SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

SPSD II

RISK ANALYSIS OF MARINE ACTIVITIES IN THE BELGIAN PART OF THE NORTH SEA "RAMA"

D. LE ROY, F. MAES

PART 2

GLOBAL CHANGE, ECOSYSTEMS AND BIODIVERSITY

ATMOSPHERE AND CLIMATE

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SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:
Global change, Ecosystems and Biodiversity

FINAL REPORT

RAMA
Risk Analysis of Marine Activities in the Belgian part of the North Sea

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PREFACE

The Belgian Part of the North Sea is an intensely used marine area. It is a rather small part of the southern North Sea but nevertheless it contains one of the most intensive merchant shipping routes in the world. Besides shipping it is also used for a wide and increasing variety of human activities.

Recent accidents in European waters has brought along an increasing awareness of the risks of merchant shipping towards the marine environment. The RAMA project and the resulting report aims to assess the environmental risks of spills by commercial shipping activities on the Belgian Part of the North Sea. The project was made up of an interdisciplinary team of experts in marine biology, shipping patterns, risk analysis and contingency planning.

The valorisation of the RAMA project will result in a thorough analysis of the current status of the shipping at the North Sea in relation to the issue of safety. The scope of the project will however go beyond the mere result of a fundamental risk analysis of the commercial shipping at the North Sea. It is also aiming at the formulation of recommendations to improve the safety level for the environment and at an optimisation of response in the framework of the Belgian "North Sea Disaster Plan".

Our acknowledgements go to the Belgian Science Policy for their financial support and all the members of the "end users committee" who were involved in discussions, data exchange and many formal and informal meetings from the very beginning.

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On behalf of the RAMA-team

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LIST OF ABBREVIATIONS

APJ	Absolute Probability Judgement
App III	Appendix III product (HNS in bulk)
AWZ	Administration of Waterways and Maritime Affairs
BPNS	Belgian Part of the North Sea
Cat.A	Category A products according to MARPOL Annex II/ the IBC code
Cat.B	Category B products according to MARPOL Annex II/ the IBC code
Cat.C	Category C products according to MARPOL Annex II/ the IBC code
CBD	Convention on Biological Diversity
CT	Cargo Type
CTSMRS	Cargo Type Ship Movement per Route Segment
DNV	Det Norske Veritas
DWT	Dead Weight Tonnage
EAC	Ecotoxicological Assessment Criteria
ERA	Environmental Risk Assessment
ESI	Environmental Sensitivity Index
ETA	Event Tree Analysis
EU	European Union
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
GIS	Geographical Information System
HAZOP	HAZard and OPerability Studies
HEART	Human Error Assessment Reduction Techniques
HNS	Hazardous and Noxious Substances
IBC code	International Bulk Chemical Code
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organisation
IVS SRK	Informatie Verwerkend Systeem van de Schelde Radar Keten
LOEC	Lowest Observed Effect Concentration
MARCS	Marine Accident Risk Assessment System
MARPOL	International Convention for the Prevention of Pollution from Ships
MCA	Maritime & Coastguard Agency
MEC	Monitored Environmental Concentration
MEHRA	Marine Environmental High Risk Area
MHB	Material Hazardous only when transported in Bulk
MI	Maritime Institute (University Gent)
MP	Marine Pollutant
N.O.S.	Not Otherwise Specified
NA	Not Applicable

NEC	No Effect Concentration
NOEC	No Observed Effect Concentration
PEC	Predicted Environmental Concentration
PNEC	Predicted No Effect Concentration
PP	indicates a severe marine pollutant.
QRA	Quantitative Risk Analysis
RAMA	Risk Analysis of Marine Activities in the Belgian Part of the North Sea
RoPax	Roll-on Roll-off ships combined with passenger transport (ferries)
RoRo	Roll-on Roll-off ships
SMRS	Ship Movement per Route Segment
ST	Ship Type
THERP	Technique for Human Error Rate Prediction
TSCA	Toxic Substances Control Act
TSS	Traffic Separation Scheme
UN	United Nations
UNEP	United Nations Environmental Programme
USES	Uniform System for the Evaluation of Substances
VTS	Vessel Traffic Service

LIST OF DEFINITIONS

Category A	Noxious liquid substances defined under Annex II MARPOL 73/78 which if discharged into the sea from tank cleaning or deballasting operations would present a major hazard to either marine resources or human health or cause serious harm to amenities or other legitimate uses of the sea and therefore justify the application of stringent anti-pollution measures. Examples are acetone cyanohydrin, carbon disulphide, cresols, naphthalene and tetraethyl lead.
Category B	Noxious liquid substances defined under Annex II MARPOL 73/78 which if discharged into the sea from tank cleaning or deballasting operations would present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify the application of special anti-pollution measures. Examples are acrylonitrile, carbon tetrachloride, ethylene dichloride and phenol.
Category C	Noxious liquid substances defined under Annex II MARPOL 73/78 which if discharged into the sea from tank cleaning or deballasting operations would present a minor hazard to either marine resources or human health or cause minor harm to amenities or other legitimate uses of the sea and therefore require special operational conditions. Examples are benzene, styrene, toluene and xylene.
UN number	The UN Number is the four digit United Nations Number assigned to a dangerous good by the United Nations Committee of Experts on the Transport of Dangerous Goods (UN List).
Marine pollutant	Marine pollutants means substances which, because of their potential to bioaccumulate in seafood or because of their high toxicity to aquatic life, are subject to the provisions of Annex III of MARPOL 73/78. P indicates a Marine Pollutant. PP indicates a severe Marine Pollutant. ● A bullet indicates a N.O.S. entry where a particular substance with a pollution potential. A Mixture containing 10% or

	more of P marine pollutants, or 1% or more of PP severe marine pollutants is a marine pollutant.
Appendix III	Substances which are deemed harmless to the marine environment.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (Article 2 of the Convention on Biological Diversity)
Biological diversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
Genetic resources	Genetic material of actual or potential value.
Sustainable use	The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

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ABSTRACT

RAMA is a 2-year project (04/2004 - 04/2006) executed by two Belgian partners, Ecolas NV (Environmental Consultancy Agency) and the Maritime Institute (University of Ghent), and financed by the SPSD II research program, specific actions, of the Belgian Science Policy (BELSPO).

RAMA aims to assess the environmental risks of spills by commercial shipping activities on the Belgian Part of the North Sea. Shipping patterns, transports of dangerous goods, probability of risks and the potential impact of spill incidents (oil & hazardous and noxious substances) will be assessed. The risk analysis within this project studies both the chances of a spill accident happening and the environmental impacts in case of an accident.

The valorisation of the RAMA project will result in a thorough analysis of the current status of the shipping at the North Sea in relation to the issue of safety. The scope of the project will however go beyond the mere result of a fundamental risk analysis of the commercial shipping at the North Sea. It is also aiming at the formulation of recommendations to improve the safety level for the environment and at an optimisation of response in the framework of the Belgian "North Sea Disaster Plan".

Key words: risk analysis, North Sea Disaster Plan, shipping activities, effect analysis, sensitivity analysis, incident analysis, probability of occurrence of incidents, hazardous substances, ecosystems, human activities at sea.

INTRODUCTION

The Belgian Part of the North Sea (BPNS) is an intensely used marine area. It is a rather small part of the southern North Sea but nevertheless it contains one of the most intensive merchant shipping routes in the world. Besides shipping it is also used for a wide and increasing variety of human activities. All these human activities are posing a certain danger to the environment. However, the frequency of incidents with environmental damage and the severity of these are only poorly known.

The interest and engagement of society to improve the quality of the sea and the coast and to protect the marine environment has lead at national and international level to increased attention. This is shown among others by recent changes in the EU legislation and steps taken by the EC to speed up enforcement of the ERIKA regulations. It also shows from points in the Bergen declaration of the 5th North Sea Conference in which the Ministers invited OSPAR to develop an appropriate system of risk assessment and risk profiles connected with relevant human activities (e.g. shipping and aquaculture) in particular regions and localities. Besides this, they also pointed toward the importance of risk reduction relating to hazardous substances and the need for action to reduce the risks and minimise adverse effects on ecosystems, habitats or naturally occurring species. At present, the Bonn Agreement is also considering ways in which relevant environmental considerations could be established in trans-boundary pollution response incidents in the North Sea area. The Bonn Agreement concluded that a key issue to that respect is the establishment in advance of knowledge about environmental sensitivities within the North Sea area and the development of and exchange of information on environmental sensitivity mapping.

To be able to keep the risk (the product of probability and impact) of unwanted incidents as low as reasonably feasible and/or acceptable, appropriate measures, both technical and organisational, need to be defined and taken. However, such preventative and mitigating measures can only be taken on the basis of a sound analysis of the risks involved.

It is in this light that RAMA "Risk Analysis of Marine Activities in the Belgian Part of the North Sea" was funded by the Belgian Science Policy (BELSPO), in the framework of the Second Scientific Support Plan for a Sustainable Development Policy (SPSD II). The main goal is to carry out a risk analysis of the hazardous activities on the Belgian Part of the North Sea (BPNS) with the focus on shipping. This general goal is translated into several specific objectives: comparison of methodologies used; identification, analysis, quantification and classification of relevant risks; proposal of preventative and mitigating measures.

In the first chapter a comparison of different methods for risk analysis will be performed. Risk analysis (or Quantitative Risk Analysis, QRA) is the determination of the likelihood and consequences of potential losses. Methods of risk analyses for the human population are quite widespread, commonly known, and are sufficiently mature. A risk analysis consists of several consecutive steps. In this chapter, a presentation will be given of a number of methods available for each consecutive step in the risk assessment process together with a qualitative comparison in which the advantages and disadvantages of these methods will be highlighted. The comparison will be based on literature research, taking into account the specific requirements of risk analysis of marine incidents resulting in environmental damages. Identification of potential gaps in data and/or models and the uncertainty issue of risk assessment will be an integral part of this task.

In the second chapter an analysis of the hazardous activities at the Belgian Part of the North Sea will be carried out. This includes:

- The identification of the hazardous activities at the BPNS
- A quantitative analysis of the shipping traffic at the BPNS (ship movements, transported cargo, etc.)

In chapter three attentions the release assessment of marine incidents will be worked out. Release assessment is the identification of the potential of the risk source to introduce hazardous agents (oil and HNS) into the marine environment. The quantitative estimation of the probability of release will be approached from both the historical and the modelling approach based on the shipping patterns described in chapter two.

The outcomes of chapter three will form the basis for the description of the effects of incidents (chapter 4). Effects two identified scenarios will be described. These will take into account the type of incident, but also the location where the impacts will take place. Impact analysis will be firstly aimed at estimating the impact on different communities. Focus will be directed towards birds, fish and benthic organisms. As far as possible the ecosystem approach will be guarded during this impact analysis. Two major parts can be distinguished within the impact analysis: sensitivity analysis and effect analysis.

Finally all these results will form the input for the risk estimation described in chapter 5. An overall estimation of the risk can be defined as the multiplication of the consequence for each damage-causing event with the frequency of that event. The frequency of an event is a result of the hazard identification and release step (Chapter 3). The consequence of a damage-causing event is usually defined as casualty probabilities (direct loss (mortality)) (Chapter 4).
The results of this risk analysis will be used as a basis for examination of the appropriateness of the Belgian 'North Sea Disaster Plan' and proposals for improvement will be worked out.

1 COMPARISON OF DIFFERENT METHODS FOR RISK ANALYSIS

1.1 INTRODUCTION

The usefulness of the risk assessment depends on the method used and the purpose of the results. The analysis of risks can be approached in several ways, from very general and rough to very detailed. Therefore, in view of the goals of the risk assessment within the current project it will be necessary to compare and evaluate different methods.

A risk analysis consists of several consecutive steps. A number of methods available for each step in the risk assessment process will be presented together with a qualitative comparison in which the advantages and disadvantages of the methods will be highlighted. The comparison will be based on literature research, taking into account the specific requirements of risk analysis of marine incidents resulting in environmental damages. Identification of potential gaps in data and/or models and the uncertainty issue of risk assessment will be an integral part of this task.

To avoid an elaboration on the whole spectrum of potential ERA (Environmental Risk Assessment) methods, we limit our analysis in this chapter to those relevant to the problem addressed in RAMA. Therefore, we will focus on methods relevant to risk sources related to marine activities and to marine and coastal ecosystems as potential receptor.

1.2 A QUALITATIVE VERSUS A QUANTITATIVE RISK ASSESSMENT APPROACH

Depending on the characteristics of the problem under review and the availability and form of data required, the annalist needs to decide upon the use of a qualitative, semi-quantitative or quantitative approach. All approaches have their own set of possible methods that can be used for each of the consecutive steps of the risk analysis.

1.2.1 Quantitative risk assessment

Quantitative Risk Analysis (QRA) is the determination of the probability and consequences of potential losses in numerical terms. The assignment of probability values to the various events in the risk model provides for a quantitative assessment of risk.

An important aspect of risk assessment is the estimation of the associated uncertainty. Therefore, the process may be completed through the use of statistical models such as probability analysis, Poisson distributions or Bayesian theory. These statistical models require the use of past data and assumptions about future trends. Much of the data may be accumulated from different sources. (Wilcox et al., 2000; Stern & Fineberg, 1996)

1.2.2 Qualitative risk assessment

Although the bulk of the effort in developing methods of risk analysis has been addressed to quantitative methods, critical aspects of risk frequently require qualitative evaluation.

Qualitative risk analysis may use "expert" opinion to estimate probability (or frequency) and consequence (or impacts) often through linguistic expressions. Based on expert judgement different qualitative consequence categories can be defined in terms of for example high, medium, low, etc. The same can be done for qualitative probability categories in terms of expressions as likely, may occur, not likely, very unlikely. This subjective approach may be sufficient to assess the risk of a system, depending on the decisions to be made and available resources. Formal processes for expert-opinion elicitation have been developed to provide consistency in qualitative information gathering (e.g. Delphi technique). Concerning qualitative uncertainty estimates, one has to rely on subjective estimates of uncertainty. (Wilcox et al., 2000)

1.2.3 Conclusion

The selection of a quantitative or qualitative method depends upon the availability of data for evaluating the hazard and the level of analysis needed to make a confident decision (Wilcox et al., 2000).

Quantitative risk assessment (QRA) is unambiguously defined as a frequency x *impact and provides a more uniform understanding among different individuals than* qualitative risk assessment. QRA is the most correct and practical approach and combines the advantages of various techniques. However, not all of the relevant risk sources and receptor specific aspects can be covered in quantitative terms and quality data essential for accurate results are not always available. In this sense, a less detailed analysis based on the use of qualitative analysis methods can be appropriate. A semi-quantitative approach, using quantitative methods if possible and qualitative methods if needed, is a pragmatic and often the most suitable approach.

Within the quantitative and qualitative approaches a wide range of methods exist, each with its own characteristics, advantages and disadvantages and fields of application. Throughout the next paragraphs dealing with the different consecutive ERA steps, quantitative as well as qualitative methods are presented.

1.3 ENVIRONMENTAL RISK ASSESSMENT

Environmental Risk Assessment (ERA) covers a broad spectrum of risks, receptors and end-points. We can execute an ERA on biological, chemical, radiation and/or physical risks.

We can focus our assessment on impacts on receptors as human beings (individuals or population), fauna and flora (single species or whole ecosystems), materials (e.g. impacts on building by acid rain, loss or damage of property), etc. For each of these risk receptors different end-points are defined: for example mortality and morbidity in human health assessment, property loss in fire, revenue loss for people depending on the harmed ecosystem in the economic impacts assessment, extinction or total catch in ecological risk assessment.

Dependant on which risks, receptors and end-points one wants to investigate, the different steps and methods to be used in ERA will differ. This illustrates that an adapted approach of ERA is required and that a general description of the key tasks and methods in risk analysis is not possible. There are however a number of unifying principles underlying all risk assessments. We base our analysis on the principles developed by Covello & Merkhofer (1993) as described in Fairman et al. (1999).

Despite the diversity of approaches, we can state that in general the same questions should be asked to come to a full answer:

- What needs to be assessed? — Problem Formulation
- What can go wrong? — Hazard Identification
- How often or how likely? — Release Assessment
- How does the released material reach the receptor, at which intensity, for how long and/or how frequent? How likely will the receptors be exposed to the released pollution? — Exposure Assessment
- What is the effect on the receptors? — Consequence or Effect Assessment
- What are the risks (quantitative or qualitative measure)? — Risk Characterisation and Estimation
- How important is the risk to those affected, those who create it and those who control it? — Risk Evaluation

The conclusions made in the Risk Characterisation and/or Risk Evaluation are used as input for Risk Management: Which actions should be taken and how should the remaining risks be handled?

The different consecutive steps are presented in the following figure:

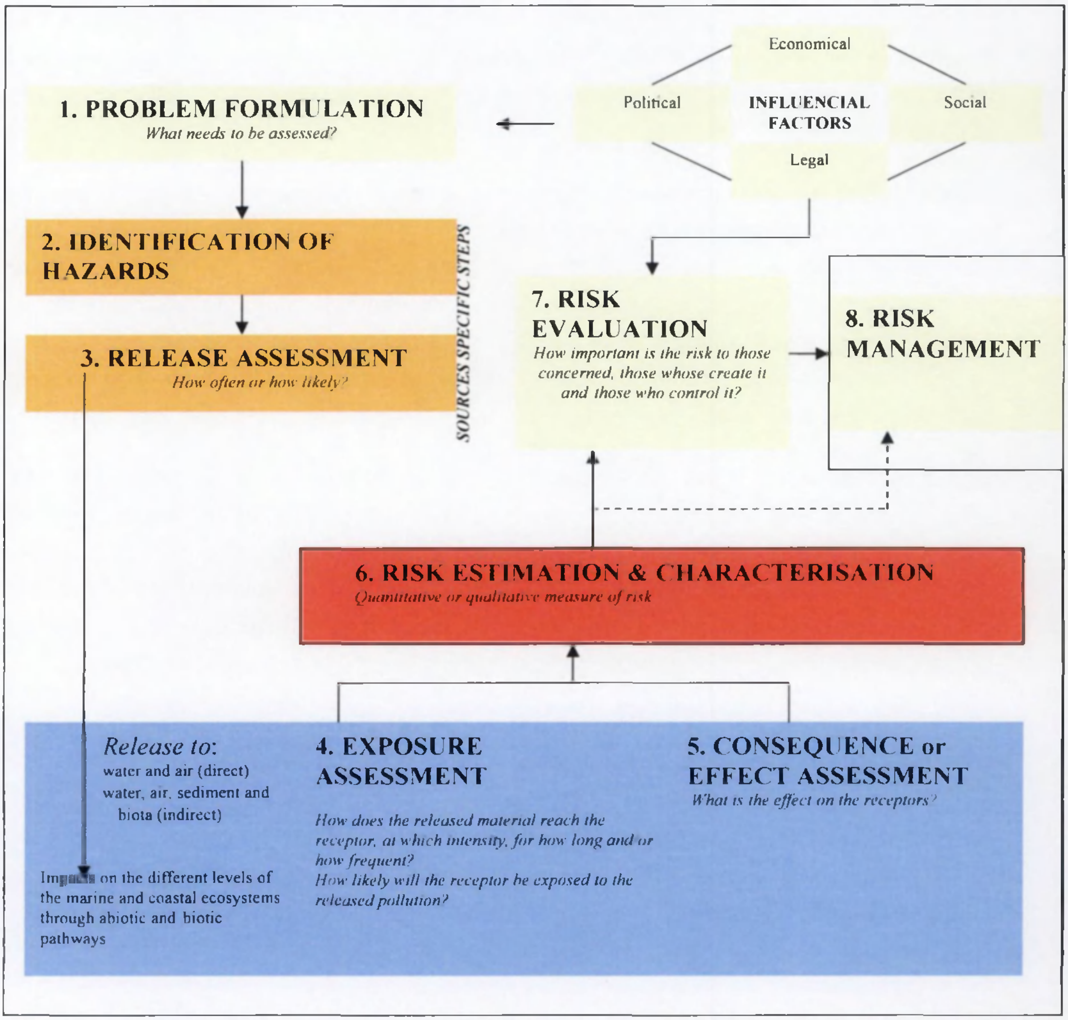

Figure 1.1: Presentation of the general key tasks in environmental risk assessment (Based on Fairman et al. (1999)

1.3.1 Problem formulation

The problem formulation step is crucial in ERA. Initially the problem has to be defined and certain issues must be clear before the assessment starts (Fairman et al., 1999; Mac Donald et al., 2001):

- What are the risk sources we want to assess? Are these point sources (e.g. wind energy park) or mobile sources (e.g. maritime transport, fishing fleet) and what are the characteristics of these risk sources?
- Are we concerned with the production, use or disposal of the hazard? What are the environmental hazards to be taken into account: mineral oil, chemicals, garbage, sewage, ballast water, tributyltin, emissions, noise etc;
- Which are the pathways in which the created hazard can reach the receptor and which are the receptors and end-points?
- Will we focus on pre-defined sensitive ecosystems (e.g. area of special conservation under the Habitats Directive, EC Birds Directive or areas with a high value in recreational amenity or commercially exploitable biological resources) or do we cover the risks for a broader area?

At this stage, a generic model should be defined to describe the functions, features, characteristics and attributes of the system under investigation. A comprehensive view should be hold, recognizing that the system, which is governed by physical laws, is in the centre of an integrated system. The technical and engineering system is integrally related to operators, engineers, etc. which are a function of human behaviour. These people interact with the organizational and management infrastructure. These systems are related to the outer environmental context, which is governed by pressures and influences all interested parties and the public. Each of these systems is dynamically affected by the others. (IMO, 2002)

Other questions that need to be handled in this first step are those related to legal and policy frameworks relevant to the risk assessment. Will we rely on regulatory standards and policy frameworks as a guide to determine "acceptable" risk and the significance of including specific end-points? Is there a legal framework that determines how we should approach the risk assessment? (Fairman et al., 1999)

1.3.2 Identification of hazards

The purpose of this step is to identify all of the conceivable and relevant hazards that could possibly cause harm to the receptor of interest. In case of RAMA the North Sea ecosystem is identified as receptor. The identification may involve the establishment of those agents that may cause harm and working backwards to identify how this harm could occur. Alternatively, hazard identification may arise from examining all possible outcomes of routine operation and identifying the consequences from normal operation. (Fairman et al., 1999)

The hazards identification step is closely linked to the next step, release assessment in the sense that these steps are both risk source related while the exposure and consequence steps are risk receptor related. Often, no distinction is made between hazard identification and release assessment, and is simply denominated as "hazard identification".

Methods by which hazards are identified, are determined by the nature of the hazard. As indicated in paragraph 1.3.1, hazards may appear from all components of the integrated system under investigation.

The approach used for hazard identification generally comprises a combination of both "creative" and "analytical" techniques, the aim being to identify all relevant hazards. The "creative" element is to ensure that the process is proactive and not confined only to hazards that have materialized in the past. The "analytical" element ensures that previous experience is properly taken into account, and typically makes use of background information (for example applicable regulations and codes, available statistical data on accident categories and lists of hazards to personnel, hazardous substance, ignition sources, etc.) (IMO, 2002).

Most of the methods described as hazard identification methods already incorporate the determination of the likelihood of hazards to be released (also defined as release assessment).

Examples of quantitative methods include:

- Fault Tree Analysis (FTA): a logic diagram showing the causal relationship between events which singly or in combination occur to cause the occurrence of a higher level event;
- Event Tree Analysis (ETA): a logic diagram used to analyse the effects of an initiating event which may be an accident, a failure or an unintended event;
- Failure Mode and Effect Analysis (FMEA): technique in which the system to be analysed is defined in terms of functions or hardware. Each item in the system is identified at a required level of analysis;
- Risk Profile Generation: a generic methodology for determining the "risk profile" of a type of vessel, system or function and for identifying the underlying causes which make up that risk profile.

Examples of qualitative methods include:

- Hazard and Operability Studies (HAZOP): An expert team examines a specific design in which they systematically consider deviations from the intended functions, looking at causes and effects. They record the findings and recommendations and follow-up actions required.
- Knowledge based HAZOP: This technique uses the knowledge gained by the entity (authority, institute, company) from previous experience.
- Checklists: specify those components of the system under investigation which require safe design, and help to ensure that designers address known hazards. The technique uses data from industry codes, past accidents and expert judgement.
- What If Analysis Technique: use in hazard identification meetings in which the system, function or operation under consideration are investigated on operation errors, measurement errors, equipment malfunction, maintenance, utility failure, loss of containment, emergency operation and external influences by asking questions starting with "what if?"
- Influence Diagrams: Used to model the network of influences on an event. These influences link failures at the operational level with their direct causes, and with the underlying organizational and regulatory influences.

