9	79
LEG_94	0	14	16	0	0	62	114	206
Route10_1	2	132	194	8	0	54	12	402
Route10_2	3	149	197	8	0	61	12	430
Route11_1	0	1	89	0	0	18	3	111
Route11_2	0	0	87	0	0	28	0	115
Route11_3	0	0	80	0	0	31	0	111
Route12_1	0	0	93	0	0	25	3	121
Route12_2	0	0	68	0	0	22	7	97
Route12_3	0	0	41	0	0	21	7	69
Route12_4	0	0	39	0	1	24	6	70
Route12_5	0	0	31	0	2	18	5	56
Route13_1	0	99	62	0	0	133	35	329
Route13_2	0	40	29	0	0	76	12	157
Route1_1	14	3558	5163	878	22	533	513	10681
Route1_2	26	3554	5036	886	21	471	475	10469
Route1_3	20	3470	4568	870	12	248	331	9519
Route1_4	1	3482	4561	870	16	235	309	9474
Route1_5	1	3078	3957	815	10	163	242	8266
Route1_6	9	3200	4273	883	15	192	289	8861
Route1_7	8	3344	4338	861	19	195	270	9035
Route1_8	9	4019	4989	904	21	240	353	10535
Route2_1	10	82	376	3	11	128	69	679
Route2_2	10	48	244	6	7	120	61	496
Route2_3	6	9	177	5	6	26	53	282
Route2_4	7	7	186	6	7	30	36	279
Route2_5	7	16	207	6	8	33	37	314
Route2_6	4	588	513	54	5	125	76	1365
Route3_1	0	760	370	945	0	1444	496	4015
Route3_2	0	38	25	918	0	72	19	1072
Route3_3	0	26	8	880	0	41	10	965
Route3_4	0	26	7	900	0	20	10	963
Route3_5	0	117	132	909	0	22	26	1206
Route4_1	0	6	147	0	0	178	99	430
Route4_2	0	6	171	1	0	193	100	471
Route4_3	0	7	127	0	1	170	23	328
Route4_4	0	7	54	0	3	70	13	147
Route4_5	0	8	51	0	4	78	10	151
Route4_6	0	5	44	0	2	33	10	94
Route5_1	0	69	88	0	0	106	15	278
Route5_2	0	79	102	0	1	111	16	309
Route5_3	0	143	112	5	1	136	17	414
Route5_4	0	71	23	0	0	182	14	290
Route5_5	0	61	38	0	0	322	61	482
Route5_6	0	175	93	0	0	431	131	830
Route6_1	0	14	264	0	3	117	22	420
Route6_2	0	2	120	0	3	119	12	256
Route6_3	0	0	147	0	0	116	8	271
Route6_4	0	36	451	0	1	22	18	528
Route7_1	0	71	174	1	1	18	20	285
Route7_2	0	78	187	1	1	18	37	322
Route7_3	0	33	47	1	1	18	17	117
Route7_4	0	48	35	0	1	11	15	110
Route7_5	0	47	26	0	1	11	14	99
Route7_6	0	50	48	0	1	13	18	130
Route8_1	3	0	1	0	1	33	1	39
Route8_2	1	0	2	0	2	37	4	46
Route9_1	0	14	104	0	0	7	17	142
Route9_2	0	17	92	0	0	11	23	143
Route9_3	0	13	124	1	0	9	26	173

Table E.3: Northbound traffic

Traffic distribution

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Sum
LEG_100	0	27	31	0	0	103	169	330
LEG_26	0	11	132	1	2	20	10	176
LEG_29	3	279	464	12	1	255	88	1102
LEG_37	11	0	1	1	1	39	12	65
LEG_43	0	0	62	0	2	569	30	663
LEG_44	1	0	63	3	2	29	17	115
LEG_47	0	105	174	4	1	64	13	361
LEG_48	0	0	19	0	0	150	2	171
LEG_58	11	0	2	0	4	23	2	42
LEG_64	0	0	1	0	0	360	3	364
LEG_87	1	10	223	0	5	227	89	555
LEG_88	0	1	1	0	0	181	1	184
LEG_89	0	0	80	0	1	13	12	106
LEG_94	0	7	17	0	0	56	114	194
Route10_1	3	174	242	6	2	106	16	549
Route10_2	3	157	241	5	2	54	8	470
Route11_1	1	0	48	0	0	8	2	59
Route11_2	0	0	92	0	0	41	1	134
Route11_3	0	0	77	0	0	41	2	120
Route12_1	0	2	136	0	0	39	9	186
Route12_2	0	1	77	0	0	8	11	97
Route12_3	0	0	38	0	0	10	10	58
Route12_4	0	0	39	0	0	14	10	63
Route12_5	0	0	32	0	1	19	6	58
Route13_1	0	73	47	1	0	153	27	301
Route13_2	0	39	31	0	0	57	24	151
Route1_1	20	1974	3933	860	33	564	480	7864
Route1_2	31	1960	3904	858	28	495	443	7719
Route1_3	37	1930	3603	853	22	243	318	7006
Route1_4	16	1921	3509	860	19	188	310	6823
Route1_5	18	1428	2863	795	17	106	220	5447
Route1_6	18	1535	3026	859	20	130	248	5836
Route1_7	21	1699	3127	859	23	124	243	6096
Route1_8	20	2322	3429	874	21	168	289	7123
Route2_1	3	14	25	1	4	61	24	132
Route2_2	6	32	49	2	4	106	37	236
Route2_3	8	2	24	2	1	13	24	74
Route2_4	11	1	19	2	1	12	21	67
Route2_5	12	1	25	2	1	16	22	79
Route2_6	6	23	43	1	0	16	25	114
Route3_1	0	763	405	950	0	1504	531	4153
Route3_2	0	91	51	912	0	122	62	1238
Route3_3	0	48	14	899	0	49	20	1030
Route3_4	0	28	5	906	0	21	8	968
Route3_5	0	96	111	905	0	26	20	1158
Route4_1	1	12	167	0	5	214	85	484
Route4_2	0	13	263	0	5	250	141	672
Route4_3	1	8	193	0	6	179	77	464
Route4_4	0	1	72	0	4	72	18	167
Route4_5	0	2	70	0	4	78	15	169
Route4_6	0	2	67	0	2	31	21	123
Route5_1	1	48	91	0	5	109	10	264
Route5_2	1	64	117	0	5	114	15	316
Route5_3	0	69	21	1	0	123	6	220
Route5_4	0	55	25	1	0	182	12	275
Route5_5	0	38	48	1	0	340	77	504
Route5_6	0	117	90	3	0	447	110	767
Route6_1	0	3	278	1	1	105	21	409
Route6_2	0	1	140	0	1	98	10	250
Route6_3	0	1	112	0	1	99	11	224
Route6_4	0	42	481	0	2	38	20	583
Route7_1	0	35	71	0	0	9	3	118
Route7_2	0	56	145	0	0	20	25	246
Route7_3	0	40	68	0	0	12	24	144
Route7_4	0	43	40	0	0	11	22	116
Route7_5	0	42	37	0	0	11	19	109
Route7_6	0	49	42	0	1	12	20	124
Route8_1	2	0	0	0	0	34	4	40
Route8_2	5	0	0	2	7	39	13	66
Route9_1	0	13	47	0	0	5	10	75
Route9_2	0	6	96	0	0	9	23	134
Route9_3	0	6	95	0	0	13	23	137

Table E.4: Southbound traffic

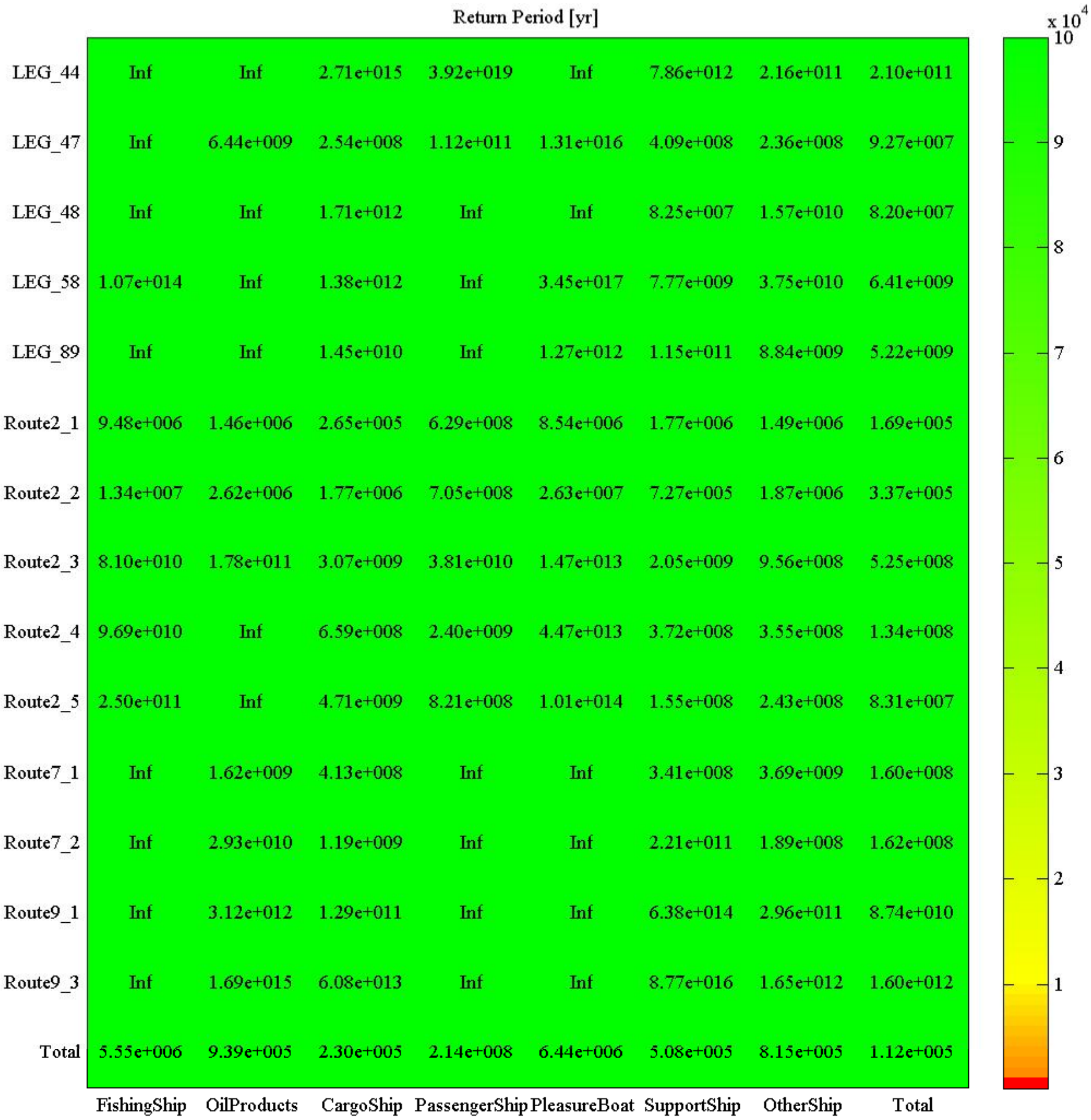
F Results from frequency analysis

F.1 Ship-turbine collisions

Return Period [yr]