Besides the above described methods, specific methods are available to assess human and organisational factors in risk assessment. Seen the importance of human and organisational issues as potential risk source in maritime transport, one should aim to develop the knowledge of these factors through modelling, database developments and statistical analyse, and to integrate these factors in quantitative assessment algorithms (EC DG TREN, 2000a). Some examples of hazard identification methods focussing on human and organisational factors include Task analysis, Absolute Probability Judgement (APJ), Technique for Human Error Rate Prediction (THERP) and Human Error Assessment Reduction Technique (HEART).

1.3.3 Release assessment

The Release Assessment step involves the identification of the potential of the risk source to introduce hazardous agents into the environment. This may be descriptive or involve the quantification of the release. Release assessment attempts to give a measure of the likelihood of a release. It will include a description of the types, amounts, timings and probabilities of the release of hazards into the environment and a description of how these attributes might change as a result of various actions or events (Fairman et al., 1999).

As mentioned in paragraph 1.3.2, the release assessment step is often executed together with the hazard assessment step.

In quantitative risk analysis (QRA), a quantitative estimation of the probability of release can be approached in two ways:

- The historical approach which uses direct statistical data on the system under investigation. This may be collected monitoring data or data from similar marine activities. This includes data on undesired events as well as data on recovery and control measures which mitigates the potential impacts.
- The approach which uses analytical and simulation techniques, breaking the system down into contributing factors and causes. Collected monitoring data or data from similar marine activities are also used to verify the modelling results.

If the historical data are of high quality, relevant and statistically significant, their use can be advantageous, as the assessment should not omit any important events that could lead to the event. However, the information may be outdated and not include recent process improvements, which may lead to a "conservative" estimate of the probability and the data are very likely to be dominated by older systems. If the historical data are considered inadequate, synthesis of event probability needs to be carried out. This will calculate the chance of an event (release) occurring. This is primarily achieved through the use of logic diagrams such as described in 1.3.2.

As for hazard identification, available data are extremely important in the quantification of event probabilities. Data banks comprising accident data, incident data and reliability and event data are all useful in probability analysis. Obviously the most appropriate data are those relating to the particular system under investigation. If these are not available it is necessary to use data from other sources on similar systems. Much of the available data may not be suitable which introduces uncertainty into the assessment. (Fairman et al., 1999)

As specified in paragraph 1.2, expert judgement can be used to estimate the likelihood or probability of a release of hazards in a non-quantitative way. Based on the results of the hazard identification, the likelihood is divided in different categories in terms of terms of expressions as likely, may occur, not likely, very unlikely. (Wilcox et al., 2000)

Application: the MARC System

The Marine Accident Risk Assessment System (MARCS) developed by DNV is a release assessment model[1] quantifying maritime accident frequencies and accident consequences. Accident frequency (or probability) calculation is based on Fault Tree Analysis or historic accident/incident to calculate the "accident frequency factors" and on shipping lane data and environmental specific data. Accident consequence calculation on its turn is based on Event Tree Analysis or historic accident consequence data to calculate the "accident consequence factors". In MARCS, the environmental accident consequences include chemical and oil spills.

1.3.4 Exposure assessment

Exposure assessment attempts to quantify the potential exposure levels of the hazard at the receptor site. It includes a description of the intensity, frequency and duration of exposure through the various exposure media (routes of exposure) and the nature of the population exposed. Risk assessment on ecosystems has to deal with a multitude of organisms, all with varying sensitivities to chemicals and various groups have distinct exposure scenarios (e.g. free swimming species have another exposure pathway than benthonic species). The exposure assessment step requires the use of monitoring data, exposure modelling techniques and also mapping models to locate ecological sensitivity incorporating GIS techniques (Fairman et al., 1999; Ecotoc, 2001).

As described in EC Directive 93/67/EEC, exposure of ecosystems to produced hazards is determined in terms of PEC or the Predicted Environmental Concentration. The PEC is calculated on both local and regional spatial scales from monitoring data where available (also called MEC or Monitored Environmental Concentration), or by using realistic worst-case scenarios. If this information is not available, estimates are made from exposure models (Ecotoc, 2001).

To derive the PEC values, information is required on the release rates of all possible emission sources (point, line, diffuse, continuous and intermittent) (results from 1.3.3 release assessment) and the physico-chemical properties of the pollution, including partition coefficients (Kow and Koc) , water solubility, volatility of chemicals (Henry's Law Cte) and biotic and abiotic degradation rates (and products) of the substance, in

[1] Actually, MARCS is defined as a risk assessment model and not a release assessment model. However, in the scope of RAMA the likelihood of oil and chemical spills forms the output of the release assessment step and is used as an input to calculate the potential risks to marine and coastal ecosystems.

order to determine the environmental transportation and fate mechanisms operating and potential exposure pathways (ECB, 2003; Ecotoc, 2001).
The PEC is calculated for each environmental compartment using the information available on release quantities and subsequent degradation processes in the "standard" environment. Site-specific information is used when available and appropriate. The relevant compartments of the marine environment are (Ecotoc, 2001):

- Water-exposure of aquatic organisms across respiratory and other permeable surfaces;
- Sediment-exposure of sediment dwelling (benthic) organisms by ingestion of, or direct contact with, sediment particles;
- Biota-exposure of higher trophic levels via the food chain (secondary poisoning), by predation on organisms that have been exposed via the water, sediment or predation on other organisms.
- Air-exposure for marine birds and mammals by inhalation of the chemical in the air they breath (likely less significant than the other three)

1.3.5 Consequence assessment

A Consequence Assessment will examine the consequences of the release or production of the hazards, to the specified population and the quantification of the relationship between specified exposures to the hazard and the consequences of those exposures. The consequences examined in ecological systems are varied and few defined end-points exist at present. Environmental risk assessment on ecosystems is concerned with different populations and communities and the effects of substances on their mortality and fecundity (Fairman et al., 1999).

In ecological impact assessment, the consequences or effects can be estimated in terms of PNEC or the Predicted No Effect Concentration (based on EC Directive 93/67/EEC). As described in Ecotoc (2001), separate PNECs values need to be derived for the relevant compartments of interest: water compartment, benthic compartment (sediments) and biota (representing organisms which are eaten by avian and mammalian predators).

PNEC values can be derived using ecotoxicity tests. In these tests, the estimation of the PNEC is primarily made on the basis of results from monospecies laboratory tests or, in some cases, from model ecosystem tests. The available ecotoxicity data are used to derive a No Observed Effect Concentration (NOEC) or a Lowest Observed Effect Concentration (LOEC). The test species used are selected to represent the sensitivities of different taxonomic groups in each environmental compartment. For aquatic effects assessments, ecotoxicity data are required on representatives of fish species, daphnia and algae (Fairman et al., 1999).

Assessment (safety) factors are applied to the toxicity value to enable extrapolation from laboratory experiments to the field, acute to chronic effects and for inter and intra species variations. The size of the assessment factor varies according to the number and type of data available and the likely duration of exposure. (Fairman et al., 1999; Ecotoc, 2001).

Ecotoxicological Assessment Criteria (EACs) are defined as effects benchmarks against which the results of environmental monitoring can be assessed in an attempt to identify possible areas of concern. The determination of EACs is based on the same principles as for the assessment factors. EACs are only derived when data which meet predefined quality criteria are available from at least three species.

As indicated in paragraph 1.2.2, expert judgement may be used to assess the magnitude of the consequences in qualitative terms. Dependent on the pollution source and ecosystem characteristics, the potential consequences on the ecosystem are divided in different categories (e.g. "minor" to "catastrophic"). (Wilcox et al., 2000)

1.3.6 Risk estimation and characterisation

Risk characterisation consists of integrating the results from the release assessment, exposure assessment and the consequence assessment to produce measures of environmental risks. This may include an estimate of the numbers of measures indicating environmental damage, and the uncertainty involved in these estimates (Fairman et al., 1999).

In the risk characterisation as described above, PEC incorporates the results of the release and the exposure assessment step while PNEC incorporates the results of the consequence assessment step. Current risk assessment practice compares the PEC with the PNEC for the relevant ecosystem using data from representative species. Implicit in this approach is the assumption that there is a tolerable threshold of any chemical substance in the environment (via the PNEC). An element of precaution is built into the approach via the use of conservative /worse-case assumptions within exposure and effects assessments (Ecotoc, 2001).

This approach is consistent with existing EU methodology requirements on the assessment of risks to man and the environment (Council regulation 793/93/EC and

Council Directive 67/548/EEC) (Ecotoc, 2001). Other similar schemes have been developed (Fairman *et al.*, 1999):

- OECD Provisional Guidance for Initial Hazard Assessment of High Production Volume Chemicals with full Screening Information Data Set; Initial Assessment of Aquatic Effects and Initial Assessment of Environmental Exposure
- US Ecological Risk Assessment Schemes under the Toxic Substances Control Act (TSCA)
- Netherlands Uniform System for the Evaluation of Substances (USES) – General Chemicals and Pesticides

The EU practice on risk characterisation involves the calculation of a quotient – the PEC/PNEC ratio. This PEC/PNEC ratio should be calculated for all relevant endpoints. If the PEC/PNEC is less than 1, the substance of concern is considered to present no risk to the environment and there is no need for further testing or risk reduction measures. If the ratio cannot be reduced to below 1 by refinement of the ratio (by gathering of further information and further testing), risk reduction measures are necessary (Fairman *et al.*, 1999).

Based on the PEC/PNEC ratio, a ranking can be made of the risks associated with the marine activity investigated. This ranking can be used as a base to prioritise risk reduction measures or further investigation.

The PEC/PNEC ratio risk characterisation method does not allow us to assess the effective risk expressed in e.g. terms of number of affected individuals or reduced population density in a specific region resulting from a particular activity.

An overall estimation of risk can be defined as the multiplication of the consequence for each damage-causing event with the frequency of that event.

The frequency of an event is a result of the hazard identification and release step (e.g. frequency of collisions, powered grounding, etc. within a particular area). The consequence of a damage-causing event is usually defined as casualty probabilities. This is presented in the PECs (e.g. amount of fuel oil spilled due to collisions at the receptor site), taking into account the relevant PNECs representing the thresholds below which no damage exists for the investigated species (e.g. no effect concentrations of fuel oil in the different relevant marine ecosystem compartments for seagulls). The population of the species under investigation (e.g. seagulls) present in the areas covered by each probability band is multiplied by the appropriate casualty probability producing the total number of the population predicted to be affected by each event. When combined with the frequency for each event, a risk estimate can be produced for this specific species. This process can be repeated for a number of key species in order to have an overall idea about the risks for the whole ecosystem.

Although a quantitative risk assessment approach is preferred, there may be cases where this can not be carried out (e.g. no PEC or PNEC can be properly calculated).

Qualitative risk assessment can be used as an alternative. In this case, the risk characterisation shall entail a qualitative evaluation of the likelihood that an effect will occur under the expected conditions of exposure. The results of the qualitative risk characterisation can be used as a base to prioritise risk reduction measures.

1.3.7 Risk evaluation

Risk Evaluation is the examination of what the characterised risks actually means in practice. What is the significance or value of the identified hazards and estimated risks?

Risk evaluation deals with the trade-off between the perceived risks and benefits. This includes acknowledgement of the public perception of the risk and the influence that this will have on the acceptability of risk and risk decisions. On its turn, the public perception of risk depends on the economic, social, legal and political context in which the affected and/or concerned population lives (see Figure 3 1) (Fairman et al., 1999).

The risk evaluation may take account of these perceived risks and benefits and incorporate them in the final risk assessment. The results from this risk evaluation may serve as an input to the risk management process. Based on the acceptable level of risk eventual choices of action are determined needed to achieve the desired level of risk. If a system has a risk value above the risk acceptance level, actions should be taken to address concerned risks and to improve the system though risk reduction measures.

The three major approaches to evaluate risks are:

- Professional judgement: technical experts most knowledgeable in their fields examine the risks and make conclusions based on 'best judgement'. Expert judgement may be used to estimate probability (step 3 and 4, see 1.3.2 and 1.3.3) and consequence (step 5, see 1.3.5). Based on a ranking of the probability and consequences of the concerned risk, experts may define acceptance levels.

- Formal analysis: Cost-benefit, cost-risk-benefit and decision analysis are the most common of formal analysis techniques for alternative risk management options. In cost benefit analysis and cost-risk-benefit analysis, benefits (e.g. avoided pollution, risk) and costs (cost of pollution reduction or risk reduction measures) associated with a particular risk management option are evaluated against each other. Decision analysis is an axiomatic theory for making choices in uncertain conditions.
- Bootstrapping: Bootstrapping approaches identify and continue policies that have evolved over time. It is argued that society achieves a reasonable balance between risks and benefits only through experience. The safety levels achieved with old risks provide the best guide as to how to manage new risks.

Professional judgement is a qualitative approach, while formal analysis and bootstrapping are both defined as quantitative approaches. For each of these approaches different methods exist.

1.4 UNCERTAINTY

Uncertainty is inherent to all risk assessments. It is important to assess the magnitude of the uncertainty to determine the "relevance" of the quantified risk.

Risks associated with a specific risk source and receptor and under pre-specified surrounding conditions will be expressed in terms of a range (with a lower and upper bound) rather than a single figure. The best estimate of risk is situated between the upper and lower bound. Comparing the magnitude of this range with the best estimate gives an idea about its relevance or value. Knowing the uncertainty is also important to ensure that the input of the results into the risk evaluation step is realistic (i.e. using cost benefit analysis methods) and thus to ensure that appropriate risk management decisions are made (Wilcox et al., 2000; MCA, 2003).

1.4.1 Sources of uncertainty

Potential sources of uncertainty are following:

- Uncertainty inherent to the used methods in each of the ERA steps (e.g. choice of model, assumptions made in used models);
- Uncertainty related to the collected data and parameters (e.g. gaps in historic/recent data, use of data from other situations and extrapolations to fill out gaps);
- Idiosyncrasies of the analyst: interpretation of ambiguous or incomplete information , human error;

- Uncertainty about the future (e.g. improved techniques and management to prevent and control pollution: improved ship structure, training of crew, adaptation of shipment routes according to pollution sensitivity areas, improved emergency plans, etc.).

1.4.1.1 The applicability of historical data to the current situation

Over a period of time there are likely to be changes to the risks associated with a system. This might be due to older equipment being replaced by modern items, degradation of existing equipment and structures, changes in management systems, changes in operating conditions, etc. These will tend to move the actual risk levels away from the average historical levels, so that the present-day risk is different from the risk used as a basis for calculation. The net result is often a lowering of the risk over a period of time. However such changes are usually very slow to occur and often have a minimal impact on accident statistics. In the shipping industry in particular there is unlikely to be a sudden step-change in overall risk levels as vessels are likely to trade for over 20 years and practices evolve rather than being replaced by entirely novel methods. It is thus expected that this will have a small impact on the uncertainty inherent in the analysis. (MCA, 2003)

1.4.1.2 Uncertainty in the completeness of the data

HAZARD IDENTIFICATION

It is extremely unlikely that every accident will be reported. This will lead to an historical risk level that is lower than the risk in reality. This is expected to be the major cause of uncertainty in the estimation of the base case risk levels. The shipping industry is very diverse, and there is no central body to which all accidents must be reported. However, there are a number of organisations which do collect shipping accident data and it is very likely that major accidents, particularly those involving loss of life, or major pollution will be known by those organisations. It is thus expected that, whilst there will be some uncertainty in the results, the high risk areas will have been adequately identified. (MCA, 2003)

Exposure and Consequence assessment

The consequence and exposure steps are one of the most important areas in which completeness of data are problematic. An example is the need of extrapolation from laboratory experiments to the field, acute to chronic effects and for inter and intra species variations because of lacking data, especially in risks assessment in marine environments. These extrapolations entail additional uncertainty which is dealt with by the introduction of assessment or safety factors.

1.4.2 Methods to assess uncertainty

Quantifying all sources of uncertainty is difficult (especially idiosyncrasies of the analyst). Methods for estimating the uncertainty are for example statistical analysis (for uncertainty related to data and parameters and models), expert judgement (for uncertainty related to models) and sensitivity analysis (for uncertainty related to future trends).

Uncertainty should be assessed for each of the ERA steps. When passing on results to other steps in the methodology, it is important that the uncertainty bounds are passed also, along with information on the key areas of uncertainty and what effect they might have on the risk levels.

1.5 CONCLUSION

Within the quantitative and qualitative approaches a wide range of methods exist, each with its own characteristics, advantages and disadvantages and fields of application. The methods treated in this chapter are summarised in Table 1.1. Despite the diversity of approaches, we can state that in general 7 steps can be identified in an Ecological Risk Assessment (ERA): Problem Formulation, Hazard Identification, Release Assessment, Exposure Assessment, Consequence or Effect Assessment, Risk Characterisation and Estimation and Risk Evaluation.

Whatever method chosen, two major topics that need to be taken into account throughout each consecutive step of the risk assessment are (1) uncertainty rating and (2) quality assessment of the input. Identification of potential gaps is also important in order to assure the quality and relevance of the available information.

Risk characterisation consists of integrating the results from the release, exposure and consequence assessment to produce measures of environmental risks
Specific to risk assessment on ecosystems different difficulties throughout the different steps of the analysis can be distinguished. According to Fairman et al. (1999), overall difficulties encountered are:

- Release Assessment (step 3) and Exposure Assessment (step 4):
  - The selection of fate, transport and exposure models;
  - The selection of ecosystem media and incorporating the interaction of pollutants within these media;

  - Understanding regarding the mode of action of chemicals. Specific modes of action are only known for a few groups of compounds and very little is known about the relationship between mode of action and mortality (i.e. what do organisms die of in toxicity tests?).
- Consequence Assessment (step 5):
  - The selection of indicative species, typically sensitive or endangered species and physiologic end-points;
  - The selection of field laboratory, mesocosm and microcosm tests;
  - The incorporation of resilience and recovery factors of the ecosystem.

Table 1.1: Summarising table

<table>
<tr><th>Problem Formulation</th><th>Hazard Identification</th><th>Release Assessment</th><th>Exposure Assessment</th><th>Consequence Assessment</th><th>Risk Estimation & Characterisation</th><th>Risk Evaluation</th></tr>
<tr><td>What needs to be assessed?</td><td>What can go wrong?</td><td>How often or how likely?</td><td>How does the released material reach the receptor, at which intensity, for how long and/or how frequent?</td><td>What is the effect on the receptors?</td><td>Quantitative or qualitative measure of risk?</td><td>How important is the risk to those effected, those whose create it and those who control it?</td></tr>
<tr><td rowspan="6">Will we use a quantitative, a qualitative or a semi-quantitative approach?
Which methods will be used in the next ERA steps?</td><td colspan="6">Quantitative methods</td></tr>
<tr><td>Risk Profile Generation
Task Analysis (human factors)</td><td></td><td rowspan="2">PEC local :
Monitoring data
Generic scenario building
PECregional:
Montoring data
Generic "box" models
PECbiota:
Bioaccumulation modelling</td><td rowspan="2">Ecotoxicological monospecies laboratory test
Ecotoxicological model ecosystem tests
Equilibrium Partitioning Method</td><td rowspan="2">PEC/PNEC ratios
Risk as product of consequence for each damage-causing event and frequency of that event.</td><td rowspan="2">Formal analysis approaches:
Cost-Benefit Analysis
Cost-Risk-Benefit Analysis
Decision Analysis
Bootstrapping approaches:
Risk Compendiums
Revealed Preference Approach
Implied Preferences</td></tr>
<tr><td colspan="2">Fault Tree Analysis
Event Tree Analysis
MARCS
THERP (human factors)
HEART (human factors)</td></tr>
<tr><td colspan="6">Qualitative Methods</td></tr>
<tr><td>What If Analysis
HAZOP
FMEA
Influence Diagrams</td><td>Expert Judgement</td><td rowspan="2"></td><td rowspan="2">Expert Judgement</td><td rowspan="2">Expert Judgement based risk characterisation</td><td rowspan="2">Professional judgement approach</td></tr>
<tr><td colspan="2">APJ Techniques(human factors)</td></tr>
</table>

2 IDENTIFICATION OF HAZARDOUS ACTIVITIES AT SEA

The Belgian Part of the North Sea is an intensely used marine area. It is a rather small part of the southern North Sea but nevertheless contains one of the most intensive merchant shipping routes in the world. Besides shipping several other activities with an environmental risk can be identified such as fishing, aggregate extraction, tourist activities, transport of gas via pipelines, cable communication and in the near future the production of wind energy (Annex 2.1).

Annex 2.1: Users of the Belgian Part of the North Sea (Maes et al, 2005)

Shipping will be the major contributor to marine incidents resulting in environmental damage. The RAMA project will therefore focus on the impact of accidental pollution (oil and chemicals) of shipping on the Belgian Part of the North Sea. Due to lack of data not all sea-traffic is included in the study (Table 2.1).

Table 2.1: Overview of the hazardous activities included in the RAMA project

	Included	Not included
Shipping	Merchant shipping	Fishery
	Ferry	Navy
	Dredgers	Pleasure crafts/recreational
Others		Aviation (helicopters, SSR)
		Gas transport by pipelines
		Tourist activities
		Wind farms
		Wrecks
		Non-shipping activities related to fishery, recreation, sand & gravel, dredging & dumping, military, off-shore construction

Except for aviation and gas transport (relative minor risk for oil or gas pollution), the environmental risk of the other activities will mainly be the impact caused by physical disturbance (sediment, noise, etc.). These impacts are beyond the scope of this study.

2.1 SHIPPING DATA ANALYSIS

2.1.1 Study area

The shipping data analysis will be restricted to the Belgian part of the North Sea (BPNS) (Annex 2.1). The total sea area of the BPNS is estimated at 3.600 km². Due to restraints in depth and dangerous currents caused by the sand banks, the merchant shipping is restricted to certain shipping lanes (including TSS). Most of the maritime traffic is situated in the Westhinder and Noordhinder TSS (Traffic Separation Schemes) and the shipping lane to the Scheldt estuary and the Zeebrugge port (Scheur). The remaining routes are sailed by coastal vessels and ferries. The BPNS includes one anchorage area, located at the Westhinder TSS near the entrance of the obligatory pilotage area.

The RAMA project will focus on the shipping lanes on the BPNS (excluding the traffic in the Scheldt) (Annex 2.2). An inventory of the shipping activities from the total Belgian Part of the North Sea (BPNS) could not be made due to missing activity data of the northbound fairway of the Noordhinder TSS. This bottleneck will be solved in the future because AWZ will map activities from sea-going vessels on the BCS with the Automatic Identification System (AIS).

2.1.2 Data collection

The Administration of Waterways and Maritime Affairs (AWZ) was the main supplier of the shipping data. The Scheldt VTS authority (AWZ) manages the IVS-SRK database with information about cruising vessels in the Belgian territorial sea (12 NM) and ferries sailing to Zeebrugge, Gent, Antwerpen and Zeeland seaports. Additional data were gathered for ferry transport from Oostende (not recorded by IVS-SRK). The data cover a one-year period (1st April 2003 until 30th March 2004). In total approximately 60.000 voyages are registered in the area covered by the VTS within this time period, which were further divided based on shipping route segment and direction, cargo and ship type.

2.1.3 Ship terminology

Before going into detail in the analysis of shipping activities, it is very important to define the used terminology to avoid any confusion. As the aim of the RAMA-project is to estimate the risk of marine activities (with the focus on shipping) in the different regions of the BPNS, the basic units of the shipping analysis are the route segments. Nevertheless, it can be interesting to know a more general pattern of shipping activities on the BPNS. In this respect following terms can be distinguished (Figure 2.1):

- Shipping route: a shipping route is a well-defined shipping traffic lane existing of several route segments which starts at the entrance of the BPNS or from a Belgian harbour and ends at the leaving of the BPNS or in a Belgian harbour. The number of route segments of a shipping route is not correlated with the length of the shipping route. On the BPNS several shipping routes can be distinguished (in both directions) (Annex 2.2);

- Shipping route segment (also referred to as "route segment"): a route segment is a part of a shipping route between two geo-points (see below) along the shipping route. All route segments are one way. In total 108 different one-way route segments have been identified for the study. Examples are the route segments NEAK-SWTH2 and SWTH2-NEAK (opposite direction) (Annex 2.2);
- Cluster of shipping routes: on the BPNS 3 clusters of shipping routes can be distinguished: West-East transit cluster, the North-South cluster and the Westhinder cluster;
- Geo-point: a geographic point ("zone"); when a ship passes the geo-point. For each geo-point the X and Y coordinates (average) are added;
- Prediction point: the term used within the IVS database for a geo-point that is passed during the voyage of the ship. Here information about the time when the ship passes that prediction point is enclosed;

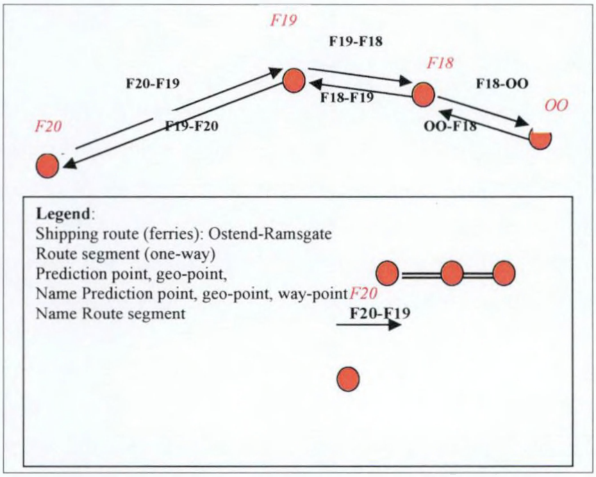

Figure 2.1: Terminology

Annex 2.2: The identified route segments on the Belgian Part of the North Sea

Besides the terminology of route units, following terminology of <u>movements taking place on these route units is used</u>:

- ship movement per route segment (SMRS): a ship movement taking place on a particular shipping route segment in one direction,
- voyage: a ship movement taking place on a shipping route in one direction.

A final distinction is related to the analysis of ship <u>movements per cargo type</u> (CT). One ship can for example transport different cargo types. In the analysis of ship movements per route segment (SMRS) this ship will be classified within the cargo type with the highest environmental risk. This gives a correct estimation of the number of ship movements per ship type, but an underestimation of the number and quantities of cargo transported. Therefore a final term should be explained related to cargo analysis:

- cargo type ship movement per route segment (CTSMRS): all transported cargo types per ship are taken into account in the description of SMRS. This gives a correct estimation of number of ship movements and quantities transported per cargo type and per route segment, but an overestimation of number of ship movements per ship type. The cargo analysis could only be carried out per route segment and not per voyage. So a ship carrying a CT1 and CT2 product on one particular shipping route segment will be counted as 2 CTSMRS, but only as one SMRS.

2.1.4 IVS-SRK database (AWZ)

The analysis of merchant shipping was mainly based on the IVS-SRK database from the VTS authority (AWZ). IVS-SRK is a complex Access database that has detailed information about followed courses of navigation, times of arrival on varied passage points, etc. for sea-going vessels sailing on Belgian territorial waters. The transformation of the database to meet the goals for RAMA was a time-consuming process during which several problems were encountered.

TIME PERIOD

Due to the possible risk on a serious delay of the results in case of waiting on the 2004 data set, there was agreed to work with a data set over a one year period, starting at 1 April 2003 until 31 March 2004.
The IVS-SRK originally covered all ship activities in the eastern side of the BPNS sailing to Zeebrugge, Gent, Antwerpen and Zeeland Seaports. Since 1 March 2005, with the activation of the Oostdyck radar post, the covered area was expanded to the total Belgian territorial sea and a part of the contiguous zone. This expansion came however too late to make use of in this study.

GEOGRAPHICAL COVERAGE OF THE DATA SYSTEM

The IVS data system covers the Belgian and Dutch part of the North Sea from Nieuwpoort on the west side till Domburg (Zeeland, Netherlands) on the north side, till the Scheldt near the Kallo lock on the east side. As RAMA is restricted to the BPNS, all ship movements in the Scheldt estuary and outside the BPNS were excluded from the database.

The IVS data system does not cover the west-east traffic route (Noordhinder TSS) with ships from and to European ports in the southern part of the North Sea, entering or leaving the North Sea via the English Channel. A small part of this major traffic scheme covers the northern strip of the Belgian part of the North Sea. No data could be obtained of this transit traffic (not publicly available, very expensive). This should be marked as a lack of knowledge as they add to the uncertainty of the risk analysis. Obtaining these data would therefore be an added value.

The IVS-SRK database contains the ferry movements leaving from and arriving in Zeebrugge (4 ferry routes), but these to/from Oostende are not included in the database. The ferry data (including the different ferry routes and their location) and the ship movements on the different ferry routes were collected additionally. Three different ferry routes leaving from and arriving in Oostende were distinguished within the Belgian part of the North Sea. For both the routes from Zeebrugge and the ones from Oostende adaptations of the existing ones had to be made and new ones had to be created. Knowing the number of ship movements during one year on the different ferry routes of Zeebrugge, the amount of movements was distributed over the four routes (Table 2.2). The ship movements on the Oostende-routes were well-known per route (Table 2.2). Furthermore the ships on these routes were given a ship type code. All ships from Oostende were identified as RoRo or Ropax (Ship type 4). For the two newly identified routes from Zeebrugge, the ships were divided (50/50) to ship type 4 (Ro/Ro, car carriers, Ropax) and ship type 8 (passenger ships).

Table 2.2: Identified ferry routes from Zeebrugge and Oostende

Ferry route	Number of ship movements per year (in two directions)
Zeebrugge - Immingham/Tees/Bligh Zeebrugge - Hull/Rosyth	2.347 (including other traffic: 3.706)
Zeebrugge - London - Gap - Purfleet/Dagenham	1.508
Zeebrugge - London - Purfleet/Dagenham	1.508
Oostende - Killinghome	624
Oostende - Ipswich - Gap	2.184
Oostende - Ramsgate	6.240

SCREENING FOR RELEVANT TABLES AND FIELDS

The database contains a lot of information that is, although relevant to the Vessel Traffic Centre, of minor use for the aim of the project. Following relevant tables were selected: prediction point, vessel-voyage, dangerous-material, geo-point and block table.

- prediction point: contains all passage points (prediction-points, geo-points or way-points) crossed by the ship during its voyage;
- vessel-voyage table: information per voyage about anchorage and ship characteristics (e.g. ship type, destination, double hull, DWT, draught, etc);
- dangerous-material table: information per voyage about dangerous material on board (UN-number, IMO-code, name material, quantity, etc.);
- geo-point table: contains the different geographic points distinguished by the IVS (abbreviation and geographical position of the several prediction points);
- block table: The IVS system divides the IVS area in 26 blocks (e.g. RZ, CA, KN). Each block contains several geo-points. Geo-points lying inside a block are named to the block. Geo-points lying on the dividing line of two blocks have the name of the two blocks separated by an oblique line (e.g. RZ/KN).

ADAPTATION OF COORDINATES OF ROUTE SEGMENTS

Based on the previous discussed tables, existing route segments were drawn in GIS. In some cases geographical adaptations had to be made in relation to opposite direction movements, bathymetry, existing navigation routes, etc.

DISTINGUISHING BETWEEN CLASSES AND EXCLUSION OF DATA

For the estimation of the risks of merchant shipping, some distinctions had to be made:

Ship types: in the database the ship type is represented by a letter code with varying length of which the first 5 letters represent the "basis ship type" and the other letters refer to specific information of the transported cargo. For some ships no data were available on the ship type or they could not be dedicated to a specific ship type (e.g. dock, slipway, fishing, sailing, pontoon, platforms, diving vessels, ACV, etc.). They were classified respectively as ship type 0 (ST0) and ship type 9 (ST9). Only 8 ship types (ST1 to ST8) were taken into account for further analysis.

Table 2.3: Overview of ship types

Ship type	Ship name	Share (%)
ST1	Oil (crude) tankers	6,5%
ST2	Chemical tankers+refined	2,3%
ST3	Gas tankers	3,4%
ST4	RoRo+car carriers+Ropax	43,4%
ST5	Bulk carriers	3,9%
ST6	General cargo+reefers	18,7%
ST7	Containers	11,5%
ST8	Others + Passenger Ships	8,7%
ST0	Unidentified	1,3%
ST9	Excluded shipping	0,4%

Double hull: a distinction was made between double hull vessels (if identifiable in the database) and the other vessels. For the risk analysis the percentages of the ships with a high DWT in relation to specific characteristics of the ship hull (single hull, double-side, double bottom and double hull) were calculated. As the database contained no information on the presence of double sides or double bottoms, a distinction could only be determined between double hull and single hull vessels.

Weight classes: In total 11 different weight classes were identified within the IVS database (Table 2.4). As for two classes (Class 9 and class 10) the dead weight tonnage (DWT) was unknown, they had to be excluded for further analysis.

Table 2.4: Overview weight classes

Weight Class	DWT-high	Amount of voyages	Percentage (%)
Class 0	0	430	0,528
Class 1	Between 1 and 5.000	34.522	42,378
Class 2	Between 5.001 and 10.000	17.032	20,908
Class 3	Between 10.001 and 50.000	17.866	21,932
Class 4	Between 50.001 and 100.000	2.914	3,577
Class 5	Between 100.001 and 150.000	276	0,339
Class 6	Between 150.001 and 200.000	130	0,160
Class 7	Between 200.001 and 250.000	4	0,005
Class 8	> 250.000 and < 999.999	4	0,005
Class 9	(no value)	8.270	10,152
Class 10	999.999	14	0,017

<u>Cargo types</u>: based on the dangerous-material table the voyages were classified under a specific cargo type (Table 2.5). Several problems were encountered: very large dataset, gaps in data, incomplete or inaccessible data of dangerous material (no UN-number, no name of the material or no IMO-code), and inconsistencies in the dangerous goods data between UN-number, name and IMO-code. Extra information was obtained from the IMDG-code (e.g. UN-number, IMO-code, name of the material, information about marine pollutants (MP)). Despite these efforts, some obscurity in the data continued to exist. Voyages of which the hazardous cargo could not be identified were classified as a separate cargo type (CT 8). Furthermore non dangerous goods (CT 10) and voyages marked as empty (CT 9) were excluded from further analysis. In total 8 cargo types (CT1 – CT8) were taken into account for the analysis.

Table 2.5: Overview of the cargo types

Cargo type	Definition	Product group code	Classification	Criteria
1	HNS with high environmental risk	Marine Pollutants (packaged) Cat A (bulk)	A product is catalogued as cargo type 1 if, according to its UN-number (IMDG CD-Rom), that product is identified as a Marine Pollutant (P, PP). A product is catalogued as cargo type 1 if identified as a Category A product under IMO (IBC). This bulk product is very harmful to human life and the marine environment.	UN-number (IMDG); IMO-code (IBC)
2	Oil products with high environmental risk	Crude oils	All oil products that have as product name "crudes" or "crude oil".	Name material
3	Oil products with medium environmental risk	Bunkers & heavy fuels	All oil products identified as bunkers or heavy fuels. The heavy and intermediate fuel oils and the marine gas and diesel oils are incorporated in this class.	Name material
4	Oil products with low environmental risk	Other oil products + Annex I	All oil products not classified as cargo type 2 and 3. Also the pure and refined products are incorporated in this class.	Name material
5	HNS with potentially high to medium environmental risk	Potential Marine Pollutants (packaged) Cat B & C (bulk)	All HNS products (packaged) not classified as CT 1 and according to its UN-number identified as potential marine pollutant (IMDG CD-Rom). All HNS products (bulk) not classified as CT 1 and identified as Cat B or Cat C. This bulk product is less harmful to human life and the marine environment.	UN-number (IMDG) IMO-code (IBC)
6	HNS with toxic properties	Toxic Products	All toxic HNS products. Identified by IMDG as 6.1 & 2.2.	IMDG

Cargo type	Definition	Product group code	Classification	Criteria
7	HNS with low environmental danger	Annex III (packaged); Annex II, Cat D, App. III, MHB (bulk); other IMO codes	All other HNS products in packaged form with an IMO code, not classified under one of the previous cargo types. Also the HNS products in bulk identified as Cat. D, App. III and MHB (materials hazardous only in bulk).	IMO-code
8	HNS non identified + transported quantity considerable	Non consistent no information not classified, code (no digital data, only fax)	All products that were non consistent or no information was filled in. Products were catalogued as NA, non consistent or code in following cases: If only a UN-number was present which didn't exist in the IMDG CD-Rom, this product was catalogued as "non consistent". If the IMO-code, UN-number and the name of the product were present, but they were not consistent, then "non consistent" was filled in the database. If no digital data were available about the name, IMO-code and UN-number of the product, but reference was made to a fax. In this case, we classified them as "code" under cargo type 8. When a product was catalogued as NA (not applicable): There was no information about the dangerous material: no IMO-code, no name, no UN-number; The product name was very general: e.g. condensate, chemicals, containers, diverse; unknown, slops, sludge.	UN-number, IMO-code, Name material
9	HNS transported quantity very low	Empty but with leftover fractions from HNS (dangerous goods assumed to be absent)	When a product was catalogued as empty, several cases were possible: For the name of the product "empty" or "no cargo" was filled in, sometimes the quantity was 1 ton; The storage room was just cleaned; The last cargo was not a dangerous good; It was free of gas.	Name material
10	Non dangerous goods	Other cargo (products without IMO code)	All other cargo that are no dangerous goods (no IMO cargo) e.g. orange juice, soya, etc. All the voyages that were not present on the dangerous material table are classified in cargo type 10.	

Other excluded data from the database: 1) route segments that deviated from the "normal" routes and were either impossible data (e.g. due to bathymetry) or were part of voyages where intermittent prediction points should have been registered but were not present in the database and 2) route segments with the same start and end point due to drift of the ship or returning of the ship.

2.2 DESCRIPTION OF MERCHANT SHIPPING PATTERNS

2.2.1 General shipping pattern

About 320.000 ship movements per route segment are registered on the Belgian Part of the North Sea (BPNS) (Annex 2.2). As mentioned before these route segments are parts of longer shipping routes. In total 57.791 voyages took place on the shipping routes of the BPNS for the period April 2003-March 2004. These shipping routes can be clustered into three well-defined groups (Figure 2.2):

- Noordhinder TSS: Each year about 150.000 ships pass through the Strait of Dover (400 each day) (OSPAR 2000). The west-east traffic route with ships from and to European ports in the southern part of the North Sea, entering or leaving the North Sea via the English Channel is part of the IMO Traffic Separation Scheme (TSS) in which counter current traffic streams are divided by making use of lanes and other regulations. A small part of this major scheme covers the northern strip of the Belgian part of the North Sea. Specific intensity data are unfortunately not available through the VTS system;
- West-east cluster including Westhinder TSS: A second west-east orientated cluster of shipping routes includes the IMO Traffic Separation Scheme (TSS), better known as the Westhinder-traffic separation scheme. The Westhinder-TSS is being used by ships from and to ports in Belgium and from and to ports along the Westerscheldt mouth. This main shipping lane is situated north of the Oostdyck sublittoral sandbank and also covers a refuge area in the north. The TSS finds its origin at the end of the Strait of Dover, adjacent to Dunkerk, and leads all the way into the Belgian territorial sea. The intensity data are dependent on the place of registration on the shipping routes. A yearly average of approximately 40.000 voyages (both directions) for the BPNS is however a good estimation. The highest fraction of these voyages (about 91%) head towards the Scheldt (or opposite direction). The other destinations are towards the harbour of Oostende (± 9,7%) and to the Netherlands (± 0,2%) (Westrond 1) (both ways). After the TSS the transport in the direction of the Scheldt can further be subdivided into two main streams: one north of the Wenduine bank (> 90%) of the voyages and one crossing the Wenduine bank. The northerly route can be seen as the extension of the IMO Westhinder-TSS and comprises the fairways "Wielingen" en "Scheur". They are used by all ships heading or leaving Antwerpen, Gent, Vlissingen, Breskens and Zeebrugge. Approximately 30.000 voyages were registered on this route for the period 2003-2004;
- the North-South cluster of shipping routes is used by ships leaving Belgian harbours for the UK (or vice versa). In the northerly point of this cluster a total of 9.530 voyages were registered during the considered period. Southwards there is a division of ships heading or leaving Zeebrugge (6.722 voyages) or Oostende (2.808 voyages). A distinction can also be seen in the ship type respectively RoRo traffic (Zeebrugge) and ferries (Oostende).

Besides these major clusters of shipping routes some other less intensively used shipping routes are also worth mentioning:

- Westrond 2 is a route passing the Westpit and used by ships leaving the Belgian or Scheldt-harbours and navigating in northerly direction to the Netherlands, Germany, Scandinavia and the Baltic area or the other way around. Westrond 2 accounts for about 3.000 voyages a year, so only a minor fraction in comparison with the other routes;
- finally there is also a more coastal ferry route from/to Oostende coming from the West. A total of 6.240 voyages were registered during the considered period.
- besides these systems, a variety of other shipping routes with vessels that are not bound to specific routing systems, exists. They are generally under a length of 80 metres.

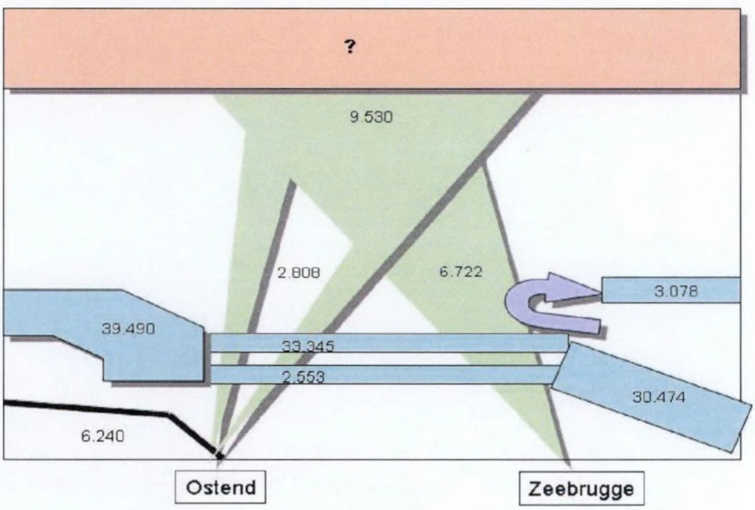

Figure 2.2: Clusters of shipping routes on the BPNS

2.2.2 Voyages

In 2003 57.791 voyages are registered within the Belgian Part of the North Sea of which about 25% are ferry transports.

2.2.2.1 Ship type

The distribution of the number of voyages according to the ship types is given in Table 2.6.

Ship type 4 is responsible for the highest number of voyages on the BPNS of which approximately 45% can be explained by ferry traffic. A lot of transport takes place with ship type 6 (18,7%) and ship type 7 (11,5%). Tankers which in general transport the environmentally most hazardous products take about 12% at their account. A small percentage of the data (ship type 0 & 9: 1,7%) could not be dedicated to a specific ship type because no information was available on the ship type or the type was excluded. These data will be excluded from further analysis.

Table 2.6: Distribution of voyages on the BPNS

Ship type	Ship name	Voyages (#)	Share (%)
ST1	Oil (crude) tankers	3.729	6,5%
ST2	Chemical tankers+refined	1.307	2,3%
ST3	Gas tankers	1.940	3,4%
ST4	RoRo+car carriers+Ropax	25.097	43,4%
ST5	Bulk carriers	2.252	3,9%
ST6	General cargo+reefers	10.811	18,7%
ST7	Containers	6.638	11,5%
ST8	Others + Passenger Ships	5.013	8,7%
ST0	Unidentified	757	1,3%
ST9	Excluded shipping	247	0,4%

2.2.2.2 Cargo type

In total approximately 1.500 different products (oils and other hazardous substances) were transported on the Belgian Part of the North Sea during the period April 2003 – March 2004. Due to the inconsistencies within the database of SRK only a rough estimation of number of products can be given.

To overcome some of these problems and to make the risk analysis feasible, the different products have been classified into 10 groups (Table 2.7).

A closer look to the distribution (%) of the voyages by the different identified cargo types (CT) transported by these ship types reveals a very high percentage (41% or 27 voyages) of cargo type 1 products (MP & Cat. A) with container ships (Table 2.7). This is however only 0,41% of all the voyages occurring with container ships. As expected most of the transport of oils (CT2, CT3, CT4) occurs with oil tankers. The highest percentage (35%) of CT5 (potential marine pollutants and Category B & C products) are also carried by oil tankers (Table 2.7). In total 207 voyages (0,36%) are voyages with CT1 & CT2 products and 3.281 voyages (5,7%) with CT3, 4 or 5 products. The most important ship type in terms of voyages (ship type 4) transports for 85% non dangerous goods (CT10). As noted before in Table 2.7 the voyages are classified according to the cargo type with the highest environmentally risk.

Table 2.7: Distribution (%) of voyages per cargo *type

Ship type	Ship name	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
ST1	Oil (crude) tankers	13,64	97,87	77,40	75,81	34,64	5,63	10,72	3,91	66,93	1,81
ST2	Chemical tankers +refined	12,12	0,00	20,55	18,36	13,97	2,40	5,77	1,67	29,13	0,87
ST3	Gas tankers	0,00	2,13	0,00	0,00	19,07	10,44	32,14	0,42	3,94	0,54
ST4	RoRo+car carriers+Ro pax	27,27	0,00	0,68	0,05	15,87	45,23	26,96	41,09	0,00	49,38
ST5	Bulk carriers	0,00	0,00	0,00	5,04	1,02	0,00	0,75	0,68	0,00	4,81
ST6	General cargo +reefers	4,55	0,00	0,00	0,51	4,66	1,05	4,38	11,81	0,00	23,25
ST7	Containers	40,91	0,00	0,00	0,23	10,48	31,18	16,08	39,27	0,00	8,27
ST8	Others + Passenger Ships	1,52	0,00	1,37	0,00	0,29	4,06	3,19	1,14	0,00	11,07
		100	100	100	100	100	100	100	100	100	100
Total # voyages (ST 1-8)		66	141	146	2.162	687	1.331	4.384	4.726	127	43.017

(*) The classification of voyages occurred according to the cargo type with the highest environmental risk transported.

2.2.2.3 Transported quantities

In Table 2.8 the average quantities transported (ton) per voyage for the different cargo and ship types are given. It should be reminded that the given figures are the average quantities of the highest risk cargo type per voyage. A more detailed cargo analysis in which all transported cargo types per ship are taken into account is given in 2.2.3.3.

The cargo with the highest environmental risk i.e. the crudes (CT2) are transported in relatively high quantities by oil tankers (ST1). Also bulk carriers (ST5) transport high quantities of dangerous goods (total average of 34.425 ton/ voyage). Bulk carriers are responsible for the main transport of cargo type 5 (marine pollutants, Cat. B & C). The data of transported quantities of the less dangerous cargo types are not reliable.

Quantity data were only available for 15% (CT8), 5% (CT9) and <1% (CT10) of the voyages. For the other cargo types between 75% and 99% of the quantity data are known.

Table 2.8: Average quantities (ton) transported per voyage per cargo*/ship type

	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
ST1	625,1	40.910,6	743,6	8.712,7	11.906,2	20.569,7	3.500,1	8.735,9	0,9	4.014,1
ST2	1.345,9		395,2	3.773,7	1.952,2	1.466,6	2.602,3	2.854,8	1,0	4.487,8
ST3		1.218,3			867,5	6.016,8	7.500,9	1,0		
ST4	8,0		1.800,0	1,0	14,7	242,9	274,3	80,8		
ST5				38.921,6	29.450,6		35.494,8	33.833,0		25.112,0
ST6	305,0			4.284,8	73,7	11,2	1.127,2	2.911,7		
ST7	184,0			141,5	2.920,8	3.074,5	451,6	978,6		
ST8	0,4		175,0		1,0	141,0	16,7			

(*) The classification of voyages occurred according to the cargo type with the highest environmental risk transported.