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_100	Inf	1.89e+007	1.53e+007	Inf	Inf	5.48e+006	4.22e+005	3.74e+005
LEG_26	4.11e+008	2.07e+007	1.49e+006	1.67e+010	1.46e+008	1.67e+007	8.06e+006	1.10e+006
LEG_37	8.29e+006	Inf	6.45e+007	2.10e+009	1.09e+008	2.61e+006	6.60e+006	1.47e+006
LEG_47	Inf	8.04e+007	4.48e+007	4.03e+010	2.68e+009	1.45e+008	2.62e+007	1.25e+007
LEG_58	6.04e+008	Inf	4.72e+010	1.87e+011	1.31e+009	4.72e+008	1.04e+009	1.81e+008
LEG_88	Inf	1.61e+010	1.64e+010	Inf	Inf	8.33e+007	1.03e+010	8.18e+007
LEG_89	Inf	1.32e+008	5.89e+005	Inf	3.21e+008	4.32e+006	4.48e+006	4.62e+005
LEG_94	Inf	5.80e+009	3.77e+009	Inf	Inf	1.20e+009	3.17e+008	2.26e+008
Route10_2	1.66e+008	3.24e+006	1.64e+006	2.34e+008	1.77e+008	4.51e+006	9.78e+006	7.95e+005
Route11_1	7.79e+008	1.83e+008	1.64e+006	Inf	Inf	4.86e+006	5.29e+007	1.19e+006
Route12_1	Inf	6.23e+008	4.25e+006	Inf	Inf	1.38e+007	5.06e+007	3.04e+006
Route13_1	Inf	3.91e+006	1.25e+006	1.36e+010	Inf	2.02e+006	9.70e+005	3.88e+005
Route13_2	Inf	3.53e+007	2.37e+007	Inf	Inf	9.47e+006	6.60e+006	3.05e+006
Route1_1	3.34e+007	4.09e+005	1.95e+005	1.85e+007	3.12e+006	9.56e+005	1.45e+006	1.03e+005
Route1_2	3.01e+005	1.68e+005	7.25e+004	8.11e+006	1.27e+006	3.52e+005	4.72e+005	3.46e+004
Route1_3	1.06e+006	9.21e+004	5.10e+004	4.42e+006	4.55e+006	4.45e+005	5.01e+005	2.77e+004
Route1_4	3.58e+007	1.97e+005	1.08e+005	8.22e+006	8.05e+006	9.91e+005	9.59e+005	6.01e+004
Route1_5	3.52e+007	3.72e+005	1.82e+005	1.17e+007	1.23e+007	2.05e+006	4.09e+005	8.83e+004
Route1_6	7.98e+009	2.87e+008	8.13e+007	3.81e+009	2.42e+009	6.59e+008	5.04e+008	4.98e+007
Route1_7	2.17e+008	1.09e+007	2.54e+006	3.59e+008	2.17e+007	1.38e+007	1.60e+007	1.48e+006
Route2_1	3.32e+006	5.73e+005	1.24e+005	1.77e+007	2.26e+006	3.33e+005	1.31e+005	4.72e+004
Route2_2	7.84e+008	2.43e+008	6.60e+007	7.17e+009	3.75e+008	1.13e+008	7.17e+007	2.17e+007
Route2_3	6.35e+009	1.02e+010	5.17e+008	2.96e+011	1.07e+010	3.34e+009	1.40e+009	3.03e+008
Route2_4	6.66e+009	2.47e+010	7.37e+008	2.25e+011	1.47e+010	4.35e+009	2.80e+009	4.53e+008
Route2_5	1.06e+010	1.90e+010	1.11e+009	3.96e+011	1.94e+010	6.29e+009	4.37e+009	6.73e+008
Route2_6	1.32e+011	Inf	5.85e+009	5.41e+012	2.96e+011	1.33e+010	2.24e+010	3.30e+009
Route3_1	Inf	2.94e+008	3.08e+006	7.64e+008	Inf	1.34e+007	6.56e+005	5.16e+005
Route3_2	Inf	1.27e+008	8.37e+006	4.77e+007	Inf	2.11e+007	3.95e+006	2.23e+006
Route3_3	Inf	1.44e+010	1.26e+010	3.64e+009	Inf	3.00e+009	6.47e+009	1.10e+009
Route3_4	Inf	1.34e+007	4.70e+007	6.64e+006	Inf	1.18e+007	2.63e+007	2.71e+006
Route3_5	Inf	4.13e+006	3.25e+006	2.09e+006	Inf	4.30e+006	2.92e+006	6.23e+005
Route4_1	1.28e+008	2.11e+007	1.55e+005	Inf	8.13e+006	2.85e+005	3.12e+005	7.49e+004
Route4_2	Inf	1.52e+007	2.13e+005	4.43e+008	3.73e+006	3.63e+005	3.89e+005	9.65e+004
Route5_4	Inf	2.25e+009	2.75e+009	6.33e+012	Inf	5.92e+008	1.59e+009	3.16e+008
Route5_5	Inf	2.82e+009	1.68e+009	5.11e+012	Inf	3.61e+008	9.61e+008	2.10e+008
Route5_6	Inf	2.78e+009	1.02e+009	4.63e+012	Inf	6.09e+008	5.05e+008	2.00e+008
Route6_3	Inf	1.23e+009	4.50e+006	Inf	9.18e+008	3.26e+006	6.11e+007	1.63e+006
Route6_4	Inf	2.50e+007	1.22e+006	Inf	1.75e+008	1.46e+007	3.92e+007	1.04e+006
Route7_1	Inf	6.73e+009	3.17e+009	1.86e+013	5.34e+011	2.53e+010	5.60e+009	1.46e+009
Route7_2	Inf	2.35e+010	1.01e+010	7.66e+011	1.89e+012	7.50e+010	5.79e+010	5.74e+009
Route7_6	Inf	1.40e+010	1.98e+010	Inf	2.26e+010	4.96e+010	3.99e+010	4.72e+009
Route8_1	5.88e+007	Inf	3.43e+008	Inf	2.66e+008	5.55e+006	9.00e+007	4.65e+006
Route8_2	4.88e+007	Inf	1.46e+007	1.42e+008	1.74e+006	3.59e+005	2.41e+006	2.58e+005
Total	2.07e+005	3.33e+004	1.26e+004	7.48e+005	3.30e+005	4.39e+004	3.49e+004	5.88e+003

Figure F.1: Drifting turbine collisions

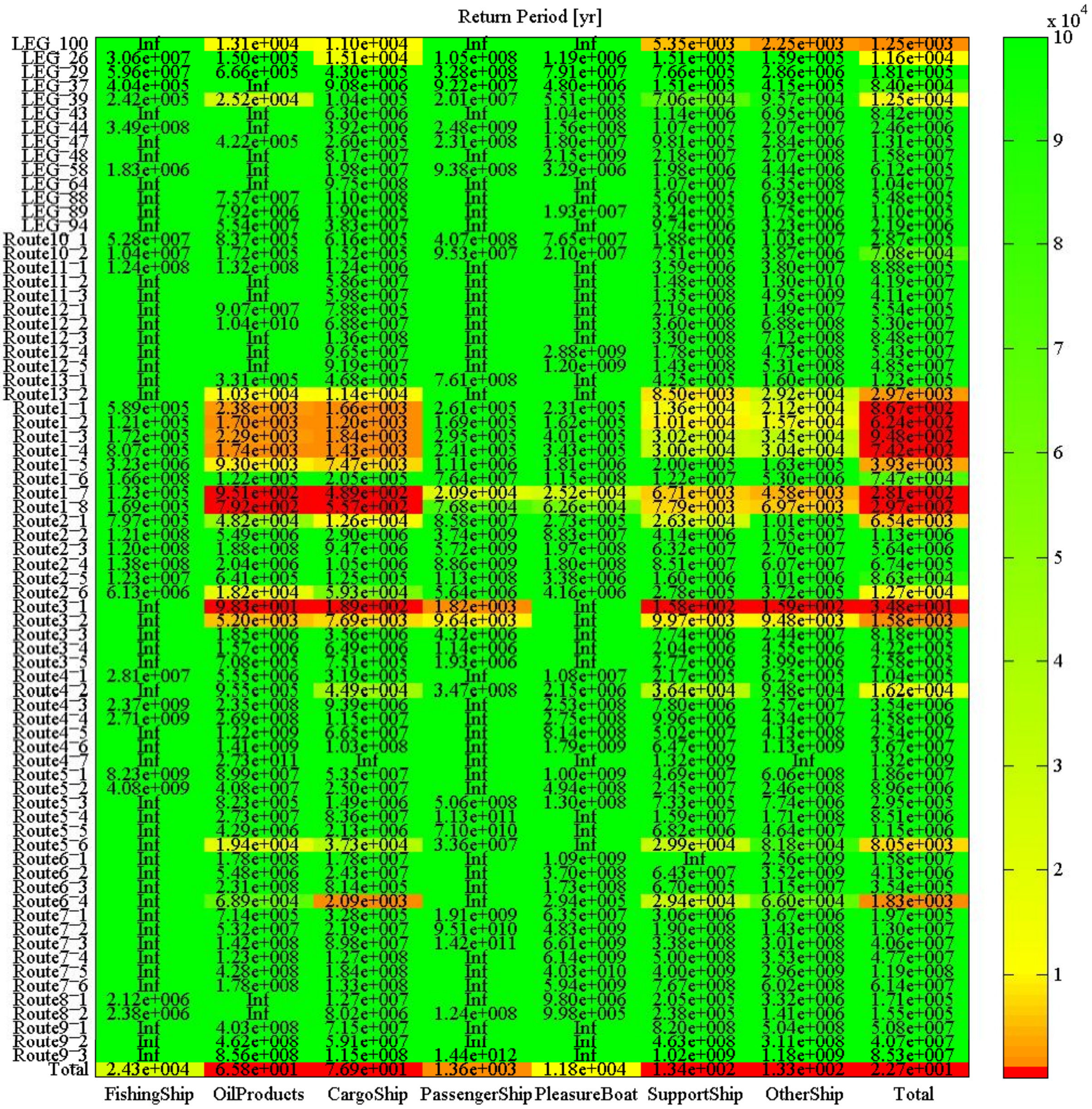


Return Period [yr]