2.2.3 Ship movements per route segment

As the aim of the RAMA-project is to estimate the risk of shipping in the different regions of the BPNS, the basic units of the shipping analysis are the route segments. In this way a more detailed geographical pattern of shipping traffic is obtained. This will form the basis for the risk analysis performed by DNV. A geographical pattern of the ship movements on the BPNS (divided in 11 subareas for further analysis) is given in Annex 2.3.

Annex 2.3: Geographical distribution of the ship movements (per km^2) on the BPNS

On the BPNS 108 different shipping route segments have been identified (Annex 2.2). These route segments are not correlated with distance. This means that route segment A will not necessarily be as long as route segment B. Nevertheless the number of SMRS per ship type and per cargo type gives a relative idea of the importance of each ship type or cargo type.

2.2.3.1 Ship type

Eight different vessel types are distinguished (Table 2.9). They are good for a total of 322.987 ship movements per route segment (SMRS) on the Belgian Part of the North Sea (BPNS). A small percentage of the data (1,5%) could not be dedicated to a specific ship type because no information was available on the ship type or the type was excluded. These data were excluded from this analysis (2.2.2.1).

On the BPNS the majority of transports occur in packaged form (ship type 4, 6, 7, 8) (81%) (Table 2.9). Bulk transport (type 1, 2, 3, 5) accounts for 19% (Table 2.9). During the studied period a maximum number of records for packaged transport has been allocated to ship type 4 (RoRo, car carriers, Ropax) with 116.466 ship movements and for bulk transport to ship type 1 (oil (crude) tankers) with 24.475 ship movements.

Table 2.9: Classification of the ship types

Ship type	Ship name	# SMRS	Share (%)
1	Oil (crude) tankers	24.475	7,6%
2	Chemical tankers+refined	8.049	2,5%
3	Gas tankers	13.540	4,2%
4	RoRo+car carriers+Ropax	116.466	36,1%
5	Bulk carriers	16.491	5,1%
6	General cargo+reefers	71.751	22,2%
7	Containers	46.219	14,3%
8	Others + Passenger Ships	25.996	8,0%

2.2.3.2 Cargo type

Table 2.10 gives an overview of the ship movements per route segment (SMRS) per cargo type. In analogy with the voyage analysis, a ship carrying different products of different cargo types will be counted as one ship movement within the cargo type with the highest environmentally risk. This gives a correct representation of the number of ship movements per route segment on the BPNS.

Table 2.10: Classification of the cargo types

Cargo type	Definition	Product group code	Type transport	# SMRS1	Share (%)
1	HNS with high environmental risk	Marine Pollutants	Packaged	432	0,13
		Cat A	Bulk		
2	Oil products with high environmental risk	Crudes	Oil	1.114	0,34
3	Oil products with medium environmental risk	Bunkers	Oil	592	0,18
4	Oil products with low environmental risk	Oil Products + Annex I	Oil	13.541	4,19
5	HNS with potentially high to medium environmental risk	Potential Marine Pollutants	Packaged	4.621	1,43
		Cat B, C	Bulk		
6	HNS with toxic properties	IMDG 6.1 & 2.2	Packaged	8.302	2,57
7	HNS with low environmental danger	Annex III	Packaged	28.592	8,85
		Annex II, Cat D, Appendix III, MHB	Bulk		
		Products with other IMO code	?		
8	HNS non identified + transported quantity considerable	Non consistent + No information (NA)	?	30.276	9,37
		Code (no digital data, fax info available)	?		
		Not Classified	?		
9	HNS transported quantity very low	Empty (no cargo)	?	600	0,19
10	Non dangerous goods	Other Cargo (Products without IMO code)	?	234.917	72,73
				322.987	100,00

(1) Total number of ship movements per route segment of which for each ship the cargo type is deduced to the cargo with the highest environmental risk (see also 1.2.1.1).

2.2.3.3 Transported quantities

In the following paragraphs an analysis is given of the transported quantities per cargo type (CT) and per ship type (ST). This means that for the following analysis all ship movements per route segment over the different cargo types are taken into account, the so-called cargo type ship movements per route segment (CTSMRS) (see also 2.1.3). So a ship carrying 3 different cargo types will be counted as 3 CTSMRS. In contrast with the earlier analysis this will give an overrepresentation of the real number of SMRS, but a correct representation of the transported quantities. From Figure 2.3 it becomes clear that for all packaged transport (ST 4, 6-8) cargo type 10 (non dangerous goods) is responsible for the highest share. For the bulk transport – with the exception of ship type 1 (oil tankers) and 5 (bulk carriers) the main fraction is the transport of cargo type 7 which is a combination of hazardous products with a minor environmental impact.

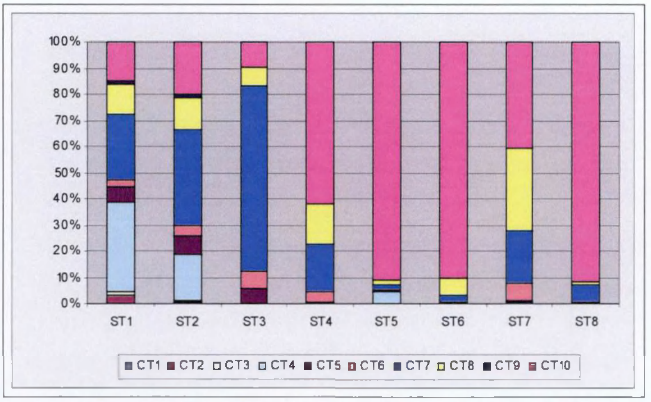

Figure 2.3: Relative distribution (%) of ship movements per cargo & ship type

The transport of dangerous goods (cargo type 1-9) is still good for approximately 40% of all cargo transports (excl. ST0 & ST9) on the BPNS (total # 149.653 CTSMRS). The distribution of the transport of dangerous cargo over the different ship types is given in Table 2.11. About 40% of the dangerous goods are transported in bulk, while 60% in packaged form. Most transport (74%) is done by ship type 1, 4 and 7.

Table 2.11: Distribution of dangerous cargo ship movements per ship type

Ship name	# CTSMRS	Share (%)
ST1: Oil (crude) tankers	31.804	21,25%
ST2: Chemical tankers+refined	10.695	7,15%
ST3: Gas tankers	16.001	10,69%
ST4: RoRo+car carriers+Ropax	41.701	27,87%
ST5: Bulk carriers	1.621	1,08%
ST6: General cargo+reefers	8.245	5,51%
ST7: Containers	37.072	24,77%
ST8: Others + Passenger Ships	2.514	1,68%

If only the dangerous goods are considered (cargo type 1 – 9) the share of cargo type 7 is the highest for all ship types except for the ship types 1 (oil tankers) and 5 (bulk carriers) (Table 2.11). Between 40% (ST1) and 50% (ST5) of their transport consist of oil products with low environmental risk (CT4) (Table 2.12). The products with the highest environmental risk - CT1 (MP & cat. A) & 2 (crudes)- are mainly transported in oil tankers (ST 1), chemical tankers (ST 2) and container ships (ST 7) with a maximum of 1.191 CTSMRS for CT2 (ST 1) and 205 CTSMRS for CT1 (ST 7) (Annex 2.4).

Table 2.12: Relative distribution (%) of dangerous CTSMRS per ship type

Cargo Type	ST 1	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8
1	0,24%	0,57%	0,01%	0,23%	0,00%	0,27%	0,55%	0,28%
2	3,74%	0,00%	0,16%	0,00%	0,00%	0,00%	0,00%	0,00%
3	1,49%	1,03%	0,00%	0,01%	0,00%	0,00%	0,00%	0,36%
4	40,04%	21,53%	0,00%	0,02%	50,77%	1,20%	0,09%	0,04%
5	7,06%	9,04%	6,42%	1,71%	3,52%	4,03%	1,77%	0,99%
6	2,86%	4,63%	6,87%	10,11%	0,00%	1,49%	10,41%	8,75%
7	29,27%	46,13%	78,22%	47,68%	23,63%	28,71%	33,18%	76,65%
8	13,73%	15,62%	8,07%	40,16%	22,09%	64,29%	53,95%	12,93%
9	1,57%	1,44%	0,26%	0,06%	0,00%	0,01%	0,04%	0,00%

Other important cargo classes are cargo types 4 for bulk transport (ST 1-3, 5) and 8 for packaged transport (ST 6-7). These cargo types pose a lower risk to the environment (Table 2.12).

In Annex 2.4 the average quantity per cargo type ship movement per route segment (avg. quantity/CTSMRS), the number of CTSMRS for which quantity data are available (# CTSMRS quantity data), the total number of cargo type ship movements per route segment (total # CTSMRS) and the percentage of quantity data known (% data known), is given per ship type. In this way the reliability of the quantity data is clarified.

Annex 2.4: Quantitative analysis of the different cargo types per ship type

The reliability of the data for bulk transport (ST 1-3, 5) (56%) is higher than for packaged transport (ST 4, 6-8) (10%) (Annex 2.4). The lack of data within ST 5 is responsible for the lower reliability of bunker transport. Based on the other bunker types (ST 1-3) the reliability increases to 72%. The exclusion of cargo type 10 (non harmful substances) causes an increase of the reliability to 81% (bulk) and 28% (packaged). In general, the reporting of hazardous products occurs systematically, especially for bulk transport of oil and HNS.

From Annex 2.4 some general conclusions can be formulated:

- 40% of the transport (excl. ST0 & ST9) on the BPNS consists of dangerous goods (oils and HNS) (total # of 149.653 CTSMRS);
- 60% of the dangerous transport is in packaged form (ST4, 6-8), 40% in bulk (ST1-3, 5);
- the average quantities of dangerous goods per CTSMRS for bulk transport are higher (up to 40.000 ton) than for packaged transport (up to 3.800 ton);
- 74% of transport is done with ship type 1 (oil tankers), ship type 4 (RoRo + car carriers + Ropax) and ship type 7 (container ships);
- cargo type 7 (HNS with low environmental danger) accounts for an average of 45% of the dangerous good transports;
- the products with the highest environmental risk (CT1 & CT2) are mainly transported in oil tankers (ST 1), chemical tankers (ST 2) and container ships (ST 7). The maximum share of both products (4%) is taken by the oil tankers.

As RAMA focuses on the environmental risks due to merchant shipping, special attention will further be given to the transport of CT 1 (MP, Cat. A) and CT2 (crudes).

2.2.4 Cargo types with the highest environmental risk

2.2.4.1 Cargo type 1 (Marine pollutants, Cat. A)

More than 90% of the CT1 transport (total 76 voyages) occurred with ship type 1 (oil tankers), 2 (chemical tankers), 4 (RoRo + car carriers + Ropax) and 7 (container ships). The higher figure obtained here in comparison with the voyage analysis is simply due to the fact that different CT1 products can be transported on the same voyage. This analysis of the cargo type 1 products separately thus increases in this way the total number of voyages (66 #) or the voyages transported by the summed ship types (62#). However, the relative contribution of 93% stays the same. Thirteen different cargo type 1 products were identified within these ship types. The transported products are classified according to IMDG and IBC in the following categories.

Table 2.13: IMO categories of cargo type 1 products transported in ship type 1, 2 & 7

IMDG/IBC	Category	Product name
Bulk (IBC)	Category A	Noxious liquid substances which if discharged into the sea from tank cleaning or deballasting operations would present a major hazard to either marine resources or human health or cause serious harm to amenities or other legitimate uses of the sea and therefore justify the application of stringent anti-pollution measure.
Packaged (IMDG-MP)	Class 2.3	Toxic gases
	Class 3	Flammable liquids
	Class 6.1	Toxic & infectious substances
	Class 8	Corrosive substances
	Class 9	Miscellaneous dangerous substances

In Annex 2.5 an overview is given of the cargo type 1 products, their classification code, UN number, the number of voyages and the average (ton) and total quantities (ton) per voyage. Most of the transports took place in container ships (ST 7) (total of 28 transports) of which the major part was due to the transport of chlorine. The highest average quantity per transport was found for 'Calcium arsenate/ arsenite mixture in solid form' (ST 1) namely 3.000 ton. About 92% of the voyages are transports with an average quantity of ≤ 1.000 ton of HNS.

Annex 2.5: Average & total quantities (tons) of cargo type 1

2.2.4.2 Cargo type 2 (crude oils)

About 98% of crude oils are transported with oil tankers (ship type 1). In Annex 2.6 an overview is given of the cargo type 2 products (crudes), the number of voyages and the average and total quantities per voyage (ton). As the available data source (IVS-SRK data) did not always specify the type of oil, all the different inputs (combination of name, UN nr, IMO) have been used as different types of crude oils. In this way the heterogeneity of data input in the SRK data base is brought to the notice.

The average quantities per voyage vary between 3.469 ton (Crude benzene) and 101.727,50 ton (Rebco crude oil). The highest number of voyages is due to petroleum crude oils respectively 45 (flashpoint < 23°C) and 27 (flashpoint ≥ 23°C) voyages. In comparison to the HNS transport (cargo type 1) the average transported quantities of crude oils are much higher, in general more than 35.000 ton per voyage.

Annex 2.6: Average & total quantities (tons) of cargo type 2

2.3 CONCLUSION

The RAMA project focuses on the shipping lanes on the BPNS (excluding the traffic in the Scheldt). An inventory of the shipping activities from the total BPNS could not be made due to missing activity data of the northbound fairway of the Noordhinder TSS. This bottleneck will be solved in the future because AWZ will map activities from sea-going vessels on the BPNS with the Automatic Identification System (AIS).
In total 57.791 voyages (or about 320.000 ship movements) took place on the shipping routes of the BPNS for the period April 2003-March 2004. The general conclusions of the shipping analysis are:

- 40% of the transport on the BPNS consists of dangerous goods (oils and HNS);
- 60% of the dangerous transport is in packaged form, 40% in bulk;
- the average quantities of dangerous goods per CTSMRS for bulk transport are higher (up to 40.000 ton) than for packaged transport (up to 3.800 ton);
- 74% of transport is done with ship type 1 (oil tankers), ship type 4 (RoRo + car carriers + Ropax) and ship type 7 (container ships);
- cargo type 7 (HNS with low environmental danger) accounts for an average of 45% of the dangerous good transports;
- the products with the highest environmental risk (CT1 & CT2) are mainly transported in oil tankers (ST 1), chemical tankers (ST 2) and container ships (ST 7). The maximum share of both products (4%) is taken by the oil tankers.

3 RELEASE ASSESSMENT OF MARINE INCIDENTS

Release assessment is the identification of the potential of the risk source to introduce hazardous agents (oil and HNS) into the marine environment (see 1.3.3). The quantitative estimation of the probability of release will be approached from both the historical and the modelling approach (1.3.3).

3.1 POSSIBLE RISK SOURCES OF OIL AND HNS

The origin of oil pollution to the sea is either natural or anthropogenic:

- natural:
  - natural seeps and erosion of bottom sediments;
  - biosynthesis by marine organisms;
- anthropogenic:
  - marine transportation: accidents, operational discharges from tankers, illegal discharges;
  - off-shore oil production (drilling discharges, accidents, etc.);
  - on-land sources: sewage waters, oil terminals, rivers and land runoff;
  - Incomplete fuel combustion.

The causes of hazardous and noxious substances (HNS) are similar except for the operational discharges from tankers, the offshore oil production, the oil terminals, the rivers and land runoff and the incomplete fuel combustion.

All causes except for incomplete fuel combustion will have a local effect on the hydrosphere. The atmosphere can also be affected by offshore oil production and incomplete fuel combustion, or any source of HNS. The regional and global scale of the pollution will depend on the type of accident. RAMA will focus on the impact of incidents related to marine transportation of oil and HNS namely operational discharge and accidents.

The causes of the shipping accidents can broadly be classified into two groups. One group is linked to navigation risks, usually following bad weather conditions causing the loss of part of the cargo, grounding, collision or a shipwreck (sinking). The navigation risks on the Belgian Part of the North Sea can be attributed to the following sources: ships and smaller vessels, wind turbine park, observation masts, wrecks The second group is linked to an initial internal event on-board ship, such as a fire, a faulty structure on board, or a false manoeuvre (the ballast of the ship, the stowage of the cargo, open door). Other reasons can be accidents during salvage operations.

It is obvious that spills at sea will have their impact on the hydrosphere. The volatile products can also have consequences for the quality of the atmosphere. Chemicals (oils and hazardous and noxious substances) can be classified in different property groups (gas, dissolve, float, sink). According to the property group the impact on the environment (atmosphere, hydrosphere) will differ.

3.2 OPERATIONAL DISCHARGE

The 1997 amendments to MARPOL make the North Sea "a Special Area" under Regulation 10 of Annex I. In special areas, discharge into the sea of oil or oily mixture from any oil tanker and ship over 400 gt is prohibited. In the framework of the Bonn Agreement (1969) Belgium started in 1991 a national programme of aerial surveillance above the North Sea to stop the illegal oil discharges from ships. The Belgian aerial surveillance is organised by the Management Unit of the North Sea Mathematical Models and the Scheldt estuary (MUMM) (RD 20/01/1999).

Fifty illegal oil discharges are yearly registered in the North Sea by MUMM. The chance of being caught is low. Nevertheless since the aerial surveillance started a decreasing trend is observed in the number of discharges. Figure 3.1 gives an overview of the oil spills observed by MUMM in the southern part of the North Sea. The majority of spills are smaller than 10 m².

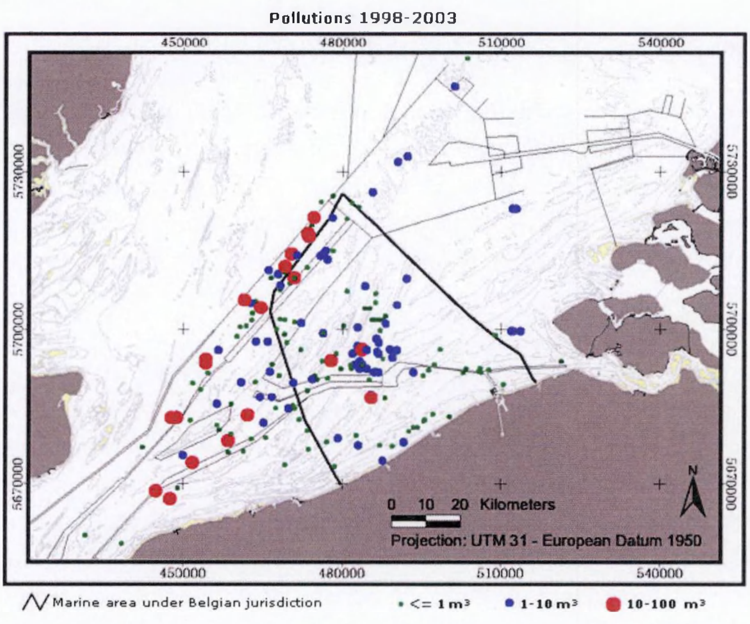

Figure 3.1: Observed oil spills in the North Sea ('98-'03) (MUMM, 2003)

3.3 ACCIDENTS AT SEA RESULTING IN SPILLS

3.3.1 Historical accident approach

3.3.1.1 Study area

The Belgian part of the North Sea covers approximately 3.600 km², which is only about a half percent of the total surface of the North Sea. The number of ships passing through the Channel is however estimated at 200 to 300.000 per year (www.mumm.ac.be). Based on the data of SRK (period 04/2003- 03/2004) approximately 57.000 voyages take place on the Belgian Part of the North Sea (BPNS) (see 2.2.2.). The risk of incidents on the BPNS is high.

In making an analysis of the historical accidents endangering the Belgian coast, one should take account of a wider scope than the Belgian Part of the North Sea only. The magnitude of the impact area of a hazardous spill will namely depend on the prevailing wind and water currents. Also the behaviour of the product will be important in estimating the risk of an incident. Oil spills will float, while spills with hazardous and noxious substances (HNS) will differ according to the behaviour of the HNS (float, sink, evaporate, dissolve).

Therefore the study area of the historical accident analysis is not limited to the BPNS, but includes the following neighbouring waters between (Figure 3.2):

- the eastern English-Dutch border from the Norfolk coast (UK) to Den Helder (Du);
- the western English-French border from South-Hampton (UK) to Cherbourg (Fr);

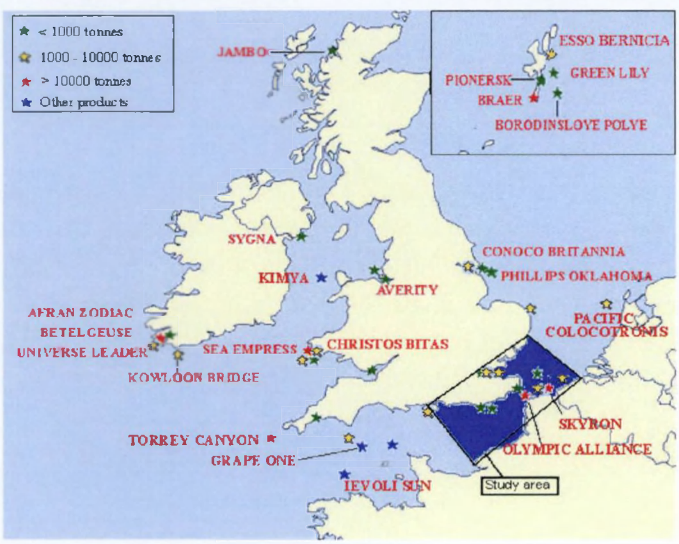

Figure 3.2: Study area of the historical accident analysis (http:www.le-cedre.be)

The borders are based on accident reports with consequences for the Belgian coastline respectively the accident with the ship Sherbro (1993) west of Cherbourg and the Anna Broere (1988) west of Ijmuiden.

3.3.1.2 Data sources

It was not the aim of the RAMA project to do a detailed historical incident analysis of the study area, but the performed analysis certainly gives an overview of the most important incidents for the BPNS during the last forty years. The incidents taken into account are given in Annex 3.1.

Annex 3.1: Incidents in the BPNS and neighbouring waters (period 1960-2003)

The historical analysis is based on following data sources:

- Shipping accidents with risk on environmental pollution by oil or HNS relevant for the Belgian Part of the North Sea since 1990 (Source: Mathematical Unit of the North Sea Mathematical Models (MUMM)).
- Accidental spills of sea transport around the British Isles since 1960 (http://www.le-cedre.fr).
- Chemical Spills at Sea – Case Studies. 11th meeting of the contracting parties to the Agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983. Bonn 99/3/6-E(L).
- Helcom Response Manual, Volulme 2: Case Studies of marine chemical incidents.
- Jacques, T.G. (1985). Scientific evaluations of an incident at sea involving a sunken ship carrying a dangerous cargo. Proceedings "Progress in Belgian Oceanographic Research": 343 – 357.
- Jacques, T.G. (1990). The Herald of Free Enterprise Accident: the Environmental Perspective. Oil & Chemical Pollution, 6: 55-68.
- Haelters, J., Kerckhof, F. & Stienen, E. (2003). Het Tricolor incident: de gevolgen voor zeevogels in de Belgische zeegebieden. 36 pp.

3.3.1.3 Historical accident analysis

During the last forty years 46 accidents happened with oil or HNS ships causing a potential environmental danger for the Belgian coast (Table 3.1). The majority of incidents (65%) occurred with oil tankers. On the BPNS 11 incidents resulting in oil spills were identified, while the share of HNS spills (#3) was much lower. In the neighbouring waters Great Britain is leading in oil spill accidents possibly affecting the Belgian coast (#10), while the Netherlands are responsible for the highest number of HNS spills (#9) (Table 3.1).

Table 3.1: Number of spill accidents affecting the BPNS

Maritime zone	HNS	Oil	Total
Belgium	3	11	14
France	2	5	7
Great Britain	2	10	12
Netherlands	9	4	13
Total	16	30	46

In total approximately 45.000 tons of hazardous material were released as a consequence of these accidents (Table 3.1). This figure should however be approached with a certain caution as for only 70% of the accidents the spilled quantity was known or mentioned in the data sources (HNS: 31%; oil: 90%). For the accidents taking place on the BPNS, quantity data were available for 67% of the cases of HNS and for 82% of the oil incidents. In Figure 3.3 the number of accidents causing oil or HNS spills is given for the studied period (1960-2003). As can be seen from Figure 3.3 the number of accidents before 1990 (#15) is much less than after 1990 (#31). Also the number of reported oil accidents is much higher than of those for HNS spills. The differences are probably due to a better reporting system for oil accidents.

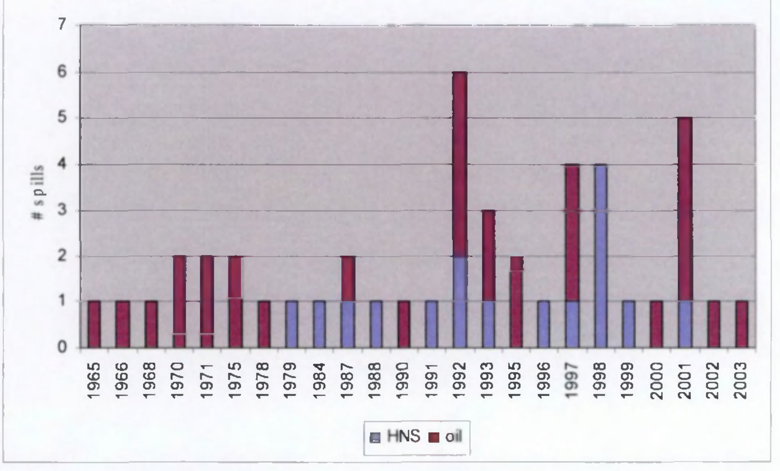

Figure 3.3: Number of accidents of oil/HNS during period 1960-2003

In Table 3.2 the total spilled quantity (ton) during the considered period and the average spilled quantity (ton) per accident are given for HNS and oil spills on the BPNS and in the neighbouring countries. It is clear that the average quantity per incident of spilled oil is much higher than in case of HNS spills. The high figure of the Netherlands is due to the Anna Broere incident (1988) which was carrying acrylonitrile (dissolve-evaporate) and dodecylbenzene (float). During the collision respectively 200 and 500 tons of the HNS products were spilled at sea.

Table 3.2: Spilled quantities (ton) of oil/ HNS on the BPNS and the neighbouring

	HNS		Oil	
Country	Total quantity	Avg quantity/ incident	Total quantity	Avg quantity/ incident
Belgium	24	12,00	5.610	623,33
France	0	No data	7.690	1.922,50
Great Britain	40	40,00	29.000	2.900,00
Netherlands	730	365,00	1.825	456,25
Total	794	158,80	44.125	1.634,26

In Figure 3.4 the spilled quantities of oil or HNS are given for the studied period (1960-2003). In contrast to the number of incidents, the spilled quantities decreased in the last decades. About 70% of the total spilled quantities are due to accidents that occurred before 1990.

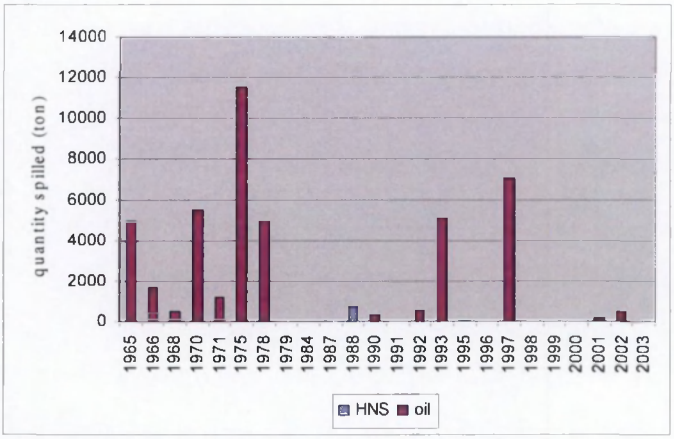

Figure 3.4: Spilled quantities of oil /HNS spills during period 1960-2003

More information about the spilled products is given in Table 3.3. The HNS products are classified according to MARPOL 73/78 Annex II (bulk) and Annex III (packaged).

For the bulk transport especially category B products will cause an environmental danger. Chemicals transported in bulk that are considered harmless to the marine environment if released in small quantities are referred to as Appendix III products. MHB stands for Materials Hazardous only transported in Bulk. For HNS in packaged form, the classification of the IMDG code (Marpol Annex III) is used. In this historical analysis following IMDG (sub-)classes are identified: poisonous gases, flammable liquids & solids, oxidizing substances, toxic substances, radioactive materials and corrosives.

Table 3.3: Identification of products spilled at sea

Class	Product	# incident	Spilled quantity (ton)
HNS (Bulk (B); Packaged (P))			
Cat. B (B)	acrylonitrile	1	200
App. III (B)	dodecylbenzene	1	500
MHB (B)	Coal	1	0
2,3 (P)	Chlorine	1	30
3 (P)	white spirit	1	0
4,1 (P)	fire lighters	1	0
4,3 (P)	Aluminium phosphate	1	0
5,1 (P)	sodium chlorate, chlorhydric acid	2	40
6,1 (P)	pesticides, sulfur-phosphine	2	0
7 (P)	uranium hexafluoride	1	0
8 (P)	detergent agent (alkyl phenol ether phosphate)	2	0
HNS (P)	mixture	3	24
Oil			
crude oil		5	18.700
fuel oil		5	10.500
gasoline		2	12.100
oil		18	2.825

Table 3.4 gives the causes of the accidents with oil, HNS transported in bulk or in packaged form since 1960 in Belgium and the relevant neighbouring waters. The causes of the incidents can be divided in (1) navigation risks usually following bad weather conditions, (2) internal event on-board the ship and (3) accidents during salvage operations. Finally also illegal discharges are taken into account. The main cause of accidents resulting in oil or HNS spills are collisions (54%), followed by incidents due to a false manoeuvre (11%).

Table 3.4: Causes of incidents resulting in oil/ HNS spills on the BPNS and neighbouring waters

	Oil	HNS (bulk)	HNS (packaged)	Total
Bad weather conditions				
loss of cargo			2	2
collision	21	1	3	25
grounding	1			1
sink	1			1
Incident on-board ship				
False manoeuvre	2		3	5
Faulty construction	1			1
Fire	1		1	2
Illegal discharge			1	1
Salvage	1			1
?	2		5	7

3.3.1.4 Conclusion

Despite the long-time series of historical accidents (1960-2003), a release assessment based on the historical approach is considered inadequate due to lack of relevant spill quantity data, difference in reporting trends which may lead to an underestimation of number of accidents, etc. Therefore in the next paragraph, a release assessment based on the MARCS model has been worked out for the Belgian Part of the North Sea based on the ship movement analysis described in 2.1.

3.3.2 Modelling approach (MARCS)

3.3.2.1 Scope and objectives

The scope of the approach is confined to the release of potentially toxic materials, such as crude oil, refined oil, bunker fuel oil and other materials, into the Belgian sector of the North Sea as a result of accidents to ships within the area. Accidents in port approach and port areas are excluded from the scope of this study. The shipping patterns and other input data are characteristic of shipping operations in the year 2003-2004. The risks evaluated are restricted to the risks to the marine environment due to the accidental release of cargo materials into the sea; human fatality and any other types of risk are excluded from the scope of this study. The risks to the marine environment are evaluated in terms of the frequency and quantity of material released into the environment. No dispersion modelling was performed. Finally, an assessment of residual risk acceptability is also excluded from the scope of this study.

The objectives are to determine:

- which cargo types, ship types or ship routes represent the highest risks (in terms of spill quantities) to the marine environment within Belgian waters. This helps to determine what are the most likely accidents which need to be planned for;
- where are the risks of spills greatest. This helps to determine what response options are feasible for the most likely accidents.

3.3.2.2 Risk assessment approach and methodology

INTRODUCTION

The risk assessment process can be summarised by the following points:

- what can happen, or hazard identification;
- how often will it happen, or accident frequency analysis;
- how bad will it be, or accident consequence analysis;
- where is it likely to happen, which supports accident contingency planning;
- what can be done to stop it, or risk reduction analysis;
- are risk reduction measures worth it, or cost benefit analysis;
- are the residual risks, after the application of the selected risk reduction measures (if any) acceptable, or risk acceptance criteria.

The project scope predominantly addresses the first 4 points and explicitly excludes consideration of the last 2 points. This chapter will focus on the hazard identification and the accident frequency analysis (release assessment)

HAZARD IDENTIFICATION

Analysis of historical ship accident data indicates that almost all open-water shipping losses (excepting causes such as war or piracy) can be categorised into the following generic accident types:

- ship-ship collision;
- powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the Exxon Valdez);
- Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the Braer);
- structural failure/ foundering whilst underway;
- fire/ explosion whilst underway;

- powered ship collision with fixed marine structures such as platforms or wind turbines (similar definition to powered grounding);
- drifting ship collision with fixed marine structures such as platforms or wind turbines (similar definition to drift grounding).

These generic accident types effectively represent the results of a high level marine transportation hazard identification (HAZID) exercise and are applicable for most marine transportation systems. This high level HAZID is considered sufficient for this project.

STUDY AREA

The study area is shown in Annex 3.2. This has been chosen so that all ship routes within 50nm (nautical miles) of the Belgian coast are included within the study area. This limit is selected because in previous marine projects performed by DNV it has been judged that 50nm is the highest credible drift distance for a mechanically disabled ship. It should be noted that any ships outside the defined study area cannot influence the marine risk analysis, or the risk results obtained.
The co-ordinates of the study area are between 52° and 51° north to south and between 2° 10' and 4° 15' west to east. The calculation resolution is 0.10 minutes (185m) by 0.20 minutes (236m); each small area defined by the calculation resolution is called a calculation location, see Annex 3.2.
Other inputs that contribute to the definition of the project study area, such as the location of offshore wind turbines and the location of the 5m depth grounding line, are described in Annex 3.3.

Annex 3.2: Description of the Marcs model

Annex 3.3: Data used by the Marcs model

RELEASE ASSESSMENT METHODOLOGY

DNV has developed the Marine Accident Risk Calculation System (MARCS) to perform this type of calculation. MARCS is described in detail in Annex 3.2, the input data used by MARCS is shown in Annex 3.3 and the results obtained are presented in Annex 3.4.

Annex 3.4: Risk results of the Marcs model

The following specific enhancements to MARCS have been made to meet the objectives (Annex 3.2):

- MARCS has been amended so that different cargo types can be transported by ships of the same ship type;
- MARCS has been amended to better represent areas of shallow water and the grounding behaviour of mixed lanes of deep and shallow draft ships.

This risk analysis methodology has been applied to the ship types, as described in more detail in Annex 3.3:

- Type 1: Oil (crude) tankers;
- Type 2: Chemical tankers and refined product tankers;
- Type 3: Gas tankers;
- Type 4: RoRo and Car carriers;
- Type 5: Bulk carriers;
- Type 6: General cargo and reefers;
- Type 7: Containers;
- Type 8: Passenger ships and other ships.

The cargo type carried by each vessel type is defined by the IMO Dangerous Goods classes as follows:

- Class 1: Marine Pollutants + Bulk Cat A;
- Class 2: Crude oils;
- Class 3: Bunkers and heavy fuels;
- Class 4: Other oil products;
- Class 5: Potential Marine Pollutants + Bulk Cat B & C;
- Class 6: Toxic Products (IMO-code 6.1 & 2.2);
- Class 7: Other identifiable dangerous goods or HNS;
- Class 8: Dangerous goods, with insufficient product information;
- Class 9: Empty but with leftover fractions from dangerous goods (dangerous goods assumed to be absent);
- Class 10: No dangerous goods (loss of this cargo type is excluded from the scope of this risk analysis).

In addition, it is assumed that all ships carry bunker fuel oil in their bunker fuel oil tanks (distinct from bunker fuel oil as a cargo).

It should be noted that whilst ship types such as RoRo/ Car carriers, General cargo, Container ships and Passenger/ other ships (Types 4, 6, 7 and 8 respectively) may be noted to carry dangerous goods (Classes 1 to 8 inclusive), they may not carry dangerous goods exclusively. That is a portion of the cargo carried may be non-dangerous. In this study it has been assumed that all cargo carried is of the dangerous goods class specified. This is in order to ensure that the estimated risk levels are not under-predicted.

RELEASE ASSESSMENT RESULTS

The following types of results are presented in this section and in Annex 3.4:

- an analysis of traffic data in terms of transits per day for each ship type (as defined within any one calculation location according to the Key shown in Table 3.5). See Figure 3.6 as an example.
  - The total number of vessel-miles within the calculation area and within each defined sub-areas (see Figure 3.5). The sub-areas are defined to assist the additional analysis. See Table 3.9 as an example.
- an analysis of total accident frequency (frequency of serious accidents per year but not necessarily involving cargo or bunker spill into the sea) in terms of:
  - The frequency of all accidents per year (as defined within any one calculation location according to the Key shown in Table 3.6). See Figure 3.7 as an example.
  - The total number of accidents per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 3.5). The sub-areas are defined to assist the additional analysis. See Table 3.10 as an example. The accident types in tables similar to Table 3.10 are abbreviated as follows:

    ~ Collis = ship-ship collision;

    ~ Struc = Structural failure or foundering whilst underway;

    ~ Fex = Fire or explosion whilst underway;

    ~ Pgrd = Powered grounding;

    ~ Dgrd = Drift grounding;

    ~ Pplat = Powered collision with offshore obstacles such as wind turbines;

    ~ Dplat = Drifting collision with offshore obstacles such as wind turbines.
- an analysis of cargo spilling accident frequency (frequency of cargo spilling accidents per year) in terms of:
  - The frequency of all cargo spilling accidents per year (as defined within any one calculation location according to the Key shown in Table 3.7). See Figure 3.8 as example.
  - The total number of cargo spilling accidents per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 3.5). See Table 3.11 and Table 3.12 as an example.
- an analysis of cargo spilling accident risk (weight of cargo spilled into the sea per year) in terms of:
  - The cargo spilling risk of all accidents per year (as defined within any one calculation location according to the Key shown in Table 3.8). See Figure 3.9 as an example.
  - The cargo spill risk per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 3.5). The sub-areas are defined to assist the additional analysis to be performed by Ecolas. See Table 3.13 as an example.

Note that in this report the terms "cargo spill" or "cargo risk" also cover bunker fuel oil releases, though strictly bunker oil is not cargo. See Annex 3.3 II for the definition of the terms study area and calculation location.

Table 3.5 Key to Ship Transit Plots

Colour	Transit Frequency (movements per day within each calculation location)
	0,5 to 1
	1 to 5
	5 to 10
	10 to 50
	50 to 100
	> 100

Table 3.6 Key to Accident Frequency Plots (total accidents)

Colour	Accident Frequency (accidents per year within each calculation location)
	1,0 E-08 – 1,0 E-06
	1,0 E-06 – 1,0 E-05
	1,0 E-05 – 1,0 E-04
	1,0 E-04 – 1,0 E-03
	1,0 E-03 – 1,0 E-02
	> 1,0 E-02

Table 3.7 Key to Cargo Spilling Accident Frequency Plots

Colour	Accident Frequency (accidents per year within each calculation location)
	1,0 E-09 - 1,0 E-08
	1,0 E-08 - 1,0 E-07
	1,0 E-07 - 1,0 E-06
	1,0 E-06 - 1,0 E-05
	1,0 E-05 - 1,0 E-04
	> 1,0 E-04

Table 3.8 Key to Accident Risk Plots

Colour	Cargo Spill Risk (tonnes cargo spilled per year within each calculation location)
	1,0 E-07 - 1,0 E-06
	1,0 E-06 - 1,0 E-05
	1,0 E-05 - 1,0 E-04
	1,0 E-04 - 1,0 E-03
	1,0 E-03 - 1,0 E-02
	> 1,0 E-02

Note the terms study area (the total area under study), the study sub-areas (as defined in Figure 3.5) and the calculation location (each "pixel" of the calculation as determined by the calculation resolution) are described further in Annex 3.2 & Annex 3.3.

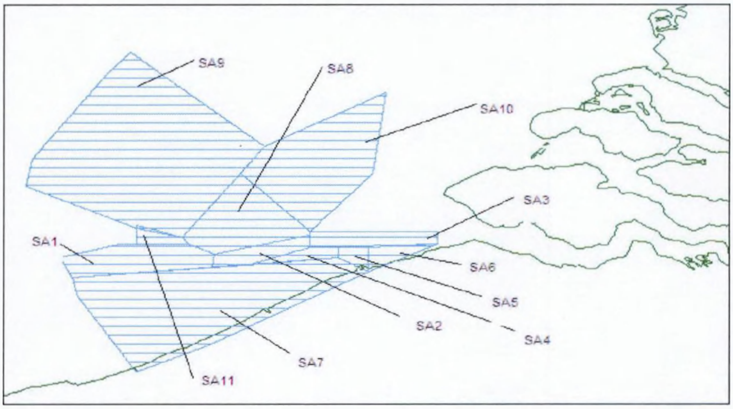

Figure 3.5: Definition of Sub-Areas defined to aid the Analysis

3.3.2.3 Summary of risk results and discussion

This section presents a summary of the results of the risk analysis for shipping in Belgian waters. It also discusses the significance of the results. The complete risk results are shown in Annex 3.4.

ANALYSIS OF TRAFFIC DATA

For a detailed analysis of the traffic data reference is also made to 2.2. As for the accident analysis the basic unit is the number of vessel miles per year a brief additional analysis is made here. Table 3.9 shows the analysis of the total traffic data (number of vessel miles per year) that is used as the basis of the risk results in this study.

Table 3.9: Analysis of Total Traffic Data (nautical miles per year)

	All Ships	Oil Tanker	Chem Tanker	Gas Tanker	RoRo	Bulk Carrier	General Cargo	Containe r	Other
All Cargo	2.067.631	1.36.564	44.992	79.280	833.581	94.892	428.534	264.258	185.529
Class 1	2.625	421	288	123	526	28	322	888	28
Class 2	6.278	6.135	10	133	0	0	0	0	0
Class 3	2.636	2.112	443	20	18	0	0	15	28
Class 4	73.870	58.732	9.844	3	1.152	3.604	372	163	0
Class 5	27.422	10.053	4.079	5.405	3.293	526	1.637	2.394	35
Class 6	51.726	3.290	2.032	9.504	17.186	124	4.497	14.807	284
Class 7	173.583	20.857	16.819	58.673	34.147	2.797	12.819	26.460	1.011
Class 8	185.366	7.734	3.264	15.688	56.779	6.386	35.631	59.213	671
Class 9	2.987	2.154	638	141	54	0	0	0	0
Class 10	1.541.138	28.478	14.615	84.892	639.210	155.019	339.521	188.863	90.541

Table 3.9 indicates that a total of 2.07 million ship-miles are travelled within the defined study area per year. Assuming an average ship speed of 10knots, this corresponds to an average of 24 ships in the study area at any one time. Table 3.9 shows also that the most common vessel types are RoRos, General Cargo and Container Ships respectively. The most common hazardous cargo (excluding Class 10 – non-hazardous cargo) is Class 8 (Dangerous goods, with insufficient product information), followed by Class 7 (Other identifiable dangerous goods or HNS) and Class 4 (Other oil products). The fact that the most common hazardous cargo class has insufficient product information is a potentially significant uncertainty when attempting to derive cargo spill response strategies. Finally Table 3.9 indicates that there are only a very small number of unloaded vessel-miles included in the study. This observation may indicate that unloaded traffic is not fully represented in the risk estimates. Unloaded ships are important because they carry bunker fuel oil and they may collide with laden ships causing cargo spill.

Figure 3.6 shows the geographical distribution of all traffic types. Figure 3.6 clearly indicates the main shipping lanes into the 3 main ports of Oostende, Zeebrugge and Antwerpenen. As expected, the main shipping lanes have intensive traffic flows of greater than 10 ships per day within each calculation location.

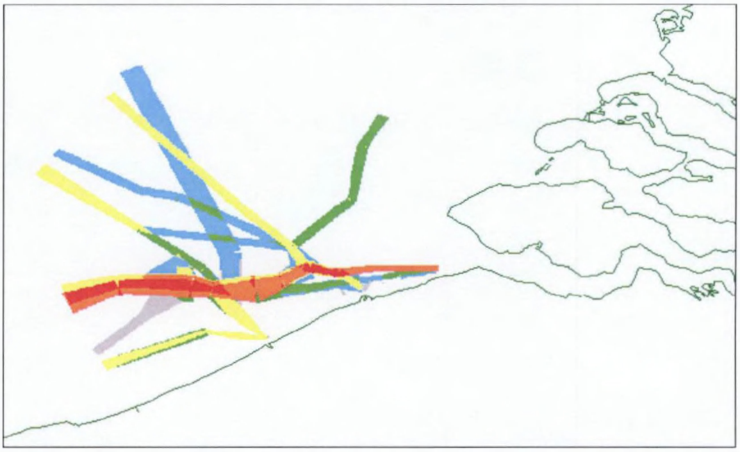

Figure 3.6: Total Traffic Data in the Study Area (see Table 3.5 for key)

ACCIDENT FREQUENCY RESULTS

Table 3.10 shows the total accident frequency results (annual frequency of serious accidents to each vessel type independent of the cargo type transported).

Table 3.10: Total Accident Frequency Results in the Study Area as a function of accident type and ship type (per year)

	Total	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
Collis	1,25E+00	9,92E-02	3,29E-02	5,58E-02	4,01E-01	6,96E-02	3,30E-01	1,78E-01	8,73E-02
Struc	9,08E-02	2,56E-03	8,25E-04	1,48E-03	4,20E-02	4,17E-03	2,58E-02	1,14E-02	2,63E-03
FEX	2,36E-02	4,55E-03	1,47E-03	2,64E-03	6,89E-03	7,79E-04	4,24E-03	1,86E-03	1,14E-03
PGrd	1,20E+01	1,04E+00	3,25E-01	3,31E-01	4,82E+00	7,04E-01	1,34E+00	2,30E+00	1,12E+00
DGrd	5,41E-01	4,35E-02	9,56E-03	1,42E-02	1,34E-01	4,12E-02	1,48E-01	1,50E-01	4,75E-04
PPlat	6,41E-01	6,95E-02	1,36E-02	2,25E-02	1,96E-01	5,91E-02	1,22E-01	9,35E-02	6,38E-02
DPlat	1,81E-02	5,81E-03	1,58E-03	1,66E-03	1,29E-03	7,15E-03	3,37E-04	1,96E-04	1,25E-04
Total	1,45E+01	1,27E+00	3,85E-01	4,29E-01	5,60E+00	8,86E-01	1,97E+00	2,73E+00	1,28E+00

Figure 3.7 shows the geographical distribution of total accident frequency.

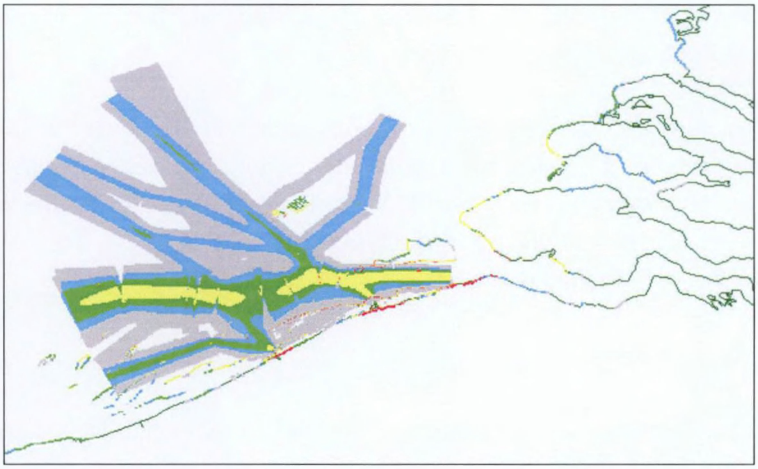

Figure 3.7: Total Accident Frequency Results in the Study Area (per year) (See Table 3.6 for key)

Table 3.10 indicates a total accident frequency of 14,5 serious accidents per year. The majority of these accidents results from powered grounding accidents (12 per year). This is considered to be an over-estimate for the following reasons:

- the lane ends are located very close to, or over, the grounding lines at the port approaches (Oostende, Zeebrugge), and at similar locations. In the model there will be a significant grounding frequency whenever a lane centreline is aligned against a grounding line then. In reality ships approach these ports down narrow channels of sufficient depth to allow safe navigation. These deep water channels cannot be fully represented in the model at the resolution chosen (which is necessary to give the total area coverage required);
- the ground type is predominantly soft. It is expected there to be significant under-reporting of powered grounding with sand/ mud banks in the area. In reality ships that ground will reverse off without reporting, in many cases.