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_44	Inf	Inf	2.71e+015	3.92e+019	Inf	7.86e+012	2.16e+011	2.10e+011
LEG_47	Inf	6.44e+009	2.54e+008	1.12e+011	1.31e+016	4.09e+008	2.36e+008	9.27e+007
LEG_48	Inf	Inf	1.71e+012	Inf	Inf	8.25e+007	1.57e+010	8.20e+007
LEG_58	1.07e+014	Inf	1.38e+012	Inf	3.45e+017	7.77e+009	3.75e+010	6.41e+009
LEG_89	Inf	Inf	1.45e+010	Inf	1.27e+012	1.15e+011	8.84e+009	5.22e+009
Route2_1	9.48e+006	1.46e+006	2.65e+005	6.29e+008	8.54e+006	1.77e+006	1.49e+006	1.69e+005
Route2_2	1.34e+007	2.62e+006	1.77e+006	7.05e+008	2.63e+007	7.27e+005	1.87e+006	3.37e+005
Route2_3	8.10e+010	1.78e+011	3.07e+009	3.81e+010	1.47e+013	2.05e+009	9.56e+008	5.25e+008
Route2_4	9.69e+010	Inf	6.59e+008	2.40e+009	4.47e+013	3.72e+008	3.55e+008	1.34e+008
Route2_5	2.50e+011	Inf	4.71e+009	8.21e+008	1.01e+014	1.55e+008	2.43e+008	8.31e+007
Route7_1	Inf	1.62e+009	4.13e+008	Inf	Inf	3.41e+008	3.69e+009	1.60e+008
Route7_2	Inf	2.93e+010	1.19e+009	Inf	Inf	2.21e+011	1.89e+008	1.62e+008
Route9_1	Inf	3.12e+012	1.29e+011	Inf	Inf	6.38e+014	2.96e+011	8.74e+010
Route9_3	Inf	1.69e+015	6.08e+013	Inf	Inf	8.77e+016	1.65e+012	1.60e+012
Total	5.55e+006	9.39e+005	2.30e+005	2.14e+008	6.44e+006	5.08e+005	8.15e+005	1.12e+005

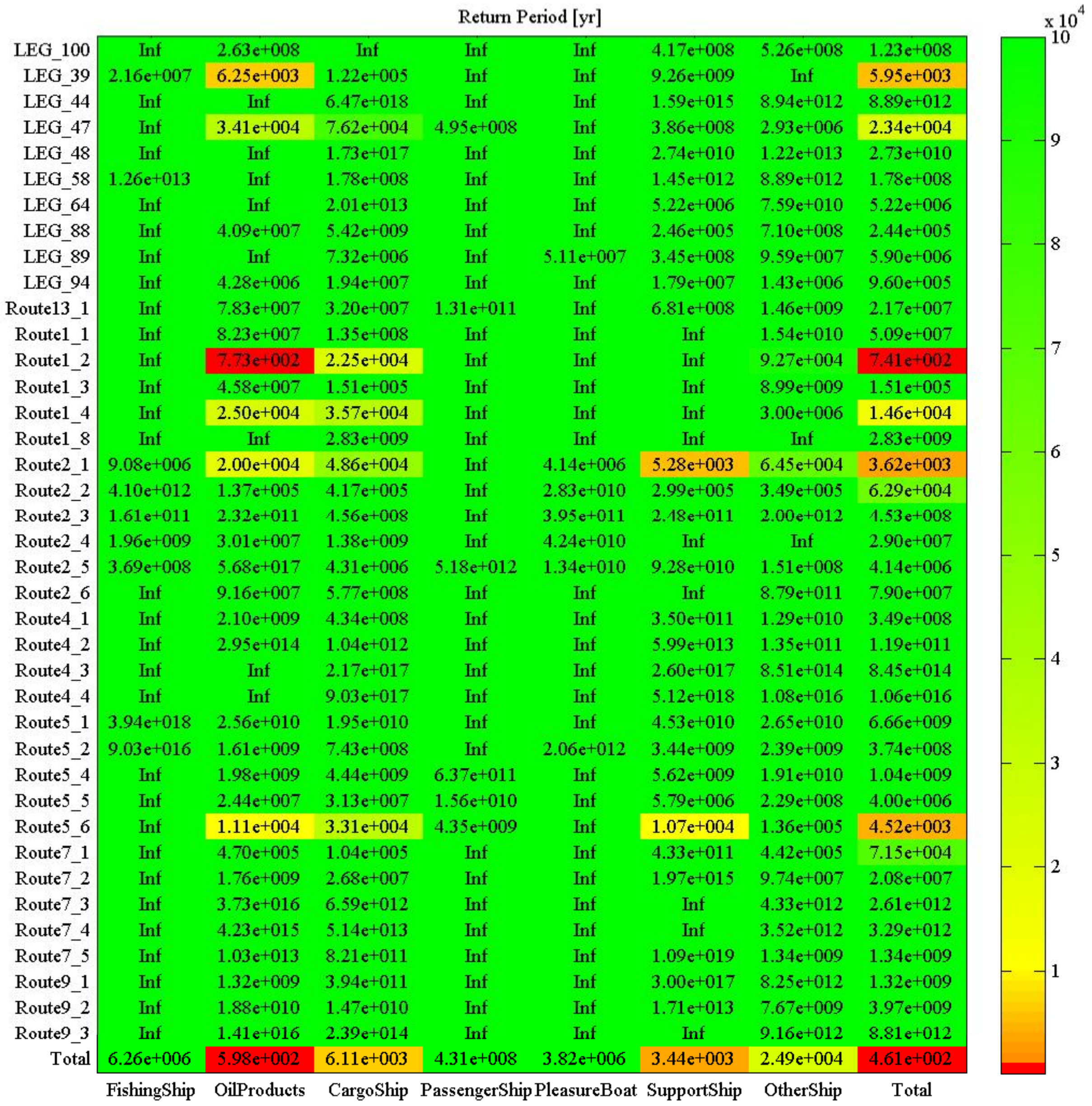
Figure F.2: Powered turbine collisions

F.2 Ship grounding incidents before



	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_100	Inf	1.31e+004	1.10e+004	Inf	Inf	5.35e+003	2.25e+003	1.25e+003
LEG_26	3.06e+007	1.50e+005	1.51e+004	1.05e+008	1.19e+006	1.51e+005	1.59e+005	1.16e+004
LEG_29	5.96e+007	6.66e+005	4.30e+005	3.28e+008	7.91e+007	7.66e+005	2.86e+006	1.81e+005
LEG_37	4.04e+005	Inf	9.08e+006	9.22e+007	4.80e+006	1.51e+005	4.15e+005	8.40e+004
LEG_39	2.42e+005	2.52e+004	1.04e+005	2.01e+007	5.51e+005	7.06e+004	9.57e+004	1.25e+004
LEG_43	Inf	Inf	6.30e+006	Inf	1.04e+008	1.14e+006	6.95e+006	8.42e+005
LEG_44	3.49e+008	Inf	3.92e+006	2.48e+009	1.56e+008	1.07e+007	2.07e+007	2.46e+006
LEG_47	Inf	4.22e+005	2.60e+005	2.31e+008	1.80e+007	9.81e+005	2.84e+006	1.31e+005
LEG_48	Inf	Inf	8.17e+007	Inf	2.15e+009	2.18e+007	2.07e+008	1.58e+007
LEG_58	1.83e+006	Inf	1.98e+007	9.38e+008	3.29e+006	1.98e+006	4.44e+006	6.12e+005
LEG_64	Inf	Inf	9.75e+008	Inf	Inf	1.07e+007	6.35e+008	1.04e+007
LEG_88	Inf	7.57e+007	1.10e+008	Inf	Inf	5.60e+005	6.93e+007	5.48e+005
LEG_89	Inf	7.92e+006	1.90e+005	Inf	1.93e+007	3.24e+005	1.75e+006	1.10e+005
LEG_94	Inf	5.54e+007	3.83e+007	Inf	Inf	9.74e+006	3.23e+006	2.19e+006
Route10_1	5.28e+007	8.37e+005	6.16e+005	4.07e+008	7.65e+007	1.88e+006	1.03e+007	2.87e+005
Route10_2	1.04e+007	1.72e+005	1.52e+005	9.53e+007	2.10e+007	7.51e+005	3.87e+006	7.08e+004
Route11_1	1.24e+008	1.32e+008	1.24e+006	Inf	Inf	3.59e+006	3.80e+007	8.88e+005
Route11_2	Inf	Inf	5.86e+007	Inf	Inf	1.48e+008	1.30e+010	4.19e+007
Route11_3	Inf	Inf	5.98e+007	Inf	Inf	1.35e+008	4.95e+009	4.11e+007
Route12_1	Inf	9.07e+007	7.88e+005	Inf	Inf	2.19e+006	1.49e+007	5.54e+005
Route12_2	Inf	1.04e+010	6.88e+007	Inf	Inf	3.60e+008	6.88e+008	5.30e+007
Route12_3	Inf	Inf	1.36e+008	Inf	Inf	3.30e+008	7.12e+008	8.48e+007
Route12_4	Inf	Inf	9.65e+007	Inf	2.88e+009	1.78e+008	4.73e+008	5.43e+007
Route12_5	Inf	Inf	9.19e+007	Inf	1.20e+009	1.43e+008	5.31e+008	4.85e+007
Route13_1	Inf	3.31e+005	4.68e+005	7.61e+008	Inf	4.25e+005	1.60e+006	1.23e+005
Route13_2	Inf	1.03e+004	1.14e+004	Inf	Inf	8.50e+003	2.92e+004	2.97e+003
Route1_1	5.89e+005	2.38e+003	1.66e+003	2.61e+005	2.31e+005	1.36e+004	2.12e+004	8.67e+002
Route1_2	1.21e+005	1.70e+003	1.20e+003	1.69e+005	1.62e+005	1.01e+004	1.57e+004	6.24e+002
Route1_3	1.72e+005	2.29e+003	1.84e+003	2.95e+005	4.01e+005	3.02e+004	3.45e+004	9.48e+002
Route1_4	8.07e+005	1.74e+003	1.43e+003	2.41e+005	3.43e+005	3.00e+004	3.04e+004	7.42e+002
Route1_5	3.23e+006	9.30e+003	7.47e+003	1.11e+006	1.81e+006	2.00e+005	1.63e+005	3.93e+003
Route1_6	1.66e+008	1.22e+005	2.05e+005	7.64e+007	1.15e+008	1.22e+007	5.30e+006	7.47e+004
Route1_7	1.23e+005	9.51e+002	4.89e+002	2.09e+004	2.52e+004	6.71e+003	4.58e+003	2.81e+002
Route1_8	1.69e+005	7.92e+002	5.57e+002	7.68e+004	6.26e+004	7.79e+003	6.97e+003	2.97e+002
Route2_1	7.97e+005	4.82e+004	1.26e+004	8.58e+007	2.73e+005	2.63e+004	1.01e+005	6.54e+003
Route2_2	1.21e+008	5.49e+006	2.90e+006	3.74e+009	8.83e+007	4.14e+006	1.05e+007	1.13e+006
Route2_3	1.20e+008	1.88e+008	9.47e+006	5.72e+009	1.97e+008	6.32e+007	2.70e+007	5.64e+006
Route2_4	1.38e+008	2.04e+006	1.05e+006	8.86e+009	1.80e+008	8.51e+007	6.07e+007	6.74e+005
Route2_5	1.23e+007	6.41e+005	1.25e+005	1.13e+008	3.38e+006	1.60e+006	1.01e+006	8.63e+004
Route2_6	6.13e+006	1.82e+004	5.93e+004	5.64e+006	4.16e+006	2.78e+005	3.72e+005	1.27e+004
Route3_1	Inf	9.83e+001	1.89e+002	1.82e+003	Inf	1.58e+002	1.59e+002	3.48e+001
Route3_2	Inf	5.20e+003	7.69e+003	9.64e+003	Inf	9.97e+003	9.48e+003	1.58e+003
Route3_3	Inf	1.85e+006	3.56e+006	4.32e+006	Inf	7.74e+006	2.44e+007	8.18e+005
Route3_4	Inf	1.57e+006	6.49e+006	1.14e+006	Inf	2.04e+006	4.55e+006	4.22e+005
Route3_5	Inf	7.08e+005	7.51e+005	1.93e+006	Inf	2.77e+006	3.99e+006	2.58e+005
Route4_1	2.81e+007	5.55e+006	3.19e+005	Inf	1.08e+007	2.17e+005	6.25e+005	1.04e+005
Route4_2	Inf	9.55e+005	4.49e+004	3.47e+008	2.15e+006	3.64e+004	9.48e+004	1.62e+004
Route4_3	2.37e+009	2.35e+008	9.39e+006	Inf	2.53e+008	7.80e+006	2.57e+007	3.54e+006
Route4_4	2.71e+009	2.69e+008	1.15e+007	Inf	2.75e+008	9.96e+006	4.34e+007	4.58e+006
Route4_5	Inf	1.22e+009	6.65e+007	Inf	8.14e+008	5.02e+007	4.13e+008	2.54e+007
Route4_6	Inf	1.41e+009	1.03e+008	Inf	1.79e+009	6.47e+007	1.13e+009	3.67e+007
Route4_7	Inf	2.73e+011	Inf	Inf	Inf	1.32e+009	Inf	1.32e+009
Route5_1	8.23e+009	8.99e+007	5.35e+007	Inf	1.00e+009	4.69e+007	6.06e+008	1.86e+007
Route5_2	4.08e+009	4.08e+007	2.50e+007	Inf	4.94e+008	2.45e+007	2.46e+008	8.96e+006
Route5_3	Inf	8.23e+005	1.49e+006	5.06e+008	1.30e+008	7.33e+005	7.74e+006	2.95e+005
Route5_4	Inf	2.73e+007	8.36e+007	1.13e+011	Inf	1.59e+007	1.71e+008	8.51e+006
Route5_5	Inf	4.29e+006	2.13e+006	7.10e+010	Inf	6.82e+006	4.64e+007	1.15e+006
Route5_6	Inf	1.94e+004	3.73e+004	3.36e+007	Inf	2.99e+004	8.18e+004	8.05e+003
Route6_1	Inf	1.78e+008	1.78e+007	Inf	1.09e+009	Inf	2.56e+009	1.58e+007
Route6_2	Inf	5.48e+006	2.43e+007	Inf	3.70e+008	6.43e+007	3.52e+009	4.13e+006
Route6_3	Inf	2.31e+008	8.14e+005	Inf	1.73e+008	6.70e+005	1.15e+007	3.54e+005
Route6_4	Inf	6.89e+004	2.09e+003	Inf	2.94e+005	2.94e+004	6.60e+004	1.83e+003
Route7_1	Inf	7.14e+005	3.28e+005	1.91e+009	6.35e+007	3.06e+006	3.67e+006	1.97e+005
Route7_2	Inf	5.32e+007	2.19e+007	9.51e+010	4.83e+009	1.90e+008	1.43e+008	1.30e+007
Route7_3	Inf	1.42e+008	8.98e+007	1.42e+011	6.61e+009	3.38e+008	3.01e+008	4.06e+007
Route7_4	Inf	1.23e+008	1.27e+008	Inf	6.14e+009	5.00e+008	3.53e+008	4.77e+007
Route7_5	Inf	4.28e+008	1.84e+008	Inf	4.03e+010	4.00e+009	2.96e+009	1.19e+008
Route7_6	Inf	1.78e+008	1.33e+008	Inf	5.94e+009	7.67e+008	6.02e+008	6.14e+007
Route8_1	2.12e+006	Inf	1.27e+007	Inf	9.80e+006	2.05e+005	3.32e+006	1.71e+005
Route8_2	2.38e+006	Inf	8.02e+006	1.24e+008	9.98e+005	2.38e+005	1.41e+006	1.55e+005
Route9_1	Inf	4.03e+008	7.15e+007	Inf	Inf	8.20e+008	5.04e+008	5.08e+007
Route9_2	Inf	4.62e+008	5.91e+007	Inf	Inf	4.63e+008	3.11e+008	4.07e+007
Route9_3	Inf	8.56e+008	1.15e+008	1.44e+012	Inf	1.02e+009	1.18e+009	8.53e+007
Total	2.43e+004	6.58e+001	7.69e+001	1.36e+003	1.18e+004	1.34e+002	1.33e+002	2.27e+001

Figure F.3: Drifting groundings

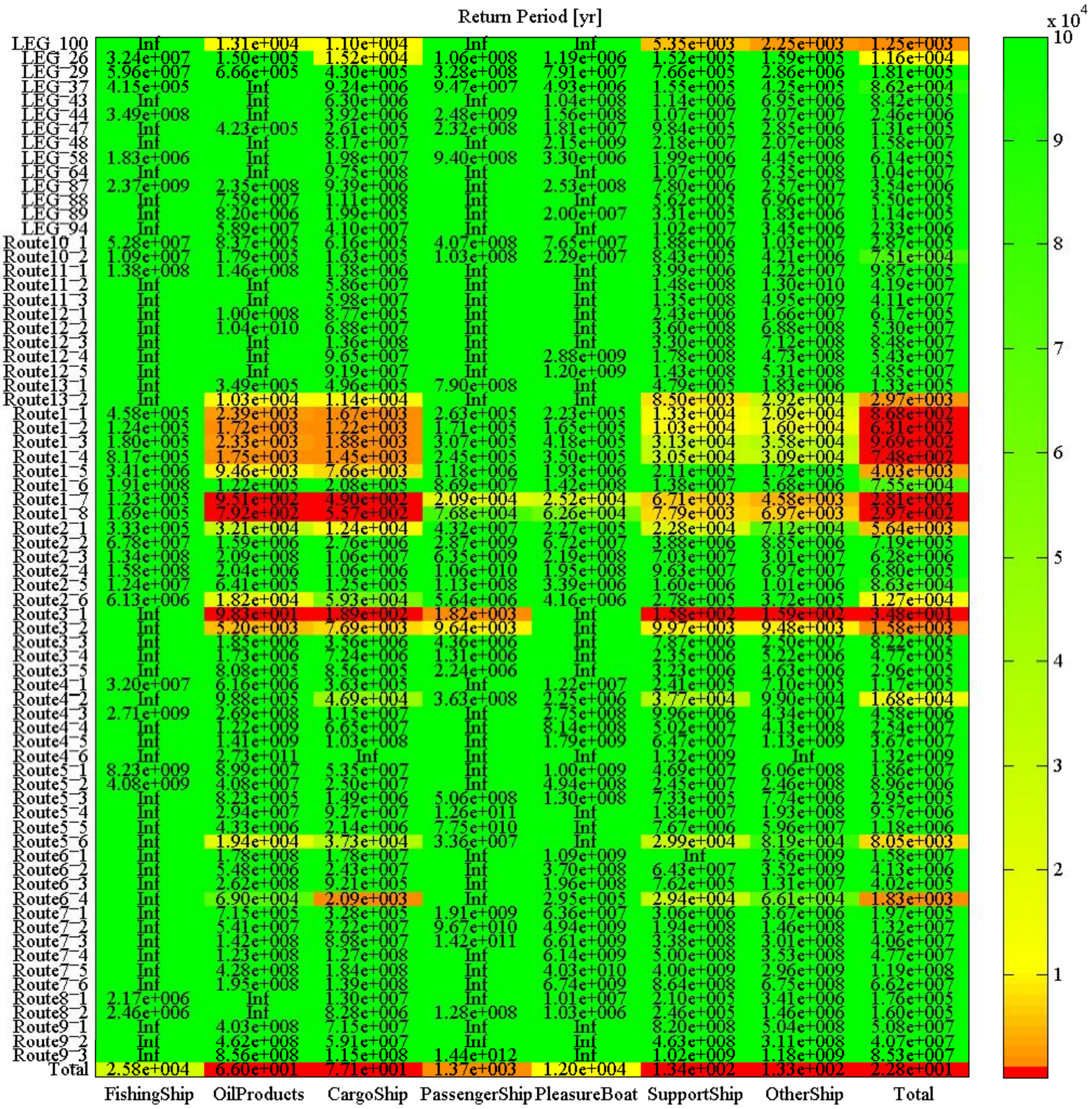


Return Period [yr]