The frequency of powered and drifting collisions with wind turbines seems also a little high. This is probably due to the fact that the offshore wind farm arrays have not yet been constructed. Once they are in place, the shipping lanes will be adjusted to provide greater separation on average (as there is plenty of sea room) and the accident frequency will consequently reduce. The frequency of the other accident types appears to be reasonable, though a detailed comparison with historical accident rates has not been performed to confirm this judgement.

The ship types most often involved in accidents reflects the frequency of ship-miles within the study area. Thus RoRos are involved in about one third of the total accident frequency, and container ships and general cargo ships are also significant ship type contributors to the total frequency of serious accidents.

Figure 3.7 indicates that the frequency of serious accidents is concentrated in the main shipping lanes (mainly ship-ship collision accidents) and at coastal locations near the main ports. At least a portion of these high accident frequencies on the coastline or grounding line, due to mostly powered grounding accidents, is considered to be unrealistic for the two reasons given above.

The frequency of accidents could be reduced by:

- extending the area where pilotage is required, or extending the classes of ships that required pilotage;
- providing a radar surveillance supervised vessel traffic service area;
- extending or enforcing traffic separation schemes.

These 3 measures should reduce the frequencies of collision and powered grounding accident types (the main contributors to the overall accident frequency).

Cargo spilling accident frequency results

Within the scope of the RAMA project the main interest lies in thee accident frequency resulting in a cargo spill. Table 3.11 shows the cargo spilling accident frequency results (frequency of accidents with cargo spill).

Table 3.11: Cargo Spilling Accident Frequency Results in the Study Area as a function of ship type and cargo type (per year)

	Total	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
Collis	2,71E-02	7,33E-03	2,14E-03	3,48E-03	5,79E-03	3,83E-04	1,73E-03	6,06E-03	2,25E-04
Struc	1,72E-03	2,09E-04	5,90E-05	1,18E-04	6,29E-04	2,85E-05	1,71E-04	4,89E-04	1,17E-05
FEX	8,41E-04	3,19E-04	9,00E-05	2,10E-04	1,03E-04	5,32E-06	2,80E-05	8,04E-05	5,10E-06
PGrd	2,49E-01	8,26E-02	2,21E-02	1,81E-02	4,31E-02	3,93E-03	6,10E-03	6,98E-02	3,12E-03
DGrd	1,26E-02	3,49E-03	6,53E-04	7,75E-04	1,92E-03	2,30E-04	9,55E-04	4,61E-03	1,32E-06
PPlat	1,46E-02	5,55E-03	9,47E-04	1,23E-03	2,83E-03	3,20E-04	6,03E-04	2,86E-03	2,87E-04
DPlat	7,13E-04	4,55E-04	1,07E-04	8,76E-05	1,66E-05	3,85E-05	1,63E-06	5,71E-06	8,74E-07
Total	3,06E-01	1,00E-01	2,61E-02	2,40E-02	5,44E-02	4,94E-03	9,59E-03	8,39E-02	3,65E-03

Table 3.11 shows that the total frequency of (dangerous goods) cargo spilling accidents is 0,3 per year (a cargo spilling accident once every 3 years). A detailed comparison with historical accident rates for the Belgian Part of the North Sea (14 accidents in 40 year) confirms this figure (3.3.1.3).

This significant reduction in cargo spilling accident frequency (Figure 3.8) compared to the accident frequencies quoted in Table 3.10 above (14,5 per year) is due to:

- many ships carry cargo classes 9 and 10 which are non-dangerous goods;
- not all accidents result in cargo spill. In particular, double hulled tanker ships in ballast (unladen) and double hulled tankers are less likely to spill their cargo if involved in an accident;
- the sea bottom is designated as soft (mud or sand). Drift or powered groundings on such material do not usually result in cargo spills.

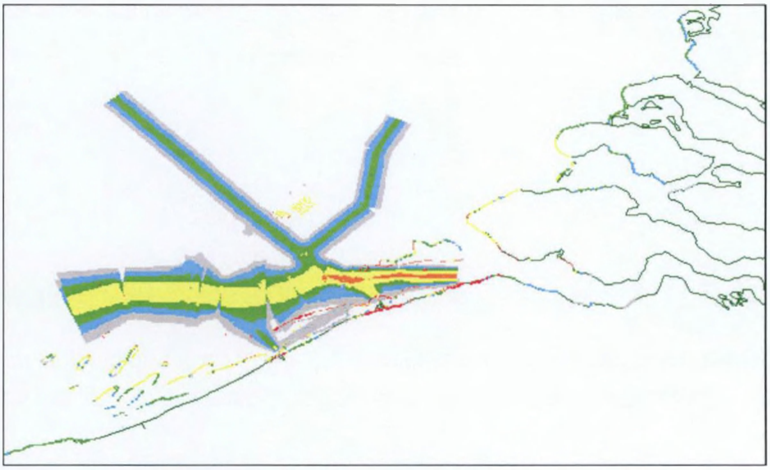

Figure 3.8: Cargo spilling accident frequency results in the study area (see Table 3.7 for key)

Similar to Figure 3.7, the majority of the cargo spilling accident frequency is located in the main shipping lanes with a main risk in the Scheur. Note in particular the significant reduction of cargo spilling accident frequency on the coastal and grounding line calculation locations. This results from the soft (sand or mud) coastal types as described above.

Table 3.12 provides an analysis of the cargo spilling accident frequency as a function of ship type and cargo class. It shows that Class 8 cargos are spilled most frequently (0,079 per year, or one spill about every 13 years). Class 4, Class 7 and bunker fuel oils are the next 3 most likely spilled materials respectively.

Table 3.12: Cargo Spilling Accident Frequency as a function of ship type and cargo class (per year)

	Total	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
Class 1	1,41E-03	2,16E-04	1,61E-04	0,00E+00	2,38E-04	0,00E+00	3,45E-05	7,50E-04	8,72E-06
Class 2	5,89E-03	5,88E-03	0,00E+00	1,62E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Class 3	6,41E-03	4,92E-03	1,43E-03	0,00E+00	1,21E-05	0,00E+00	0,00E+00	0,00E+00	5,77E-05
Class 4	6,96E-02	5,48E-02	1,21E-02	0,00E+00	9,76E-06	2,51E-03	8,52E-05	1,13E-04	0,00E+00
Class 5	1,40E-02	7,12E-03	1,86E-03	1,18E-03	1,38E-03	1,49E-04	3,13E-04	1,92E-03	3,91E-05
Class 6	2,31E-02	1,78E-03	9,31E-04	2,76E-03	6,75E-03	0,00E+00	1,58E-04	1,02E-02	5,95E-04
Class 7	6,48E-02	1,02E-02	5,04E-03	1,60E-02	1,28E-02	7,65E-04	1,90E-03	1,66E-02	1,56E-03
Class 8	7,90E-02	5,05E-03	1,94E-03	1,31E-04	2,44E-02	6,98E-04	5,55E-03	4,05E-02	7,83E-04
Class 9	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Class 10	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Bunker	4,22E-02	1,00E-02	2,62E-03	3,89E-03	8,89E-03	8,12E-04	1,55E-03	1,38E-02	6,02E-04
Total	3,06E-01	1,00E-01	2,61E-02	2,40E-02	5,44E-02	4,94E-03	9,59E-03	8,39E-02	3,65E-03

CARGO SPILL RISK RESULTS

The following results, which are similar to those presented in the previous section, are presented below:

- Table 3.13 shows the predicted cargo spill risk results (tonnes of cargo spilled/year)
- Figure 3.9 shows the geographical distribution of cargo spill risk results;
- Table 3.14 shows the predicted cargo spill risk as a function of the cargo class.

Table 3.13: Cargo Spill Risk Results (tonnes dangerous cargo spilled per year) in the Study Area

	Total	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
Collis	1,14E+02	3,34E+01	4,09E+00	7,41E+00	1,41E+01	5,16E+00	5,45E+00	4,41E+01	4,01E-01
Struc	1,50E+01	1,71E+00	2,04E-01	5,23E-01	3,25E+00	7,94E-01	1,13E+00	7,34E+00	3,73E-02
FEX	4,48E+00	2,08E+00	2,48E-01	6,60E-01	3,79E-01	1,05E-01	1,32E-01	8,56E-01	1,16E-02
PGrd	1,19E+03	2,93E+02	2,96E+01	5,51E+01	1,35E+02	6,05E+01	2,34E+01	5,83E+02	6,71E+00
DGrd	7,25E+01	1,67E+01	1,13E+00	2,37E+00	6,76E+00	3,58E+00	3,72E+00	3,83E+01	4,15E-03
PPlat	6,98E+01	2,48E+01	1,66E+00	2,94E+00	8,99E+00	4,98E+00	2,25E+00	2,37E+01	5,19E-01
DPlat	3,15E+00	2,03E+00	1,84E-01	2,23E-01	4,92E-02	6,08E-01	6,18E-03	4,75E-02	1,44E-03
Total	1,47E+03	3,74E+02	3,71E+01	6,92E+01	1,68E+02	7,58E+01	3,61E+01	6,97E+02	7,68E+00

Table 3.13 shows that the average quantity of dangerous goods predicted to be spilled in the study area is 1.470 tonnes per year. The main accident types that contribute to the spill risk is powered grounding (1.190 tonnes per year) followed by collision (114 tonnes per year). Powered grounding results are likely to be over-predicted for the reasons given above. The main ship type that contributes to spill risk is container ships: 583 tonnes per year for powered groundings and 44,1 tonnes per year for collisions. It should be reminded however that during analysis container ships were assumed to be fully loaded with the class of dangerous goods specified (see 3.3.2.2 – Release assessment methodology); this is likely to be a conservative assumption.

As for the figures presented above, the location of the cargo spill risk reflects the main shipping lanes. The higher proportion of red and orange colouration probably reflects the scale of the plot selected (Table 3.8), rather than a high risk level (red indicates greater than 0,01 tonnes/year spilled in a calculation location measuring 185m by 236m).

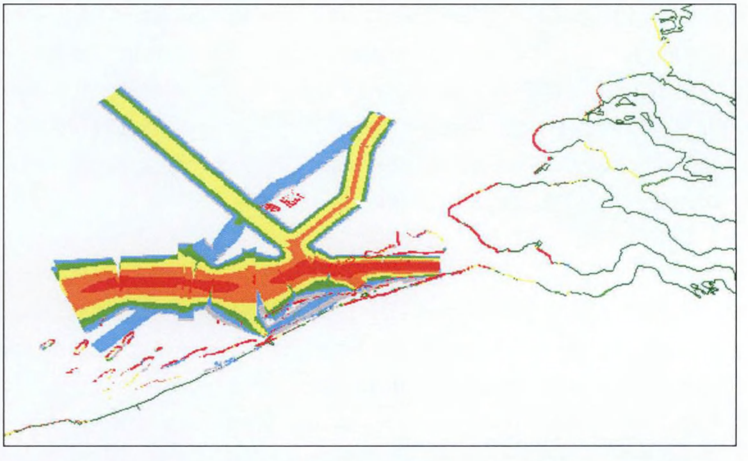

Figure 3.9: Accident Risk Plot: Total Cargo Spill Risk in the Study Area (see Table 3.8 for key)

Table 3.14: Cargo Spill Risk as a function of ship type and cargo class (tonnes)

	Total	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
Class 1	1,23E+01	6,50E-01	3,10E-01	0,00E+00	1,15E+00	0,00E+00	2,46E-01	9,92E+00	5,32E-03
Class 2	1,01E+02	1,01E+02	0,00E+00	9,86E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Class 3	8,02E+00	7,26E+00	6,33E-01	0,00E+00	8,84E-02	0,00E+00	0,00E+00	0,00E+00	3,52E-02
Class 4	2,46E+02	1,78E+02	1,56E+01	0,00E+00	1,79E-02	5,19E+01	1,84E-01	5,49E-01	0,00E+00
Class 5	6,80E+01	3,46E+01	3,40E+00	1,43E+00	5,10E+00	2,53E+00	1,26E+00	1,94E+01	2,32E-01
Class 6	1,50E+02	3,95E+00	2,15E+00	1,95E+01	2,45E+01	0,00E+00	7,17E-01	9,82E+01	1,18E+00
Class 7	3,21E+02	2,37E+01	8,96E+00	4,71E+01	5,03E+01	1,15E+01	7,34E+00	1,69E+02	2,84E+00
Class 8	5,39E+02	2,06E+01	5,70E+00	9,00E-02	8,48E+01	8,73E+00	2,58E+01	3,90E+02	3,28E+00
Class 9	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Class 10	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Bunker	2,03E+01	4,25E+00	4,21E-01	1,02E+00	2,48E+00	1,12E+00	5,26E-01	1,03E+01	1,14E-01
Total	1,47E+03	3,74E+02	3,71E+01	6,92E+01	1,68E+02	7,58E+01	3,61E+01	6,97E+02	7,68E+00

Table 3.14 shows that the highest cargo spill risk results from Class 8 cargos followed by Class 7, Class 4 and bunker oil respectively. Considering the two most dangerous cargo classes Class 1 (MP + cat. A) and Class 2 (crude oils) the cargo spill risk are respectively 12,3 and 101 tonnes per year. The highest risk of Class 1 products is due to the container traffic (9,92 tonnes per year). The cargo spill risk for crude oils is like expected from the result of accidents with oil tankers.

General discussion

In correspondence with most marine risk analysis projects, the results presented above are mostly controlled by the number of vessel miles per year included in the ship traffic data. Thus in Table 3.9 RoRo, General cargo and Container ships have the highest number of annual vessel-miles in the study area and these ship types generally contribute most to the frequency of accidents, the frequency of cargo spilling accidents and the cargo spill risk. Similarly, cargo Class 8, 7 and 4 are the most commonly transported cargo types in Table 3.9 and these cargo classes are also highlighted in the risk results.

When interpreting these results it is important to consider the following factors:

- the relative risk results quoted do not consider the relative ecotoxicities or degree of persistence in the marine environment of the different cargo classes;
- *two important, unverified assumptions* underlie the high risk results predicted to arise from RoRo, General cargo and Container ships (see Annex 3.2, Section I.6):
  - In the absence of better data, the liquid cargo outflow models, derived for oil tankers, have been assumed to apply to these ship types.

- These ships are assumed to carry exclusively dangerous goods of the specified class.

Expert judgement based methods have focused on oil tankers and similar vessels as the major source of concern regarding marine pollution for good reasons; despite the above analysis result it would be unwise to neglect these potential pollution sources from any spill contingency planning activity.

3.3.2.4 Conclusion

A marine risk analysis of the BPNS has been performed. The results show:

- that risk parameters, such as accident frequency (accidents per year) and cargo spill risk (tonnes of cargo spilled per year) tend to follow the number of vessel-miles defined in the shipping pattern input data. The quality of this input data is therefore of critical importance to the output from this risk analysis;
- the risk reduction measures that are predicted to be effective are those that may reduce the frequency of powered grounding and collision accident types, such as pilotage, vessel traffic services and traffic separation schemes;
- the total frequency of dangerous goods spilling accidents is once every 3 years;
- the highest risk is predicted to arise from spillage of Class 8 from containers
- Cargo spill risks of the two most dangerous product classes vary between 12,3 tonnes per year (Class 1: MP + cat A.) and 101 tonnes per year (Class 2: crude oils).

4 DESCRIPTION OF THE EFFECTS OF THE INCIDENTS

The analysis of probability of occurrence of incidents and the release assessment was done for 8 different ship types, 7 types of accidents and 10 cargo types (see 3.3.2). A discussion of the effects of all these scenarios is unfeasible in the time frame of the project and a selection of incident scenarios is therefore unavoidable. Effects for each of the identified scenarios will be described. These will take into account the type of incident, but also the location where the impacts will take place.

Impact analysis will be firstly aimed at estimating the impact on different communities. Focus will be directed towards birds, fish, marine mammals and benthic organisms. As far as possible the ecosystem approach will be guarded during this impact analysis. If an ecosystem approach is not feasible for certain incidents, indicator species will be used to estimate the impact. To be able to assess correctly the impacts, a sensitivity-analysis will be carried out that includes besides biological values also socio-economical parameters.

4.1 SELECTION OF INCIDENT SCENARIOS

The selection of incident scenarios can be done on several criteria:

- Which ship type gives cause to the highest frequency of accidents?
- Which is the most occurring type of accident?
- Which type of accident gives the highest chance on a spill?
- Which cargo type is most frequently spilled at sea?
- Which cargo type is spilled in the highest quantities?
- Which spilled cargo poses the highest environmental danger?
- Where is the most sensitive area?

Based on the accident analysis and the environmental risk of the cargo types, the following incident scenarios have been selected for further effect analysis:

- worst case scenario of an oil spill at the BPNS;
- worst case scenario of a HNS spill at the BPNS.

4.1.1 Scenario 1: Worst case scenario of an oil spill at the BPNS

In this scenario a worst case scenario of an oil spill happening at the Belgian Part of the North Sea (BPNS) is worked out. Oils transported at the BPNS were classified into three categories: crude oils (cargo type 2), bunkers & heavy fuel (cargo type 3) and other oil products (cargo type 4). In terms of environmental risk the crudes are the most hazardous products. Scenario 1 will therefore deal with an oil spill of cargo type 2.

The cargo spilling accident frequency of cargo type 2 estimated for the whole BPNS is about 0,006 accidents per year or once every 170 year. This figure includes all accident types, ship types and subareas. A closer look to the individual subarea frequencies reveals that approximately 70% of these accidents take place in subarea SA3 (entrance to the Scheldt estuary). Furthermore from the analysis we can conclude that more than 99% of the spill accidents are caused by oil tankers. As already mentioned powered groundings are the main cause of accidents in general. They are responsible for about 80% of the cargo type 2 spills. When the powered groundings are excluded from the analysis, we observe a high share of collisions (31%), powered platforms (35%) and drift groundings (28%). If only subarea SA3 is considered the percentage of collisions (48%) increases at the expense of the other two mentioned accident types.

The spill quantity of crudes per year for the whole BPNS is estimated at 101 ton. If the total cargo spilling accident frequency is taken into account this means about 17.175 ton crude oil per accident. The spilled quantity of only the powered groundings (16.866 ton/acc) and the spilled quantity caused by all the other types of accidents (18.342 ton/acc) (over all ship types) are comparable, despite the large difference in cargo spilling accident frequency respectively every 214 years and 822 years.

To summarize scenario 1 can be described as follows:

- ship type: Oil tanker
- cargo type: CT 2 (crude oils)
- cargo spilling accident frequency: 0,00589 accident/yr (or every 170 years)
- spill quantity per accident: 17.000 ton/accident

4.1.2 Scenario 2: Worst case scenario of a HNS spill at the BPNS

Due to the different behaviour of oil spills in comparison to HNS spills a distinction has been made between both. Similar to scenario 1, a worst case scenario of a spill of hazardous and noxious substances has been worked out for the BPNS.

Hazardous and noxious substances (HNS) transported at the BPNS were classified into six categories with increasing environmental danger. Cargo type 1 represents the highest risk namely marine pollutants (packaged) and the category A products (bulk) and was therefore chosen for this scenario.

The cargo spilling accident frequency of cargo type 1 estimated for the whole BPNS is about 0,001 accidents per year or once every 710 year. This figure includes all accident types, ship types and subareas. Just like in scenario 1, most accidents (>50%) take place in subarea SA3 (entrance to the Scheldt estuary) due to powered groundings (>80%). The majority of accidents (between 44% - 53% depending if the powered groundings are included or not) are due to accidents with container ships. If the powered groundings are excluded from the analysis the main cause of accidents are collisions (42% in whole BPNS or 63% in SA3).

The spill quantity of cargo type 1 products per year for the whole BPNS is estimated at 12,3 ton. If the total cargo spilling accident frequency is taken into account this means about 8.722 ton per accident, so approximately half of the quantity calculated for crudes. Again the spilled quantity is comparable if we only consider the powered groundings (8.920 ton/acc) or the other types of accidents (7.824 ton/acc) (over all ship types) despite the large difference in cargo spilling accident frequency respectively every 82 years and 4.000 years. Again, it has been assumed that container ships are fully loaded with the class of dangerous goods specified (3.3.2.2. Release assessment). This is likely to be a conservative assumption. In reality chemical tankers/containers will transport a mixture of products which can vary from extremely harmful to almost harmless. Furthermore the spill quantity will be less because the majority of the products are transported in containers which do not necessarily leak when spilled at sea. Statistical models about the proportion of containers that will be damaged and the quantity of harmful substances spilled at sea are currently not available. As a worst case scenario is taken as point of departure the total amount of cargo spill quantity will be considered and a mixture of cargo type 1 products will be taken.

The selection of the cargo type 1 product for the worst case scenario of HNS has been based on the frequency of transport, the average quantity per voyage transported, the toxicity of the product (LC50) and the behaviour of the product. Three products were eligible for the scenario namely chlorine, acetone cyanohydrin and calciumcyanide. As acetone cyanohydrin is for >98% soluble in water (Mackay model) this product was finally selected.

To summarize scenario 2 can be described as follows:

- ship type : Containers
- cargo type : CT 1 (MP, cat A.): acetone cyanohydrin
- cargo spilling accident frequency: 0,00141 accident/yr (or every 710 years)
- spill quantity per accident: 8.700 ton/accident

4.2 ECOSYSTEM APPROACH

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Application of the ecosystem approach will help to reach a balance of the three objectives of the Convention on Biological Diversity (CBD): conservation, sustainable use, and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. This focus is consistent with the definition of "ecosystem" provided in Article 2 of the CBD. The approach also recognizes that humans, with their cultural diversity, are an integral component of ecosystems. Furthermore the ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. (UNEP, 2000)

The basic elements in the ecosystem approach are presented in Figure 4.1.

According to principle 5 of the ecosystem approach it is of greater significance for the long-term maintenance of the biological diversity of an ecosystem like the North Sea to conserve and, where appropriate, to restore the interactions and processes within species, among species and between species and their abiotic environment than simply protect species.

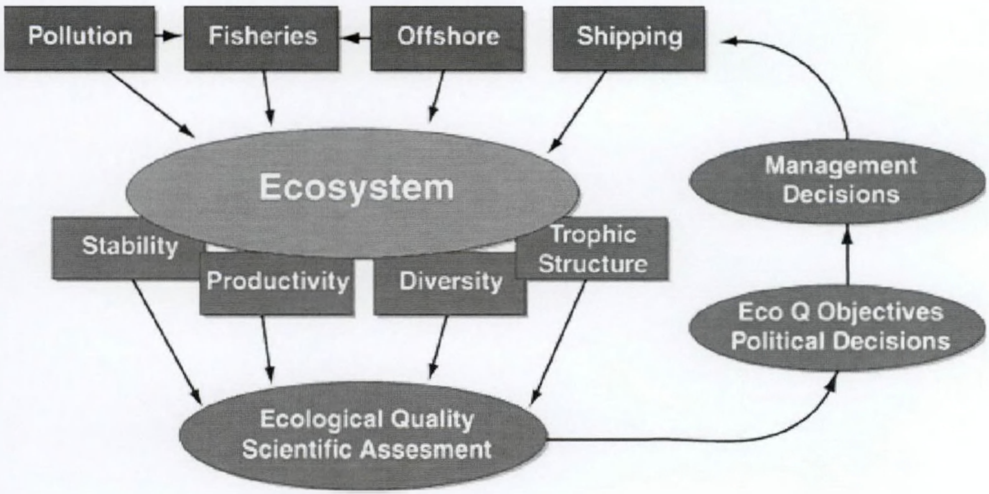

Figure 4.1: Basic elements in the ecosystem approach

Figure 4.1 indicates that shipping and pollution are two key elements affecting the ecosystem of the North Sea. The ecosystem itself is described by four main components: stability, productivity, diversity and trophic structure. For the RAMA project the impact analysis will focus on the effects of shipping and related pollution on the ecosystem with emphasis on the two latter components.

We are aware of the simplification of the following description compared with the complexity of the North Sea, but it should be detailed enough as basis for the effect analysis of the RAMA project.

4.2.1 Trophic structure

In Figure 4.2 a schematic overview is given of the food web of the North Sea. Different trophical levels can be distinguished with man on top of the food web and the primary producers on the basis. A negative impact on one of the levels will have its consequences on the rest of the food web. The effect analysis will focus on the (macro)benthic, fish, bird and mammal component of the ecosystem.