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_100	Inf	2.63e+008	Inf	Inf	Inf	4.17e+008	5.26e+008	1.23e+008
LEG_39	2.16e+007	6.25e+003	1.22e+005	Inf	Inf	9.26e+009	Inf	5.95e+003
LEG_44	Inf	Inf	6.47e+018	Inf	Inf	1.59e+015	8.94e+012	8.89e+012
LEG_47	Inf	3.41e+004	7.62e+004	4.95e+008	Inf	3.86e+008	2.93e+006	2.34e+004
LEG_48	Inf	Inf	1.73e+017	Inf	Inf	2.74e+010	1.22e+013	2.73e+010
LEG_58	1.26e+013	Inf	1.78e+008	Inf	Inf	1.45e+012	8.89e+012	1.78e+008
LEG_64	Inf	Inf	2.01e+013	Inf	Inf	5.22e+006	7.59e+010	5.22e+006
LEG_88	Inf	4.09e+007	5.42e+009	Inf	Inf	2.46e+005	7.10e+008	2.44e+005
LEG_89	Inf	Inf	7.32e+006	Inf	5.11e+007	3.45e+008	9.59e+007	5.90e+006
LEG_94	Inf	4.28e+006	1.94e+007	Inf	Inf	1.79e+007	1.43e+006	9.60e+005
Route13_1	Inf	7.83e+007	3.20e+007	1.31e+011	Inf	6.81e+008	1.46e+009	2.17e+007
Route1_1	Inf	8.23e+007	1.35e+008	Inf	Inf	Inf	1.54e+010	5.09e+007
Route1_2	Inf	7.73e+002	2.25e+004	Inf	Inf	Inf	9.27e+004	7.41e+002
Route1_3	Inf	4.58e+007	1.51e+005	Inf	Inf	Inf	8.99e+009	1.51e+005
Route1_4	Inf	2.50e+004	3.57e+004	Inf	Inf	Inf	3.00e+006	1.46e+004
Route1_8	Inf	Inf	2.83e+009	Inf	Inf	Inf	Inf	2.83e+009
Route2_1	9.08e+006	2.00e+004	4.86e+004	Inf	4.14e+006	5.28e+003	6.45e+004	3.62e+003
Route2_2	4.10e+012	1.37e+005	4.17e+005	Inf	2.83e+010	2.99e+005	3.49e+005	6.29e+004
Route2_3	1.61e+011	2.32e+011	1.56e+008	Inf	3.95e+011	2.48e+011	2.00e+012	1.53e+008
Route2_4	1.96e+009	3.01e+007	1.38e+009	Inf	4.24e+010	Inf	Inf	2.90e+007
Route2_5	3.69e+008	5.68e+017	4.31e+006	5.18e+012	1.34e+010	9.28e+010	1.51e+008	4.14e+006
Route2_6	Inf	9.16e+007	5.77e+008	Inf	Inf	Inf	8.79e+011	7.90e+007
Route4_1	Inf	2.10e+009	4.34e+008	Inf	Inf	3.50e+011	1.29e+010	3.49e+008
Route4_2	Inf	2.95e+014	1.04e+012	Inf	Inf	5.99e+013	1.35e+011	1.19e+011
Route4_3	Inf	Inf	2.17e+017	Inf	Inf	2.60e+017	8.51e+014	8.45e+014
Route4_4	Inf	Inf	9.03e+017	Inf	Inf	5.12e+018	1.08e+016	1.06e+016
Route5_1	3.94e+018	2.56e+010	1.95e+010	Inf	Inf	4.53e+010	2.65e+010	6.66e+009
Route5_2	9.03e+016	1.61e+009	7.43e+008	Inf	2.06e+012	3.44e+009	2.39e+009	3.74e+008
Route5_4	Inf	1.98e+009	4.44e+009	6.37e+011	Inf	5.62e+009	1.91e+010	1.04e+009
Route5_5	Inf	2.44e+007	3.13e+007	1.56e+010	Inf	5.79e+006	2.29e+008	4.00e+006
Route5_6	Inf	1.11e+004	3.31e+004	4.35e+009	Inf	1.07e+004	1.36e+005	4.52e+003
Route7_1	Inf	4.70e+005	1.04e+005	Inf	Inf	4.33e+011	4.42e+005	7.15e+004
Route7_2	Inf	1.76e+009	2.68e+007	Inf	Inf	1.97e+015	9.74e+007	2.08e+007
Route7_3	Inf	3.73e+016	6.59e+012	Inf	Inf	Inf	4.33e+012	2.61e+012
Route7_4	Inf	4.23e+015	5.14e+013	Inf	Inf	Inf	3.52e+012	3.29e+012
Route7_5	Inf	1.03e+013	8.21e+011	Inf	Inf	1.09e+019	1.34e+009	1.34e+009
Route9_1	Inf	1.32e+009	3.94e+011	Inf	Inf	3.00e+017	8.25e+012	1.32e+009
Route9_2	Inf	1.88e+010	1.47e+010	Inf	Inf	1.71e+013	7.67e+009	3.97e+009
Route9_3	Inf	1.41e+016	2.39e+014	Inf	Inf	Inf	9.16e+012	8.81e+012
Total	6.26e+006	5.98e+002	6.11e+003	4.31e+008	3.82e+006	3.44e+003	2.49e+004	4.61e+002

Figure F.4: Powered groundings

F.3 Ship grounding incidents After



Return Period [yr]