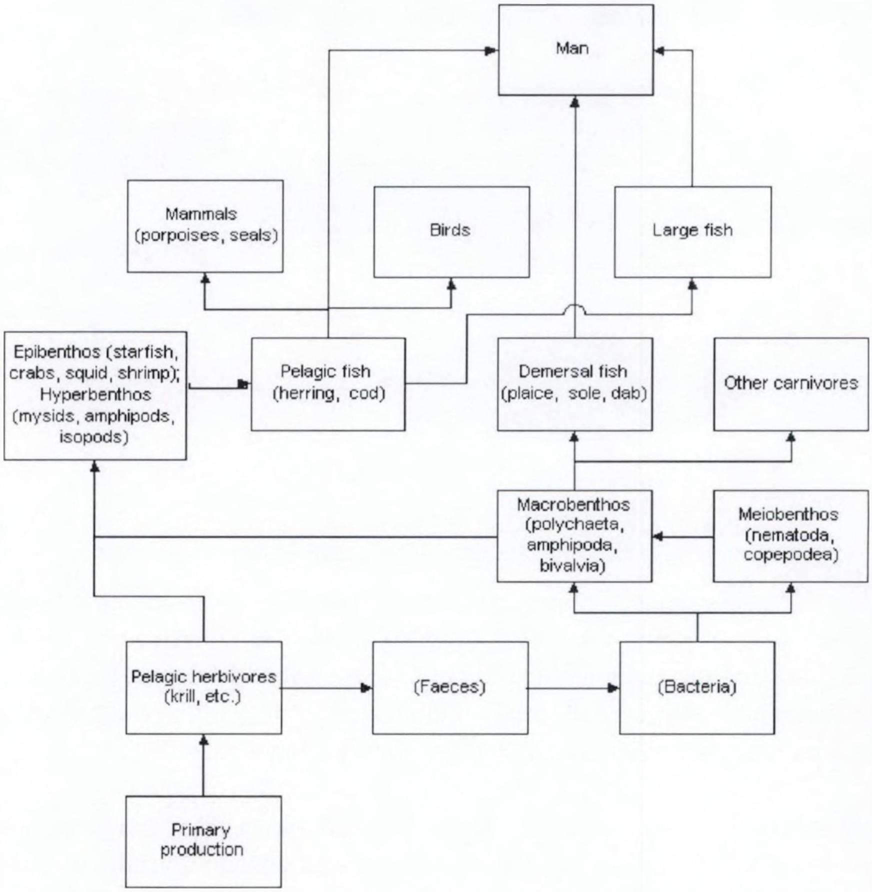

Figure 4.2: Food web of the North Sea

4.2.2 Diversity along the Belgian Part of the North Sea

The ecosystem approach focuses rather on the interactions and processes within species, among species and between species and their abiotic environment than on the individual species. The basic units of the description of the diversity of the ecosystem and of the effect analysis are therefore the "communities".

4.2.2.1 Benthos

Due to its ecological importance and obvious presence within the marine ecosystem, the macrobenthos is the most intensively investigated marine (benthic) ecosystem component. Macrobenthos is the infauna retained on a 1 mm sieve. The most important organisms are bivalves, polychaete worms and amphipods, next to infaunal echinoderms, decapods, gastropods and oligochaetes that are less representative organisms. The dominance of the polychaetes increases in off shore direction, while the opposite trend can be seen for the bivalves. Two gradients can be distinguished on the Belgian part of the North Sea: a decreasing biodiversity along the west-east gradient and a decreasing density and diversity along the onshore-offshore gradient. So in general the western coastal zones are the most diverse zones for the macrobenthos (Cattrijsse & Vincx, 2001; Van Hoey et al., 2004).

Data on the spatial distribution of macrobenthic species and species assemblages is available for many areas worldwide. Being ecologically important and well known, the spatial distribution patterns of the macrobenthos is often used to ecologically adjust marine management (i.e. ecosystem-based decision making and management).

The BPNS has a surface area of only 3.600 km², but includes a wide variety of soft sediment habitats. The area is characterized by a highly variable and complex topography, due to the presence of several series of sandbanks. Consequently, sediment types are highly variable throughout the area. Since the spatial distribution of the macrobenthos is largely dependent on the physical environment, a high diversity of macrobenthic life can be expected (Degraer et al., 2002; 2003).

Detailed knowledge on the macrobenthos of the BPNS became available through several Flemish and Belgian research projects. Based on a combination of datasets (data from 728 macrobenthos samples), Van Hoey et al. (2004) summarized the soft sediment macrobenthic community structure. They discerned between three sub-tidal communities: (1) the Abra alba – Mysella bidentata community, (2) the Nephtys cirrosa community and (3) the Ophelia limacina – Glycera lapidum community. Next to these communities, several transitional species assemblages connecting the three communities were defined.

Each community was restricted to a specific habitat. Sediment grain size distribution (i.e. median grain size and sediment mud content) was found to be the major structuring physical variable.

Annex 4.1: Spatial distribution of benthic communities at BPNS
(Maes et al., 2005)

4.2.2.2 Fish

The Belgian part of the North Sea is an important spawning and nursery area for several fish species (Table 4.1). A higher diversity in fish plankton can be seen in the western coastal zone in comparison to the east due to a lower dominance of Clupeiformes (herring). The most important commercial fish species are the demersal fish species Solea solea (L.) (sole), Pleuronectes platessa (plaice), Limanda limanda (dab), Gadus morrhua (cod), Merlanguis merlangus (whiting) and Melanogrammus aeglefinus (shell fish) (De Clerck et al., 2003). Certain distribution patterns could be observed, but in general it can be stated that especially the whole 10 mile zone is important as nursery room and fishery zone.

Table 4.1: Importance of BPNS as spawning and nursery area

BPNS as Spawning area: Medium important area on Belgian scale Minor important area on European scale	Highly important area for: Sole (entire BCS) Medium important area for: Plaice, Sprat and Sandeels (BCS except coastal zone) Minor important ara for: Herring (NW corner) Cod (NE corner), Whiting (N part), Lemon sole (W part)
BNPS at Nursery area: Highly important area on Belgian scale Medium important area on European scale	Highly important area for: Mackerel, Cod and Sprat (entire BCS) Medium important area for: Sandeels (BSC) except coastal zone) Minor important area for: Sole (small strip along coast), Lemon sole (W part of BCS), Plaice (coastal zone)

4.2.2.3 Birds

Sea birds can be defined as birds that are situated at sea for an important part of their life, that mainly live on marine food and that are well adapted at their marine life. This also includes some birds breeding in non-marine environments, but that outside the breeding season are bound to marine areas (for example the Common Scoter).

The Belgian sea areas are relatively important as wintering area, fouraging area or migration corridor for a number of seabirds. The highest diversity can be seen during migration periods (spring, autumn).

In Annex 4.2 a division is made of the importance of the BPNS for the most important seabirds based on following criteria: importance for the biogeographical population, protection status, function of BPNS (Stienen & Kuijken, 2003).

Annex 4.2: Importance for biographical population, protection status (BD= bird directive, BE= Bern Convention; BO= Bonn Convention) and function BPNS (R=

resting place (winter; M= migration corridor; F= fouraging area (breading season)) of the most important bird species (Stienen & Kuijken, 2003)

Two spatial gradients are observed in the Belgian waters: an onshore-offshore and an east-west gradient from the Scheldt estuary until the deeper and less turbid areas on French territory. Fish eating birds with a preference for clear water and mid to offshore circumstances (auks, Kittiwake, Northern Gannet) are more numerous in the west. Divers, grebes and Larus-gulls are more prominent as the water becomes more turbid. Skuas and fulmars are more typical for the offshore areas (> 20 km) (Seys, 2001).

Besides, a clear seasonal difference can be seen between the winter (November - March) and summer (April – October) period. Indicators for the winter are grebes, divers and guillemots, while terns, skuas and gulls are more typical for the summer (Seys, 2001; Stienen & Kuijken, 2003).

Several areas are protected under national or international protection.

- Coastal Banks area (Ramsar site, 27/09/1984): to protect the Black Scoter. The area is used by large numbers of wintering grebes and sea ducks and provides important winter foraging and roosting areas for numerous species of shorebirds.
- Zwin, including adjacent beach zone (Ramsar site, 27/09/1984). This area is also designated as a Special Protected Area under the EC Birds Directive and is classified as a Nature Reserve and Classified Landscape. It's an important area for staging, roosting, wintering and breeding various species of water birds.

Three other areas are recently approved (RD 14/10/2005) as Special Protection Areas in the framework of the Bird Directive:

- Nieuwpoort (Great Crested Grebe and Sandwich Tern): area along the West coast (in front of Koksijde & De Panne; 6 NM);
- Oostende (Great Crested Grebe, Sandwich Tern, Common Tern, Little Gull): area along Mid coast (Middelkerke – Bredene; 6 NM in west and between 1,5 and 6 NM in east of area);
- Zeebrugge (Sandwich Tern, Common Tern, Little Gull): area situated in harbour of Zeebrugge.

4.2.2.4 Mammals

Four mammals use the North Sea to reproduce and as fouraging area: Common seal Phoca vitulina, Grey seal Halichoerus grypus, Harbor porpoise Phocaena phocoena and Bottlenose Dolphin Tursiops truncates. The Whitebeaked dolphin Lagenorhynchus albirostris, the Atlantic White-sided dolphin Lagenorhynchus acutus, the Minke whale Balaenoptera acutorastrata are regularly observed in great numbers in large parts of the North Sea to feed (ICES, 2001).

The most general species for the BPNS is the Harbor porpoise. Especially in the period January – May lots of observations are made. Harbor porpoises don't seem to have a specific preference for a certain area at the BPNS. The Common and Grey seals are more coastal bounded and are rarely seen at open see.

4.3 SENSITIVITY ANALYSIS

4.3.1 Introduction

An environmental manager needs a comprehensive database providing a holistic view of the present resources, the demands, and the various direct and indirect inter-relationships. The best representation of such a database is a 'resource' map (Tortell, 1992). A large amount of data used for coastal zone management can be used as basic data for the sensitivity analysis. Data were received from different Belgian partners involved in the RAMA project (Table 4.2).

Data were acquired in different formats and were converted to ArcGis database files (.dbf) that could be used for the effective sensitivity analysis. Multiple conversions in spatial data increase inaccuracies in geographical positioning of entities. However, spatial analysis showed that the error on location of entities could be kept accurate enough for the goal of this project. The GIS computations used in the analysis will be discussed in the sensitivity analysis methodology section (4.3.3.1.).

Table 4.2: Data overview: original data formats for all the categories

Category	Dataset	Original format
Administrative	Coastline	Shape file
	Marine borders	Shape file
Land info	Population densities	Text file
	Shoreline type	Text file
	infrastructure	Shape file
Oceanography	Bathymetry	Shape file
	Wind regime	Text files
	Currents	Text files
Conservation	Nature protection areas	Shape file, text files
	Fishing areas	No data
	Spawning areas	No data
Commercial use	Bathing waters	Text file
	Aggregate extraction	Shape file
	Wind energy	Shape file
	Economical value coastal municipalities	Text file
Shipping	Harbours (marinas, ports)	Shape file
	Anchorage area	Shape file
	Shipping routes	Shape file
	IMO traffic separation scheme	Shape files

4.3.2 Geographical information system (GIS)

Cooper and McLaughlin (1998) stated that GIS (Geographical Information System) is the most common approach used (>50%) for deriving a coastal vulnerability index. Its ability to conduct spatial operations in the data, to integrate with modelling and remote sensing applications and to link different data sets all combine to make GIS a powerful analytical tool for coastal management (Cooper and McLaughlin, 1998). It offers a quick and efficient way of determining marine and coastal areas of environmental, economic and strategic sensitivity that could be impacted in the event of pollution incidents (Gilbert, 2002). Consequently it accommodates valuable resource and logistical information for combat authorities.

GIS has been used extensively for oil sensitivity, vulnerability and impact analyses (Moe et al., 2000), oil spill risk assessments (Lenting and Pratt, 1998), identification of marine environmental high-risk areas (MEHRA's) (McDonald et al., 1999), oil spill response atlas systems (Gilbert, 2002) and coastal zone sensitivity mapping applications (Tortell, 1992).

4.3.2.1 Classification

Classification procedures are being used in sensitivity analysis for quantification purposes. It is interesting for spill response planning to have a hierarchy of prioritised areas to protect against the impacts of a spill. Different authors used different systems:

- ESI (NOAA, 2002a): Coastlines are scored according to their sensitivity to oil spill impacts ranging from 1 (least sensitive) to 10 (very sensitive) (Table 4.3). The classification scheme is based on an understanding of the physical and biological character of the shoreline. The sensitivity ranking is directed by the following factors (NOAA, 2002a): relative exposure to wave and tidal energy, shoreline slope, substrate type (grain size, mobility, penetration and traffic ability), biological productivity and sensitivity. Wildlife and human resource data were indicated on maps but left unranked (NOAA, 2002b). There was no unit of area that was used as a base for coastline classification;
- MEHRA (McDonald et al., 1999): Marine environmental high-risk areas (MEHRA) were identified considering 2 factors: the risk of pollution from shipping incidents and the environmental sensitivity of the coastal waters in UK territory. A grid-based GIS system was set up to score risk and sensitivity values for the coastal and marine zones using fixed unit cells. All different sensitivity criteria were scored as objectively as possible. As the aim of this project was to designate a maximum 10% of the UK coastline as marine environmentally sensitive area, a scoring system was set up that added up all the sensitivity scores for each cell to give a final sensitivity value. All the coastal cells were then ranked in 5 sensitivity classes (very low – low – medium – high – very high) to valuate coastal vulnerability.

Table 4.3: ESI shoreline classification for oil impact studies (NOAA, 2002b)

ESI rank	Shoreline environment
1	Exposed rocky shores, exposed man-made structures
2	Exposed wave-cut platforms in bedrock, mud or clay
3	Fine to medium-grained sand beaches
4	Coarse-grained sand beaches
5	Mixed sand and gravel beaches
6	Gravel beaches; Riprap
7	Exposed tidal flats
8	Sheltered scarps in bedrock, mud or clay; sheltered rocky shores, sheltered man-made structures, sheltered riprap, sheltered rocky rubble shores; peat shorelines
9	Sheltered tidal flats, vegetated low banks, hyper-saline tidal flats
10	Salt- and brackish-water marshes; swamps, scrub-shrub wetlands, mangroves

4.3.3 Sensitivity analysis

4.3.3.1 Methodology

A sensitivity analysis is set up to identify vulnerable areas in the coastal and marine zone of Belgium. The representation of all different sensitivity assets is very important in this process. This approach preserves objectivity and leaves the decision-maker to put weightings on all different sensitivity assets. Nevertheless a classification procedure will be developed to provide an overall sensitivity assessment of the Belgian marine and coastal area. This provides an overview of sensitivity and can be used as a basis for further in-depth research of the categorical sensitivity of certain areas. A "broad-spectrum" threat like an oil or chemical spill requires a "broad-spectrum" approach. This is why this approach will be a combination of the ESI- and the MEHRA-approach (4.3.2.1).

Parameters for a sensitivity analysis can be assigned within the ecological, socio-cultural-economical, physical field. This results in a strategy similar to the 'Marine Environmental High Risk Area' - project in the UK. The marine and coastal zone of Belgium is structured as a grid with equally sized cells (1 km^2). Sensitivity is scored considering the presence of one or more of the sensitive entities within a cell. An entity for a parameter could be for example a nature reserve for the parameter "protected areas". The scores are added up to give a final mark to the coastal cells. These marks will then be categorised to distinguish different 'overall' sensitivities. Figure 4.3 shows a schematic representation of the scoring methodology.

		score
Ecological	Conservation Bird, habitat, fish	0-5
cultural	Landscape, heritage	0-1
physical	Shoretype, currents	0-2
economic	Aquaculture, fisheries, ports, saltworks	0-3
social	population	0-1
		SUM of SCORES

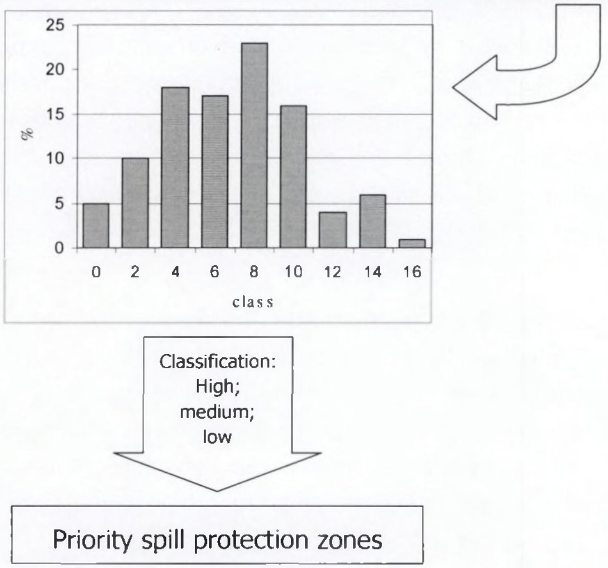

Figure 4.3: Schematic representation of the sensitivity analysis methodology

The scores are based on literature research, expert judgement and public participation with the end-users committee (see Annex 4.3).

Annex 4.3: Determination of the sensitivity scores for the ecological and socio-economical parameters of the BPNS

4.3.3.2 Ecological attributes

Internationally and nationally protected areas, areas of specific scientific interest are important in conservation so damage to these areas is critical compared to ecologically less-important areas. The intrinsic ecological sensitivity value was not considered in this analysis, as no data were available.

The analysis distinguishes different protected area statuses. International categories include RAMSAR sites, which are wetlands of global importance as well as EU natura 200 sites (bird or habitat directive areas). According to the recent Royal

Decree of 14/10/2005 five new zones have been established: three as Special Protected Areas (bird) and two as Special zones for nature conservation (habitat). Also these zones are identified as zones of international importance receiving the highest sensitivity score. For national reserves an IUCN (The World Conservation Union) categorisation was taken into account. Besides the recently approved special protected areas, some other areas are proposed as conservation areas of national importance. As these areas are likely to be established as protected areas in the near future by the Belgian government, they have also been included in the analysis. The scoring for ecological parameters is given in Table 4.4. The scoring of the ecological criteria was based on the protected area statuses and verified through public participation with the end-users (Annex 4.3).

Table 4.4: Scoring for different designations of ecological criteria

Entity	Number	Score
RAMSAR sites	2	5
EC – Special Protected Area (SPA) (in framework of habitat or bird directive)	2 (habitat) 3 (bird)	5
EC – Habitat Directive Area (Natura 2000)	13	5
EC – Bird Directive Area (Natura 2000)	3	5
Marine Protected Areas (MPA)	3*	3
Strict nature reserve	0	3
Beach (nature) reserves	2	3
National park	0	1
Nature reserve	1	1
Natural moment	0	1
Landscape reserve (classified landscape)	1	1

* Proposed areas of conservation

4.3.3.3 Socio-economic attributes

Socio-economic attributes are harder to score objectively. No international body recognises different rankings for these attributes. It is in a nation's interest however to preserve a tourist or highly populated area from being damaged by a spill.

Population density at the Belgian coast is relatively high, and increases drastically during the tourist season. Areas with a dense population should be mentioned as sensitive areas for spills; especially for chemical spills. Chemical spills can incorporate gas clouds, which could be dangerous for highly populated coastal communities. Although it is hard to score such a parameter, a differentiation was made between areas with more than 1000 inhabitants per km², which received a score of 1, and those with less than 1000 inhabitants per km² with a score of 0. To incorporate the seasonal increase of people inhabiting the Belgian coast the overnight stays per month have been taken into account with a distinction between the summer (April to September) and winter (October to March) season.

With regard to economic activities a number of points have to be made.

- no information was received on fish spawning areas or fish concentration sites, and data obtained from ICES are to broad-scaled to be incorporated in the analysis for the Belgian part of the North Sea;
- because of the important economic function of the Port of Zeebrugge this area received a value of 5 in the scoring, while Oostende a score of 3;
- tourism and recreation are a very important source of economic welfare for the Belgian coast and therefore a global tourist impact factor for beach recreation received a score of 5 and garded swimming zones a score of 1. Also marina's received a score of 1. The relative importance (intensity) of each coastal city with respect to these parameters was calculated and multiplied by the sensitivity score to get a final score (relative sensitivity calculation). For example the number of guarded swimming zones in De Panne is low compared to Koksijde, therefore Koksijde will get the highest score namely 1 while De Panne will get a score of 0,33;
- the economical tourist value of the coast was calculated based on 4 parameters (overnight stays, rental homes/secondary residences, day tourists and employees) and was given a score of 5. Just like for the previous parameters a relative sensitivity calculation was executed for the tourist value of the coast. At sea aggregate extraction and wind energy are the two most important economical sectors. The concession zones were given a score of 1.

For more details about the scoring of the socio-economic attributes reference is made to Annex 4.3. An overview of the scoring for socio-economic parameters is given in Table 4.5

Table 4.5: Scoring for different designations of socio-economic criteria

Parameter	Entity	Score	Remark
Recreation	Global tourist factor (beach recreation)	5	Relative sensitivity calculation (Source: Maes et al., 2005)
	Guarded swimming zones	1	Relative sensitivity calculation (Source: Maes et al., 2005)
	Marinas	1	Relative sensitivity calculation (Source: Maes et al., 2002)
Fisheries	Spawning sites	5	No spawning areas were identified/reported
	Concentration of fish	5	No specific areas were identified/reported
Shipping	Port	5	
	Local port	1	
	Anchorage area/Shipping lane	0	
Economical aspects	Tourist value coast	3	Relative sensitivity calculation (Source: Maes et al., 2002)
	Concession zone aggregate extraction at sea	1	
	Concession zone wind energy at sea	1	
Social aspects	High population (inh/km²)	1	(Source: FPS Economy, SMEs, Self-employed and Energy, 2005; http://statbel.fgov.be)
	Overnight stays per month summer	3	(Source: FPS Economy, SMEs, Self-employed and Energy, 2005; http://statbel.fgov.be)
	Overnight stays per month winter	1	(Source: FPS Economy, SMEs, Self-employed and Energy, 2005; http://statbel.fgov.be)

4.3.3.4 Physical attributes

Physical attributes concern factors like shoreline type, wind and current regime. This is a less tangible characteristic.

Little is known about the geological sensitivity of different types of shorelines to chemical spills. Oil spill sensitivity of coastal areas could be used as a guideline for sensitivity to chemical spills with characteristics similar to oil spills, but it must be mentioned that these are not to be generalised. Coastlines can be scored according to the ESI-scoring system that rates an overall sensitivity for oil spills. This scoring will not be considered for the overall sensitivity of a coastline area, but serve as a guideline in sensitivity analysis.

When looking at the determining factors that were considered in ESI ranking for oil spill sensitivity, it becomes clear that some of these are transferable in a general way. Relative exposure to wave and tidal energy and shoreline slope are two shoreline characteristics that determine the residence time and the area affected by the spill pollution (NOAA, 2002a). The substrate type will determine the difficulty in clean-up operations and the penetration of the pollutant. The intrinsic biological productivity and sensitivity will generally designate the ecosystem's vulnerability to a spill of any origin. This sensitivity analysis will be based on the ESI ranking (Table 4.3). In general it can be stated that the appearance of the whole Belgian coast is dominated by sandy beaches with the alternation of exposed man-made structures (groynes). The medium grain size increases towards the east coast. The beach of Knokke-Heist has been identified as coarse-grained sand beach, while the others are fine to medium-grained.

Wind regime and residual currents form independent characteristics in the sensitivity analysis. It is tricky to integrate these into the scoring process, because sensitivity is different to oil and chemical spills. For oil spills the specific meteorological conditions play an important role as oil dispersion is to a larger extent dependent on wind than on currents. The prevailing wind direction is south – south west with a maximum for WSW (8.5 – 9.5 m/s). In general only winds within the range NNE-WSW are responsible for spills washing ashore the Belgian or Dutch coast. Especially during persistent NNW winds the chance on a spill on the Belgian coast is high. Strong (>16.5 m/s) NNW winds occur in 0.1% to 0.2% of all wind observations, depending on the observation station or respectively during 1.6% - 3.6% of all NNW winds.