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_100	Inf	1.31e+004	1.10e+004	Inf	Inf	5.35e+003	2.25e+003	1.25e+003
LEG_26	3.24e+007	1.50e+005	1.52e+004	1.06e+008	1.19e+006	1.52e+005	1.59e+005	1.16e+004
LEG_29	5.96e+007	6.66e+005	4.30e+005	3.28e+008	7.91e+007	7.66e+005	2.86e+006	1.81e+005
LEG_37	4.15e+005	Inf	9.24e+006	9.47e+007	4.93e+006	1.55e+005	4.25e+005	8.62e+004
LEG_43	Inf	Inf	6.30e+006	Inf	1.04e+008	1.14e+006	6.95e+006	8.42e+005
LEG_44	3.49e+008	Inf	3.92e+006	2.48e+009	1.56e+008	1.07e+007	2.07e+007	2.46e+006
LEG_47	Inf	4.23e+005	2.61e+005	2.32e+008	1.81e+007	9.84e+005	2.85e+006	1.31e+005
LEG_48	Inf	Inf	8.17e+007	Inf	2.15e+009	2.18e+007	2.07e+008	1.58e+007
LEG_58	1.83e+006	Inf	1.98e+007	9.40e+008	3.30e+006	1.99e+006	4.45e+006	6.14e+005
LEG_64	Inf	Inf	9.75e+008	Inf	Inf	1.07e+007	6.35e+008	1.04e+007
LEG_87	2.37e+009	2.35e+008	9.39e+006	Inf	2.53e+008	7.80e+006	2.57e+007	3.54e+006
LEG_88	Inf	7.59e+007	1.11e+008	Inf	Inf	5.62e+005	6.96e+007	5.50e+005
LEG_89	Inf	8.20e+006	1.99e+005	Inf	2.00e+007	3.31e+005	1.83e+006	1.14e+005
LEG_94	Inf	5.89e+007	4.10e+007	Inf	Inf	1.02e+007	3.45e+006	2.33e+006
Route10_1	5.28e+007	8.37e+005	6.16e+005	4.07e+008	7.65e+007	1.88e+006	1.03e+007	2.87e+005
Route10_2	1.09e+007	1.79e+005	1.63e+005	1.03e+008	2.29e+007	8.43e+005	4.21e+006	7.51e+004
Route11_1	1.38e+008	1.46e+008	1.38e+006	Inf	Inf	3.99e+006	4.22e+007	9.87e+005
Route11_2	Inf	Inf	5.86e+007	Inf	Inf	1.48e+008	1.30e+010	4.19e+007
Route11_3	Inf	Inf	5.98e+007	Inf	Inf	1.35e+008	4.95e+009	4.11e+007
Route12_1	Inf	1.00e+008	8.77e+005	Inf	Inf	2.43e+006	1.66e+007	6.17e+005
Route12_2	Inf	1.04e+010	6.88e+007	Inf	Inf	3.60e+008	6.88e+008	5.30e+007
Route12_3	Inf	Inf	1.36e+008	Inf	Inf	3.30e+008	7.12e+008	8.48e+007
Route12_4	Inf	Inf	9.65e+007	Inf	2.88e+009	1.78e+008	4.73e+008	5.43e+007
Route12_5	Inf	Inf	9.19e+007	Inf	1.20e+009	1.43e+008	5.31e+008	4.85e+007
Route13_1	Inf	3.49e+005	4.96e+005	7.90e+008	Inf	4.79e+005	1.83e+006	1.33e+005
Route13_2	Inf	1.03e+004	1.14e+004	Inf	Inf	8.50e+003	2.92e+004	2.97e+003
Route1_1	4.58e+005	2.39e+003	1.67e+003	2.63e+005	2.23e+005	1.33e+004	2.09e+004	8.68e+002
Route1_2	1.24e+005	1.72e+003	1.22e+003	1.71e+005	1.65e+005	1.03e+004	1.60e+004	6.31e+002
Route1_3	1.80e+005	2.33e+003	1.88e+003	3.07e+005	4.18e+005	3.13e+004	3.58e+004	9.69e+002
Route1_4	8.17e+005	1.75e+003	1.45e+003	2.45e+005	3.50e+005	3.05e+004	3.09e+004	7.48e+002
Route1_5	3.41e+006	9.46e+003	7.66e+003	1.18e+006	1.93e+006	2.11e+005	1.72e+005	4.03e+003
Route1_6	1.91e+008	1.22e+005	2.08e+005	8.69e+007	1.42e+008	1.38e+007	5.68e+006	7.55e+004
Route1_7	1.23e+005	9.51e+002	4.90e+002	2.09e+004	2.52e+004	6.71e+003	4.58e+003	2.81e+002
Route1_8	1.69e+005	7.92e+002	5.57e+002	7.68e+004	6.26e+004	7.79e+003	6.97e+003	2.97e+002
Route2_1	3.33e+005	3.21e+004	1.24e+004	4.32e+007	2.27e+005	2.28e+004	7.12e+004	5.64e+003
Route2_2	6.78e+007	1.59e+006	2.76e+006	2.87e+009	6.72e+007	3.88e+006	8.85e+006	7.19e+005
Route2_3	1.34e+008	2.09e+008	1.06e+007	6.35e+009	2.19e+008	7.03e+007	3.01e+007	6.28e+006
Route2_4	1.58e+008	2.04e+006	1.06e+006	1.06e+010	1.95e+008	9.63e+007	6.97e+007	6.80e+005
Route2_5	1.24e+007	6.41e+005	1.25e+005	1.13e+008	3.39e+006	1.60e+006	1.01e+006	8.63e+004
Route2_6	6.13e+006	1.82e+004	5.93e+004	5.64e+006	4.16e+006	2.78e+005	3.72e+005	1.27e+004
Route3_1	Inf	9.83e+001	1.89e+002	1.82e+003	Inf	1.58e+002	1.59e+002	3.48e+001
Route3_2	Inf	5.20e+003	7.69e+003	9.64e+003	Inf	9.97e+003	9.48e+003	1.58e+003
Route3_3	Inf	1.85e+006	3.56e+006	4.36e+006	Inf	7.87e+006	2.50e+007	8.22e+005
Route3_4	Inf	1.73e+006	7.24e+006	1.31e+006	Inf	2.35e+006	5.22e+006	4.77e+005
Route3_5	Inf	8.08e+005	8.56e+005	2.24e+006	Inf	3.23e+006	4.63e+006	2.96e+005
Route4_1	3.20e+007	6.16e+006	3.63e+005	Inf	1.22e+007	2.41e+005	7.10e+005	1.17e+005
Route4_2	Inf	9.88e+005	4.69e+004	3.63e+008	2.25e+006	3.77e+004	9.90e+004	1.68e+004
Route4_3	2.71e+009	2.69e+008	1.15e+007	Inf	2.75e+008	9.96e+006	4.34e+007	4.58e+006
Route4_4	Inf	1.22e+009	6.65e+007	Inf	8.14e+008	5.02e+007	4.13e+008	2.54e+007
Route4_5	Inf	1.41e+009	1.03e+008	Inf	1.79e+009	6.47e+007	1.13e+009	3.67e+007
Route4_6	Inf	2.73e+011	Inf	Inf	Inf	1.32e+009	Inf	1.32e+009
Route5_1	8.23e+009	8.99e+007	5.35e+007	Inf	1.00e+009	4.69e+007	6.06e+008	1.86e+007
Route5_2	4.08e+009	4.08e+007	2.50e+007	Inf	4.94e+008	2.45e+007	2.46e+008	8.96e+006
Route5_3	Inf	8.23e+005	1.49e+006	5.06e+008	1.30e+008	7.33e+005	7.74e+006	2.95e+005
Route5_4	Inf	2.94e+007	9.27e+007	1.26e+011	Inf	1.84e+007	1.93e+008	9.57e+006
Route5_5	Inf	4.33e+006	2.14e+006	7.75e+010	Inf	7.67e+006	5.96e+007	1.18e+006
Route5_6	Inf	1.94e+004	3.73e+004	3.36e+007	Inf	2.99e+004	8.19e+004	8.05e+003
Route6_1	Inf	1.78e+008	1.78e+007	Inf	1.09e+009	Inf	2.56e+009	1.58e+007
Route6_2	Inf	5.48e+006	2.43e+007	Inf	3.70e+008	6.43e+007	3.52e+009	4.13e+006
Route6_3	Inf	2.62e+008	9.21e+005	Inf	1.96e+008	7.62e+005	1.31e+007	4.02e+005
Route6_4	Inf	6.90e+004	2.09e+003	Inf	2.95e+005	2.94e+004	6.61e+004	1.83e+003
Route7_1	Inf	7.15e+005	3.28e+005	1.91e+009	6.36e+007	3.06e+006	3.67e+006	1.97e+005
Route7_2	Inf	5.41e+007	2.22e+007	9.67e+010	4.94e+009	1.94e+008	1.46e+008	1.32e+007
Route7_3	Inf	1.42e+008	8.98e+007	1.42e+011	6.61e+009	3.38e+008	3.01e+008	4.06e+007
Route7_4	Inf	1.23e+008	1.27e+008	Inf	6.14e+009	5.00e+008	3.53e+008	4.77e+007
Route7_5	Inf	4.28e+008	1.84e+008	Inf	4.03e+010	4.00e+009	2.96e+009	1.19e+008
Route7_6	Inf	1.95e+008	1.39e+008	Inf	6.74e+009	8.64e+008	6.75e+008	6.62e+007
Route8_1	2.17e+006	Inf	1.30e+007	Inf	1.01e+007	2.10e+005	3.41e+006	1.76e+005
Route8_2	2.46e+006	Inf	8.28e+006	1.28e+008	1.03e+006	2.46e+005	1.46e+006	1.60e+005
Route9_1	Inf	4.03e+008	7.15e+007	Inf	Inf	8.20e+008	5.04e+008	5.08e+007
Route9_2	Inf	4.62e+008	5.91e+007	Inf	Inf	4.63e+008	3.11e+008	4.07e+007
Route9_3	Inf	8.56e+008	1.15e+008	1.44e+012	Inf	1.02e+009	1.18e+009	8.53e+007
Total	2.58e+004	6.60e+001	7.71e+001	1.37e+003	1.20e+004	1.34e+002	1.33e+002	2.28e+001

Figure F.5: Drifting groundings

Return Period [yr]

	FishingShip	OilProducts	CargoShip	PassengerShip	PleasureBoat	SupportShip	OtherShip	Total
LEG_100	Inf	2.63e+008	Inf	Inf	Inf	4.17e+008	5.26e+008	1.23e+008
LEG_44	Inf	Inf	7.83e+018	Inf	Inf	1.70e+015	9.54e+012	9.48e+012
LEG_47	Inf	3.41e+004	7.62e+004	4.95e+008	Inf	3.87e+008	2.93e+006	2.34e+004
LEG_48	Inf	Inf	1.92e+017	Inf	Inf	3.02e+010	1.35e+013	3.01e+010
LEG_58	1.26e+013	Inf	1.78e+008	Inf	Inf	1.56e+012	9.59e+012	1.78e+008
LEG_64	Inf	Inf	2.01e+013	Inf	Inf	5.22e+006	7.59e+010	5.22e+006
LEG_87	Inf	Inf	2.16e+017	Inf	Inf	2.60e+017	8.49e+014	8.43e+014
LEG_88	Inf	4.09e+007	5.42e+009	Inf	Inf	2.46e+005	7.10e+008	2.44e+005
LEG_89	Inf	Inf	7.32e+006	Inf	5.11e+007	3.45e+008	9.59e+007	5.90e+006
LEG_94	Inf	4.28e+006	1.94e+007	Inf	Inf	1.79e+007	1.43e+006	9.60e+005
Route13_1	Inf	7.83e+007	3.20e+007	1.31e+011	Inf	6.81e+008	1.46e+009	2.17e+007
Route1_1	Inf	8.22e+007	1.34e+008	Inf	Inf	Inf	1.54e+010	5.09e+007
Route1_2	Inf	7.73e+002	2.25e+004	Inf	Inf	Inf	9.27e+004	7.41e+002
Route1_3	Inf	4.58e+007	1.51e+005	Inf	Inf	Inf	8.99e+009	1.51e+005
Route1_4	Inf	2.50e+004	3.57e+004	Inf	Inf	Inf	3.00e+006	1.46e+004
Route1_8	Inf	Inf	2.83e+009	Inf	Inf	Inf	Inf	2.83e+009
Route2_1	3.96e+006	6.14e+003	4.77e+004	Inf	3.51e+006	5.00e+003	6.35e+004	2.50e+003
Route2_2	1.12e+011	5.99e+003	3.34e+005	Inf	2.45e+010	2.99e+005	3.49e+005	5.68e+003
Route2_3	1.61e+011	2.32e+011	4.56e+008	Inf	3.95e+011	2.48e+011	2.00e+012	4.53e+008
Route2_4	1.96e+009	3.01e+007	1.38e+009	Inf	4.24e+010	Inf	Inf	2.90e+007
Route2_5	3.69e+008	5.68e+017	4.31e+006	5.18e+012	1.34e+010	9.28e+010	1.51e+008	4.14e+006
Route2_6	Inf	9.16e+007	5.77e+008	Inf	Inf	Inf	8.79e+011	7.90e+007
Route4_1	Inf	2.10e+009	4.34e+008	Inf	Inf	3.50e+011	1.29e+010	3.49e+008
Route4_2	Inf	2.95e+014	1.04e+012	Inf	Inf	5.99e+013	1.35e+011	1.19e+011
Route4_3	Inf	Inf	9.02e+017	Inf	Inf	5.12e+018	1.08e+016	1.06e+016
Route5_1	3.94e+018	2.56e+010	1.95e+010	Inf	Inf	4.53e+010	2.65e+010	6.66e+009
Route5_2	9.03e+016	1.61e+009	7.43e+008	Inf	2.06e+012	3.44e+009	2.39e+009	3.74e+008
Route5_4	Inf	1.98e+009	4.44e+009	6.37e+011	Inf	5.62e+009	1.91e+010	1.04e+009
Route5_5	Inf	2.44e+007	3.13e+007	1.56e+010	Inf	5.79e+006	2.29e+008	4.00e+006
Route5_6	Inf	1.11e+004	3.31e+004	4.35e+009	Inf	1.07e+004	1.36e+005	4.52e+003
Route7_1	Inf	4.70e+005	1.04e+005	Inf	Inf	5.08e+011	4.42e+005	7.15e+004
Route7_2	Inf	1.77e+009	2.69e+007	Inf	Inf	2.34e+015	9.80e+007	2.09e+007
Route7_3	Inf	3.73e+016	6.59e+012	Inf	Inf	Inf	4.33e+012	2.61e+012
Route7_4	Inf	4.23e+015	5.14e+013	Inf	Inf	Inf	3.52e+012	3.29e+012
Route7_5	Inf	1.03e+013	8.21e+011	Inf	Inf	1.09e+019	1.34e+009	1.34e+009
Route9_1	Inf	1.32e+009	4.12e+011	Inf	Inf	3.21e+017	8.78e+012	1.32e+009
Route9_2	Inf	1.88e+010	1.47e+010	Inf	Inf	1.71e+013	7.67e+009	3.97e+009
Route9_3	Inf	1.43e+016	2.44e+014	Inf	Inf	Inf	9.22e+012	8.88e+012
Total	3.91e+006	5.60e+002	6.39e+003	4.31e+008	3.28e+006	3.32e+003	2.47e+004	4.38e+002

Figure F.6: Powered grounding

F.4 Ship grounding incidents compared

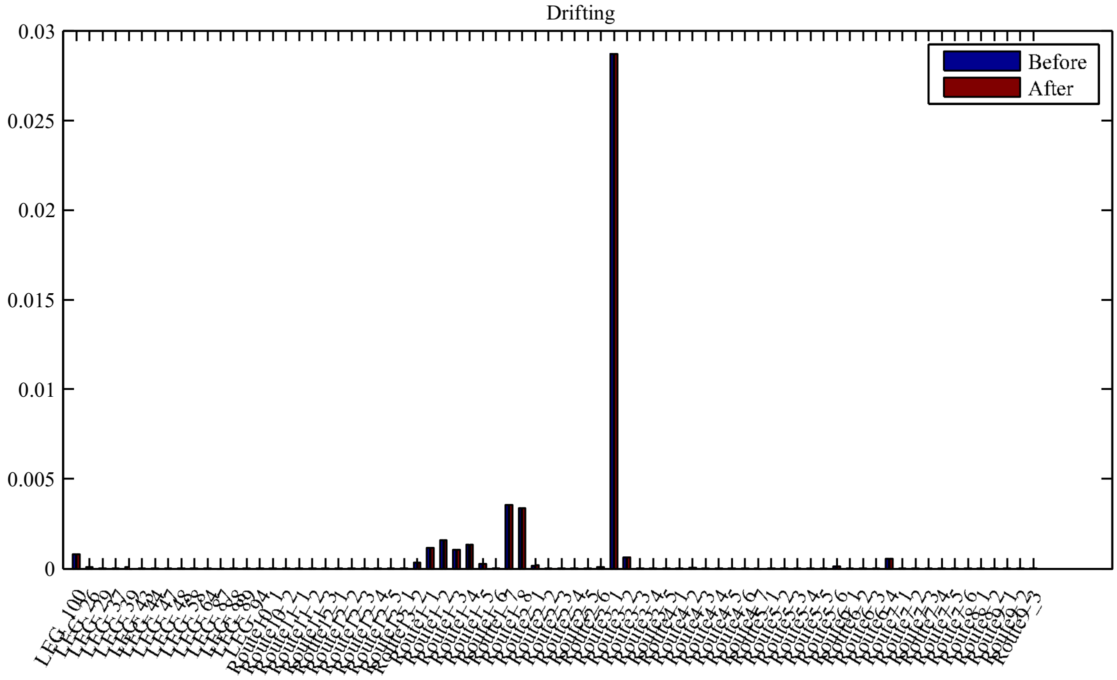


Figure F.7

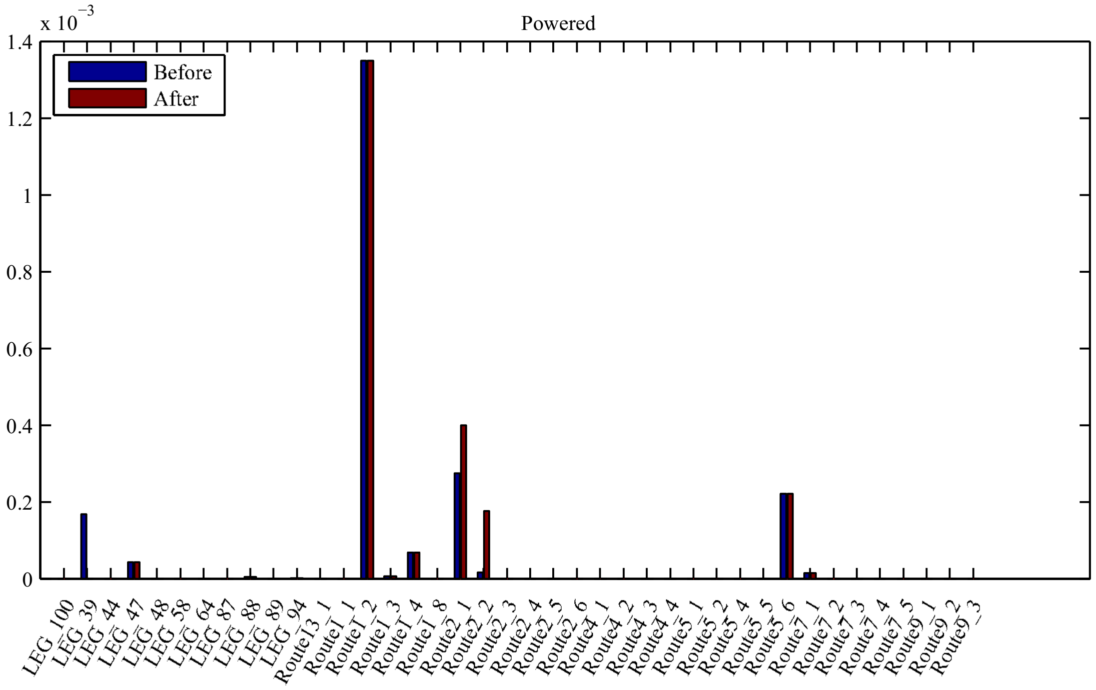


Figure F.8

F.5 Ship-ship collision incidents compared

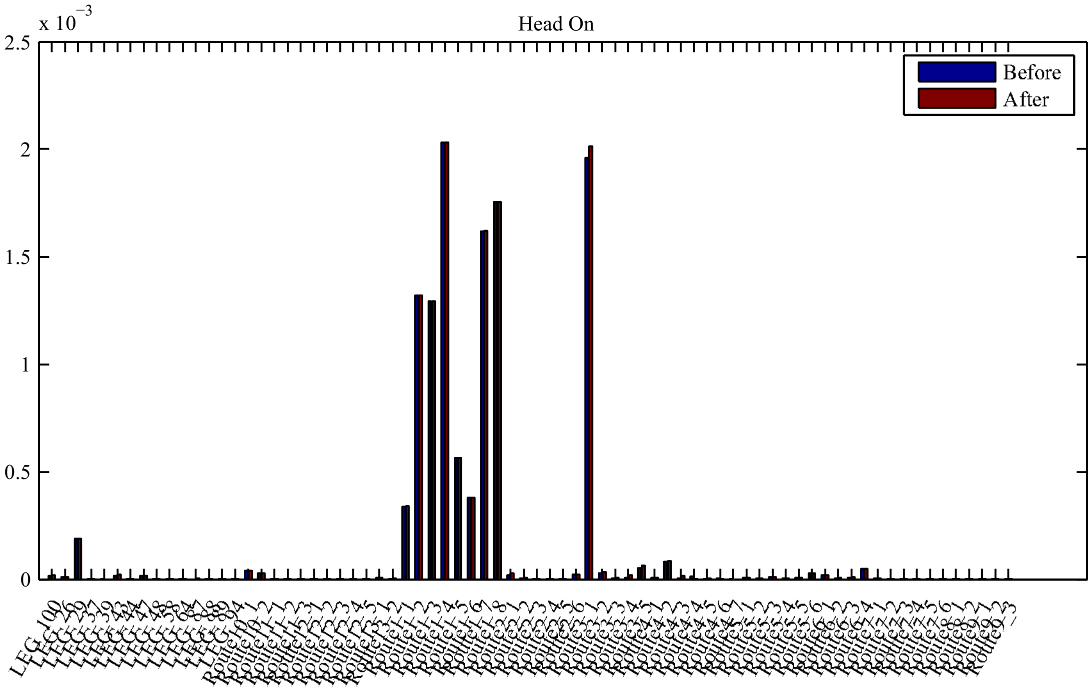


Figure F.9

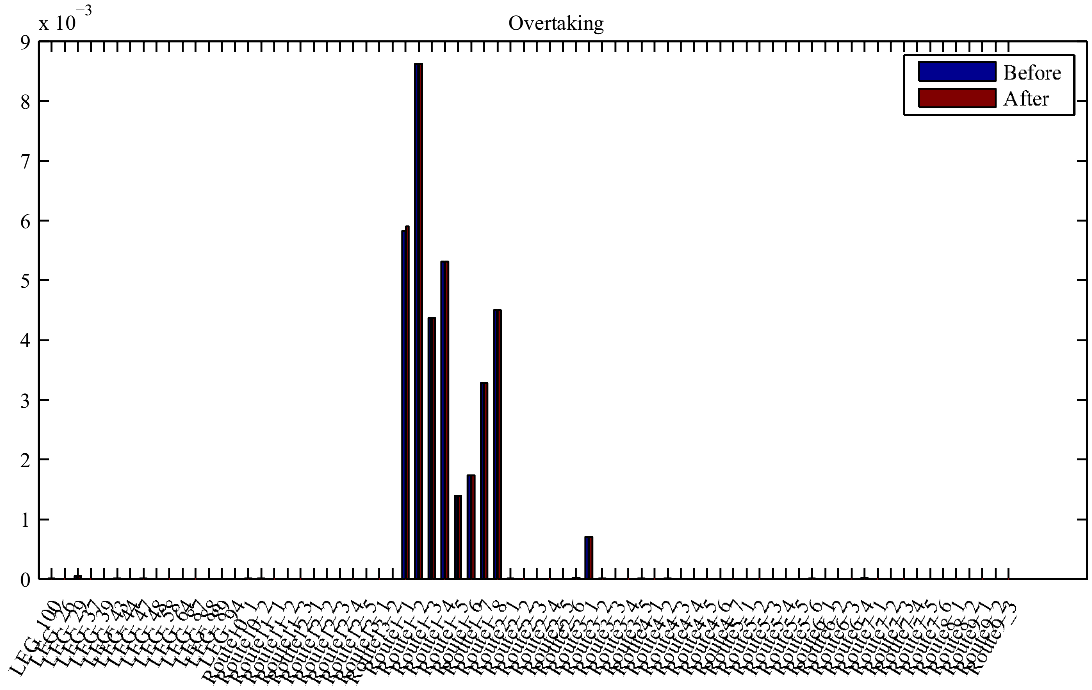


Figure F.10

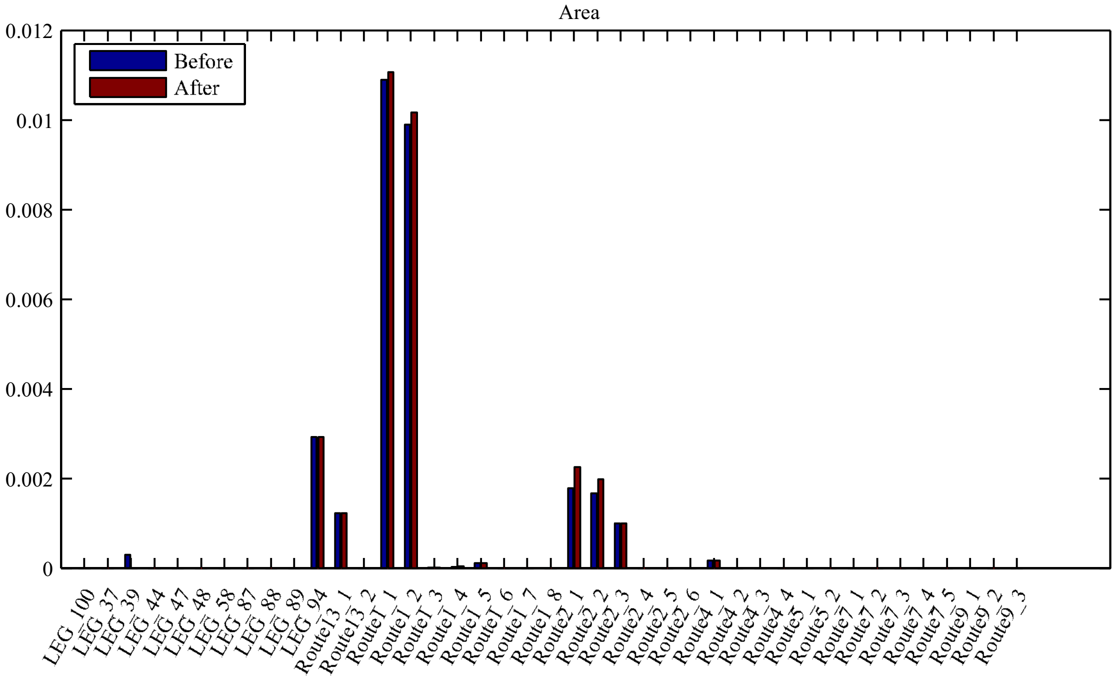


Figure F.11

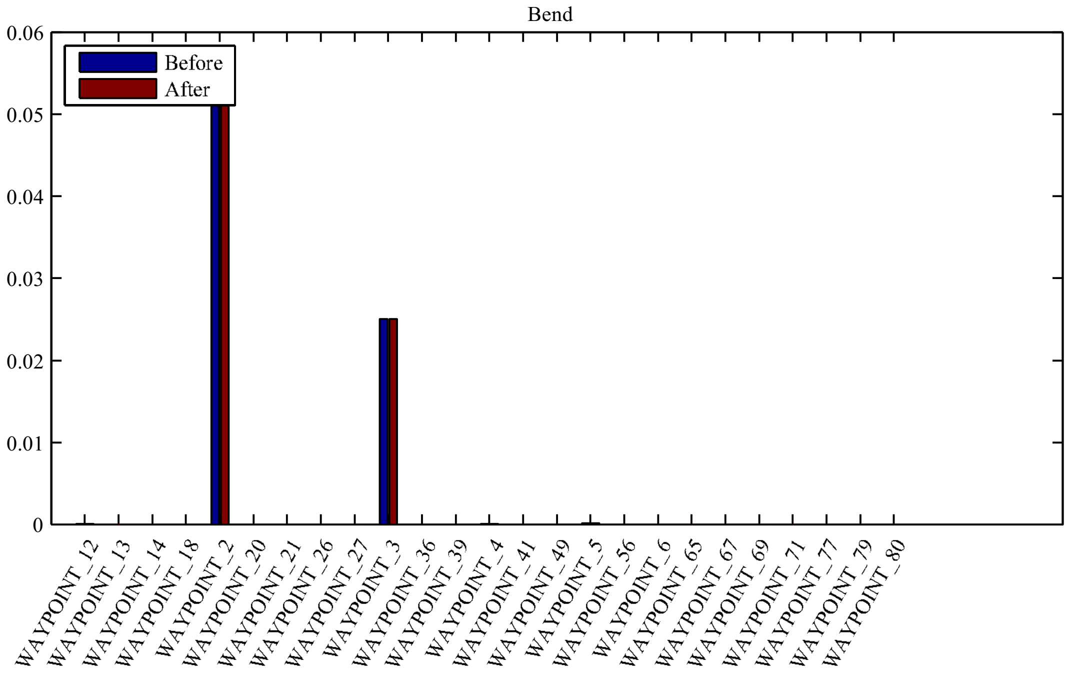


Figure F.12

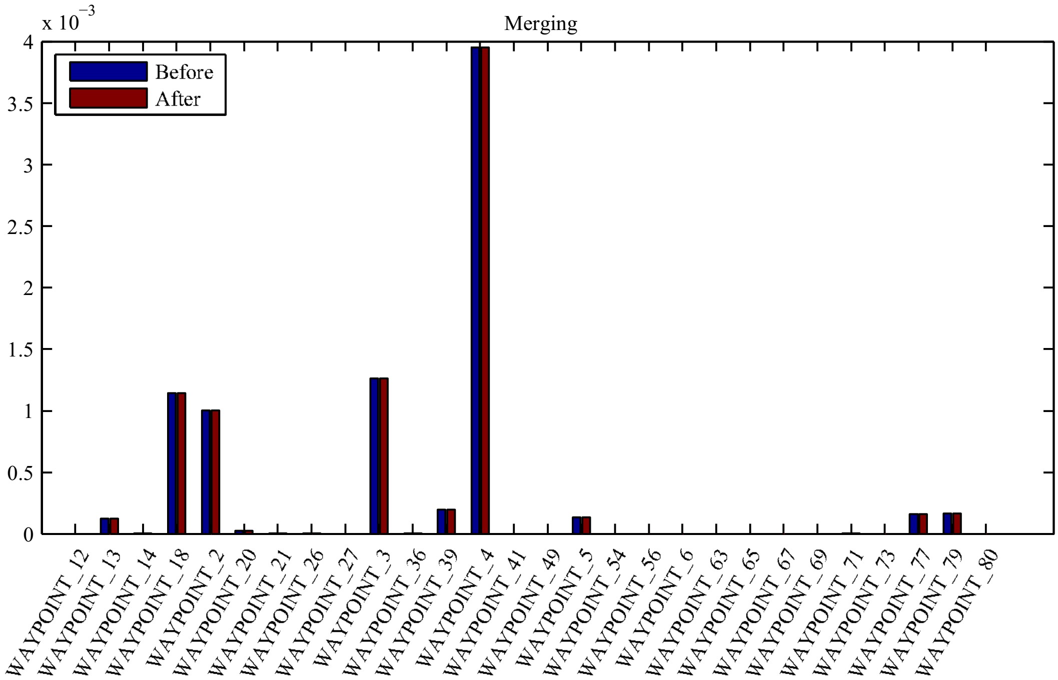


Figure F.13

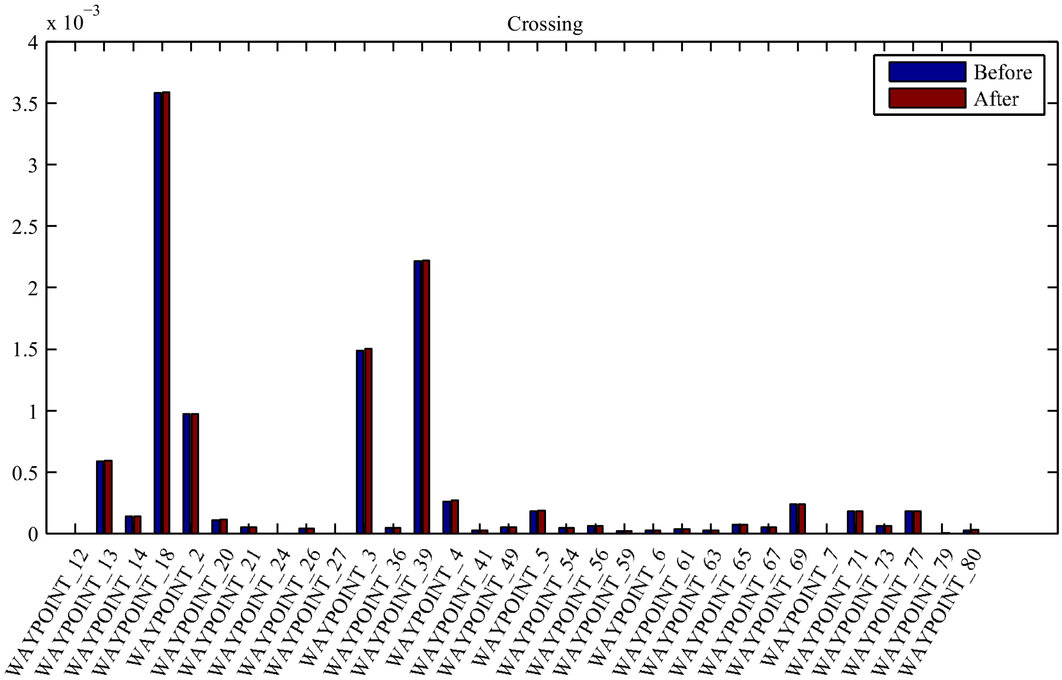


Figure F.14

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.