From a hydrodynamic point of view, the tidal current velocities reach their maximum value during flooding (NE) in the near coastal zone and along most of the Flemish Banks region. The maximum current velocity is in the ebb direction (SW) along the Hinder Banks and along some of the swales of the Flemish Banks. High currents of up to 1.6 m/s have been modelled at the Westerschelde estuary (throat), running in a SE-NW direction. The zone of high current velocity extends north of the Paardenmarkt shoal with values of 1 - 1.2 m/s and is roughly E-W oriented. High currents of up to 1.4 m/s are also found to the north of the BCS, towards the main channel of the Southern Bight of the North Sea (Maes et al., 2005).

The sensitivity to chemical spills (gas clouds, dissolved substances, sunken chemicals) is in some cases enhanced, in other cases reduced and sometimes not influenced by these physical characteristics at all. Downwind areas are only more sensitive to spills if a spill occurs upwind. Currents and wind can carry a floating substance to a shore, in this way enhancing the vulnerability of a coastal stretch. But in case of a spill concerning a dissolved substance currents may help dispersing and diluting chemicals, quiet waters can concentrate a substance.

Also, these characteristics do not embody a pure sensitivity to spills; they are not a spaciously fixed entity. They should be incorporated into a specific forecast analysis of an oil or chemical spill, once the location and identity of the spill is known. Generally it could be said that exposure to wind and currents will expose a coastal stretch more to spills but also to a more enhanced natural 'clean up'. These attributes are better disregarded for the total sensitivity scoring procedure in our process. They can be visualised in maps, to assist as an aid, when a spill occurs, but should not weigh on a site-specific scoring system.

4.3.3.5 Scenarios

The marine and coastal zone of Belgium is an intensively used area. The interests of the different users of the BPNS vary however in time. The tourist sector is mainly summer dependent, while for example some nature areas are of important value for wintering birds. Three different scenarios leading to different sensitivity maps have been identified as the impact and response to a spill will also depend on these seasonal interests:

- general scenario: a scenario in which all parameters are evenly important or with other words have received the same weight factor (=1);
- summer scenario: a scenario in which the tourist and recreational values of the coastal and marine areas have been given special attention (weight factor= 2), while the other factors have received a weight factor of 1;
- winter scenario: a scenario in which the nature values (wintering-, fouraging- and spawning areas) of the coastal and marine areas have been given special attention (weight factor= 2), while the other factors have received a weight factor of 1.

4.3.4 Results

4.3.4.1 Socio-economical information

In Annex 4.4 the official population densities of the coastal cities are given. Oostende, Bredene and Blankenberge are densely populated coastal municipalities with more than 1000 inhabitants per km². Middelkerke counts the lowest number of inhabitants (233 inw/km²) (FPS Economy, SMEs, Self-employed and Energy, 2005).

Annex 4.4: Socio-economical parameters of the Belgian coast and marine waters

In the tourist season the population density of the Belgian coast increases drastically. This trend has been taken into account by the social parameter "overnight stays per month". In Table 4.6 the number of overnight stays is given for the tourist months (July-August), the summer season (April-September) and winter season (October-March).

Table 4.6: Overnight stays per month at the Belgian coast for different time periods (FPS Economy, SMEs, Self-employed and Energy, 2005)

Coastal municipality	Average per year	Average July/August	Summer average (April – Sept.)	Winter average (Oct. till March)
De Panne	27.374	65.153	43.826	10.922
Koksijde	74.957	129.183	82.360	36.255
Nieuwpoort	64.529	128.196	85.276	28.194
Middelkerke	50.671	131.449	89.964	11.378
Oostende	89.177	124.907	81.065	60.223
Bredene	17.934	59.174	32.221	3.648
De Haan	64.757	134.910	97.234	32.280
Blankenberge	53.240	123.335	79.806	26.676
Zeebrugge	3.562	5.139	4.655	2.469
Knokke-Heist	26.087	53.449	38.443	13.732

On average the number of stays per month in the summer period is approximately 3,8 times higher than in winter season. In July and August the overnight stays are on average 2 times higher than the average number per year. The highest increase can be seen for Bredene where the number of overnight stays increases with 330% in July/August in comparison with the average per year. Because of this seasonal difference a distinction has been made between the overnight stays for the summer and winter period (dependent on the scenario).

A current inventory of the most important economical activities at sea, such as the ship traffic system, the aggregate concession zones and the wind concession zones (C-Power & the delineation of the wind energy area by the Cabinet North Sea) is also given in Annex 4.4. Except for shipping all activities take place beyond 6 nautical miles. Due to a lack of specific information on the most important fishing grounds, the fishing industry is excluded from the analysis.

4.3.4.2 Ecological information

In Annex 4.5 the different coastal and marine nature reserves are presented. It is clear that the west coast (Flemish Banks area) has a higher ecological potential than the east coast due to its status of RAMSAR area (± 66 km²) and habitat area (± 169 km²). Also two areas have recently been approved as nature conservation area in the framework of the Bird directive (total area: ± 238 km²). At the east coast the Vlakte van de Raan has been approved as habitat area (17 km²) and the area around Zeebrugge (total area: ± 47,2 km²) is protected in the framework of different conventions (Habitat and bird directive, SPA-birds, marine reserve, beach reserve).

A biological sensitivity map of the BPNS based on the intrinsic biological values (benthos, birds, fish, etc.) should be a great surplus value for this overall sensitivity analysis of the North Sea. In this respect the BWZee project is worth mentioning. BWZee is a two year SPSD-II project (April 2004-March 2006) leading to an integrated, full-coverage biological valuation map representing the biological and ecological value of all subareas within the Belgian BCS. Due to the time schedule of the projects these results could not be incorporated in RAMA, but are an additional input for the ecological parameters for further up-dating the sensitivity analysis.

Annex 4.5: Ecological parameters of the Belgian coast and marine waters

4.3.4.3 Cell sensitivity scoring

The cell sensitivity scoring will be discussed per scenario. For each scenario a sensitivity map is given with the total score of the different parameters for the whole coastal area and marine waters of Belgium. Furthermore an outline is given of the sensitivity ranking representing the relative importance of the different scores as a percentage of the cells that received a score above 0. Based on their distribution the scores were divided into 5 classes ranging from very low to very high.

4.3.4.4 Scenario: General

Annex 4.6 shows the sensitivity map for the general scenario and Table 4.7 the relative importance of the different sensitivity scores.

Table 4.7: Sensitivity ranking (general scenario) of BPNS and coastal area

Total score	Colour code	Percentage of cells	Ranking
1-5	Yellow	70,24%	Very low
6-10	Light orange	10,76%	Low
11-14	Dark orange	16,47%	Medium
15-19	Red	2,41%	High
20-23	Brown	0,12%	Very high

COASTAL ZONE

The highest scores (>19) are found for the Zwin (Knokke-Heist) and a small area eastwards of the harbour of Oostende. The score is due to a combination of socio-economical (densely populated, high tourist and economical coastal value) and ecological parameters. The Zwin is namely recognised as a Ramsar, a habitat and bird area. The area around Oostende is part of a habitat area and a proposed area in the framework of the bird directive (SPA-bird* Wenduine).

The area of the Yzermonding is known as beach reserve and habitat area. In contrast with Knokke-Heist and Oostende is the number of inhabitants in Nieuwpoort rather low (350 inw/km²), but the other socio-economical and ecological parameters compensate this.

Other important areas within the coastal stretch are the harbours and the coastal municipalities Koksijde, De Haan and Blankenberge. The harbours form a new economical value of a coastal municipality and increase in this way the score. Especially around Zeebrugge the difference between the harbour area and the rest of the municipality is clear, as Zeebrugge its tourist value (swimming zones, beach recreation, economical coastal value) is rather low, but the economical value of the port area is very high. The tourist value (overnight stays, beach recreation, etc.) is responsible for the high sensitivity score of Koksijde, De Haan and Blankenberge.

MARINE WATERS

In the Belgian part of the North Sea the score is mainly determined by the ecological status of the area. In conclusion how more the area is protected by different environmental laws how more sensitive the area for oil or chemical pollution. In this respect the west coast and the area around Zeebrugge where the majority of the medium to high level (11 to 19) sensitivity areas are situated, are the most valuable ecological sites that merit special attention in case of a spill.

Shipping has not been considered as adding to the sensitivity of an area (score 0) and no data are available on fishery. The other economical values (wind energy, aggregate extraction) have both been given a score of 1 because the sensitivity of pollution for these activities is rather low. Therefore a large part of the Belgian marine waters are characterized by a sensitivity score of 0, except the concession zones and the ecological zones mentioned before.

It is evident that if new or updated information becomes available and can be integrated in the GIS, the sensitivity analysis has to be updated and changes in the scoring of the coast and marine waters can become apparent.

Annex 4.6: Sensitivity map (general scenario) of the Belgian coastal & marine area

4.3.4.5 Scenario: Summer (April till September)

Annex 4.7 shows the sensitivity map for the summer scenario and Table 4.8 the relative importance of the different sensitivity scores.

Table 4.8: Sensitivity ranking (summer scenario) of BPNS & coastal area

Total score	Colour code	Percentage of cells	Ranking
1-7	Yellow	62,29%	Very low
8-13	Light orange	16,24%	Low
14-19	Dark orange	12,76%	Medium
20-26	Red	8,41%	High
27-32	Brown	0,29%	Very high

COASTAL ZONE

The picture of the sensitivity map for the summer scenario is comparable with the general scenario, with this difference that all coastal municipalities except De Panne receive a higher sensitivity score. Due to the lower tourist impact at De Panne, the sensitivity score remains similar as in the general scenario.

Beside the Zwin (Knokke-Heist) and a small area eastwards of the harbour of Oostende, also two Habitat directive areas in De Haan-Wenduine are identified as most sensitive areas (score > 26).

MARINE WATERS

It is obvious that in the summer scenario the attention lays on the coastal stretch, more than on the marine areas. In the marine zone it is however again the west coast that receives the highest score but now with a priority of low to medium.

Annex 4.7: Sensitivity map (summer scenario) of the Belgian coastal & marine area

4.3.4.6 Scenario: Winter (October till March)

Annex 4.8 shows the sensitivity map for the winter scenario and Table 4.9 the relative importance of the different sensitivity scores.

Table 4.9: Sensitivity ranking (summer scenario) of BPNS and coastal area

Total score	Colour code	Percentage of cells	Ranking
1-8	Yellow	70,53%	Very low
9-16	Light orange	19,94%	Low
17-23	Dark orange	4,53%	Medium
24-31	Red	3,76%	High
32-38	Brown	1,24%	Very high

COASTAL ZONE

In the winter scenario only the harbour areas (Nieuwpoort, Oostende and Zeebrugge) and De Haan-Blankenberge are of a certain importance.

MARINE WATERS

Because in this scenario the emphasis lays on the intrinsic values of the nature areas for f. ex. wintering birds (resting places, fouraging areas) which is mostly linked with the natural status, the value of the nature areas increases in general. In the west coast area the Nieuwpoort- and Wenduinebank receive the highest sensitivity score.

Annex 4.8: Sensitivity map (winter scenario) of the Belgian coastal & marine area

4.3.5 Discussion

4.3.5.1 Overall sensitivity analysis score

The Belgian territorial waters and coastline were analysed on their sensitivity and this for the three identified scenarios. Maps with different attributes and parameters show the distribution of sensitive entities which were summarized in a "total sensitivity" map for the Belgian coastline and marine areas. From the results it can be deducted that the sensitivity varies spatially. The most apparent trends to be observed in sensitivity, is an increase in sensitivity towards the western parts of the BPNS. The picture on the coastal stretch is more scattered due to specific socio-economical values.

4.3.5.2 Unscored parameters

Although not parametrically scored, physical attribute maps also demonstrate a certain sensitivity trend for the Belgian coastline. Based on the resulting sensitivity distribution along the coast some interpretation of unscored parameters can be attempted. As the major regional wind direction is south to south west, the coastal stretch with the most ecological sensitive west coast (Flemish Banks area) would be relatively protected from spills. Only in case of persistent NNW winds the chance on a spill on the Belgian coast is high. Therefore accidents happening in the BPNS will mostly affect the mid to east coast in case of NNW winds.
The effect of currents and tides will probably to a lesser extent have an influence than the wind, as the general direction of the currents of the top water layers is not directed towards the most sensitive areas. Only during high tide currents are important as they could transport floating spill into the Westerschelde estuary and the mouth of the Yzermonding.

4.3.5.3 Methodological aspects

DATA ISSUES

Shortage of data that is mentioned as a problem in other studies (Cooper and McLaughlin, 1998) and has to be acknowledged in this analysis as well. The available data were adequate for a general sensitivity analysis, but did not allow for an in-depth sensitivity analysis.

Physical data were given in hardcopy, providing only the general trends for the whole coastline. No detailed data were available on important fishing grounds. Population density figures are available for the coastal municipalities, but without taking into

account the drastically increase during the tourist season. This has been partly resolved by including the overnight stays for the summer and winter season.
The analysis could be improved with integration of new or more detailed data, which is easily done with GIS database management. New information can be injected fairly easy into the database and integrated in the sensitivity analysis. Original data quality cannot be discussed, as there is no knowledge or information on the data collection methodology for some of the data.

SENSITIVITY ANALYSIS

When looking at the sensitivity methodology, the flexibility of the output is clearly an important issue. A scoring methodology was set up to visualize a total sensitivity. By assigning parameters for specific sensitivity, according to the available data, the total scoring range varied between zero and 38 (highest score). If more parameters are used in a scoring system, total sensitivity scoring will be higher.

Scoring methodology is an implementation of a quantitative representation of qualitative characteristics. Classifying sensitivity is therefore not an absolute measure of sensitivity but it is useful as a guide. The sensitivity analysis consists of the final sensitivity score together with all the mapped sensitivity scored and unscored attributes so the user can adjust the system to his needs and weightings. Again, flexibility emerges as an important attribute of a GIS-based spatial analysis.

To illustrate this three scenarios have been worked out in this sensitivity analysis. A general scenario in which all identified parameters received the same weight, a summer scenario in which the tourist value of the coast received a higher weight and a winter scenario in which the emphasis was given to the nature values of the marine and coastal zone.

One of the major advantages of the sensitivity scoring methodology is that it is not a closed approach. Data can be added, parameters can be redefined, scores can be adapted, new categories and scenarios can be entered. This is a positive characteristic for a GIS used as a guidance tool. The scoring method itself can be further questioned by asking to what extent summing up scores is the most appropriate approach in all situations.

As the final sensitivity ranking has been chosen arbitrarily, it serves only as a relative sensitivity analysis.

4.3.5.4 Areas for improvements

This analysis was based on a set of coastal and marine data originating from national statistics (FPS Economy, SMEs, Self-employed and Energy, 2005), from other projects financed by the Belgian Science Policy (GAUFRE (Maes et al., 2005); Maredasm (Maes et al., 2002)) and collected within the framework of the RAMA project. It is clear that this sensitivity analysis is not a static result. As better, more detailed or new information becomes available, especially in GIS format, the sensitivity analysis can be updated and refined. It should also be mentioned that the scoring system should be based on scientific analysis, but be grounded by a stakeholder analysis.

Better and more detailed datasets could thus improve the overview of the sensitivity of the Belgian coastal and off-shore area, e.g. intrinsic ecological sensitivity, more detailed wind and current data, and fish information (spawning area; density data; biodiversity data). Detailed knowledge of specific areas (e.g. the presence of easily "defendable" inlets and outlets) and consideration of feasible protective actions should be taken into account in future versions of the sensitivity analysis. For example the making of a biological valuation map for the Belgian Continental Shelf – current research action within SPSD-II (end march 2006)- will be a major contribution for the ecological parameters used in the sensitivity analysis.

The general approach to undertake this sensitivity analysis would be the same. However the scoring system could have been statistically tested, to check its sturdiness and the weightings of each parameter. Parameter selection and correlation could be researched with Principal Component Analysis (PCA) or Pearson's correlation coefficient, should all data conditions apply. This could provide a more objective basis. Scoring procedures could be developed for the scoring of physical attributes.

4.3.6 Conclusion

In general, the western part of the Belgian marine zone (Flemish Banks area) and the area around the harbours of Zeebrugge and Oostende neighbouring the important coastal municipality Blankenberge-De Haan are the most sensitive zones for spills in terms of ecological (focus marine waters/ winter scenario) and socio-economical value (focus coastal municipalities/ summer scenario).

4.4 EFFECT ANALYSIS OF THE SELECTED SCENARIOS

The effect analysis of the selected scenarios will be restricted to an ecological impact assessment. An accidental spill also has economical consequences, but the economical impact assessment is beyond the scope of the RAMA project. The ecological impact assessment model is schematically given in Figure 4.4.

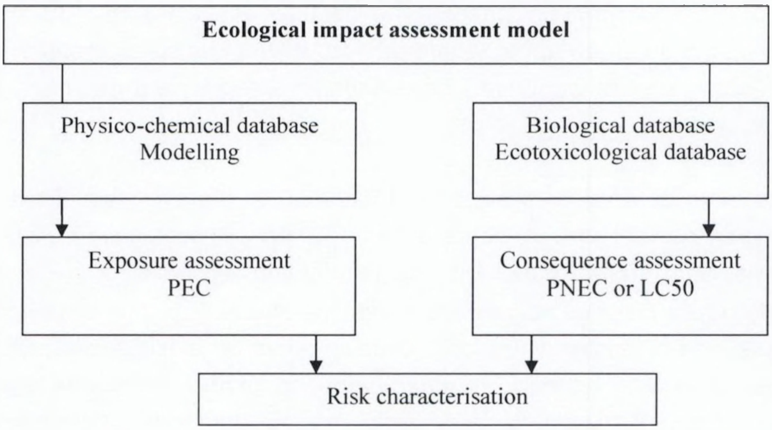

Figure 4.4: Schematic representation of the ecological impact assessment model

The effect analysis can be subdivided into three ERA steps (see 1.3):

- The exposure assessment quantifying the Predicted Environmental Concentration (PEC) based on the calculated release rates (see 3.3.2) and the physico-chemical properties of the oil/HNS. On the basis of a physico-chemical submodel (Mackay-model, MU-SLICKLETS, sediment transport model) the distribution of the spill and the concentration of that product over the different environmental compartments (surface, soil, water) are calculated.
- The consequence assessment estimating the consequences or effects of the release in terms of the Predicted No Effect Concentration (PNEC) or the 50% mortality Concentration (LC50). These values are derived using ecotoxicity tests of model organisms, originating from the eco-toxicological database.
- The risk characterisation or ecological impact assessment based on the PEC/PNEC or PEC/LC50 ratio. Based on these results and on the spill surface the direct short term losses are calculated for the different biota with the Biological Effects Submodel. The direct loss (mortality) is calculated on the basis of corrected (for temperature, time) acute (laboratory) toxicity data.

The described method is only a method of approach of the reality: a number of assumptions and simplifications had to be made. Indirect losses (e.g. loss of primary production) and potential long term losses (e.g. changes in the food web or productivity, chronical effects, etc.) are not included in the analysis.

4.4.1 Scenario 1: Worst case scenario of an oil spill at the BPNS

In this scenario the effect of an oil spill at the BPNS is considered. On the one hand the effect of the spill at open sea is evaluated, on the other hand the impact of a beach stranding on the biota – in particular on the bird population- is described.

4.4.1.1 Exposure assessment

The characteristics and the behaviour of crude oils vary greatly according to their type and origin. As no detailed information is given in the IVS-SRK database about the specific crudes transported, no data are known about the composition of the spilled crudes (f.ex. total percentage of hydrocarbons or the water-soluble fraction of aromatics). Given the fact that in general the toxicological data on oils are scarce and the aromatic components can be seen as the most toxic fraction, the impact of oil spills will be determined based on the calculated concentrations of its dissolved aromatic components (Persoone et al., 1996). In previous studies (Vandenbroele et al., 1997; Maes et al., 2002) the eco-toxicological characteristics of No 2. fuel oil (HFO) were studied in detailed. As the fraction of aromatic components is higher for heavy fuel oils (HFO) than for crudes, these data will be taken as a base for the effect analysis of the worst case scenario of an oil spill at the BPNS. It is further assumed that the predicted environmental concentration (PEC) will be 80% of the initial water dissolved aromatic fraction by intense mixture with the sea water and that the exposure time is 4 days.

Table 4.10: Concentrations of aromatic components in 100% water-soluble fraction of No.2 fuel oil and the derived environmental concentrations (Vandenbroele et al., 1997)

Chemical compound	Water-soluble fraction (mg/l)	PEC (mg/l)
Benzene	0,55	0,44
Toluene	1,04	0,832
Ethylbenzene	0,475	0,38
Xylene (m, p, o)	0,795	0,636
Trimethylbenzene	0,97	0,776
Naphtalene	0,84	0,672
1-methylnapthalene	0,34	0,272
2-methylnapthalene	0,48	0,384
Dimethylnapthalene	0,24	0,192
Trimethylnapthalene	0,03	0,024

Another assumption that has to be made is the thickness of the surface oil layer. When spilled at sea, crude oils rapidly break into areas of dark, thicker oil interspersed with areas of intermediate and thin sheens.

Considering the amount of oil spilled (17.000 ton/accident) and a northwest wind of 4 à 5 Beaufort the MUMM (responsible authority for oil monitoring) has estimated that a spill accident occurring in Subarea SA3 (entrance Scheldt estuary) will lead to an oil spill of 12,6 km² (or 0,35 % of BPNS) based on the MU-SLICKLETS model (Annex 4.9). The average thickness of the layer will be 1 mm and the diameter of the spill approximately 4 km. Considering the weather conditions the spill will reach the coast near the Zwin in 13 hours. The Zwin is an important breeding and wintering ground for many bird species.

Annex 4.9: Modelling result of oil scenario (performed by MUMM, 2006)

To summarize, scenario 1 can be described as follows:

- ship type: Oil tanker
- cargo type: Cargo type 2 (crude oils)
- location of accident: Subarea SA3 (entrance Scheldt estuary)
- cargo spilling accident frequency: 0.00589 accident/yr (or every 170 years)
- spill quantity per accident: 17.000 ton/accident (= 19.550 m³/ accident)
- eco-toxicological characteristics: based on No. 2 Fuel oil (heavy fuel)
- thickness layer: 1 mm

- oil slick surface: 12,6 km²
- wind condition: northwest (NW) winds (4 à 5 Bft)
- time of accident: March

4.4.1.2 Consequence assessment

For every biota group the LC50 values were determined and corrected for temperature (T) and exposure time (t) according to following formulas (Vandenbroele et al., 1997):

- for temperature: Log10 (LC50T) = log10(LC50To) + a (To - T)
  - With a = 0.07113 for organophosphate compounds and a= 0.04956 for all other compounds;
- for time: Log10 (LC50t) = -b (log10t – log10t0) + log10 (LC50t0)
  - With b = 0.8175 for all compounds.

The LC50 values were corrected for a temperature of 5,6°C (mean sea water temperature in March in subarea SA3) and an exposure time of 4 days.

For several chemical compounds a large set of eco-toxicological data exist. A selection was made per biota group of the species with the lowest LC50 value, as this implies the highest toxicity risk.

In Table 4.11 a summary is given of the corrected toxicity data for all the chemical compounds for the different biota groups.

Table 4.11: Corrected eco-toxicological data (LC50 (mg/l) for the different biota groups (Vandenbroele et al., 1997) (*based on derived ecotox data)

Chemical compound	Phytoplankton	Zooplankton	Invertebrates	Molluscs	Fish
Benzene	32,5	43,8	58,9	1.240	7,2
Toluene	32,5	57,5	12,2	565,8	5,3
Ethyl benzene	21,1	8,8	28,9	1.062,5	33,1
Xylene (m, p, o)	32,5	1,7	4,2	555,9	18,0
Trimethylbenzene	1,3*	29,7*	31,3	-	9,3*
Naphtalene	5	3,6	1,5	361,8	1,6
1-methylnapthalene	6,5*	5,9	4,4	153,6*	46,5
2-methylnapthalene	0,2*	1,4	3,5	3,6*	1,1*
Dimethylnapthaleen	0,5	2,3	11,6	11,6	3,5
Trimethylnapthalene	-	-	-	-	-

4.4.1.3 Ecological impact assessment

DIRECT LOSS BIOTA

The direct loss (mortality) for the different biota groups as a result of the aromatic compounds was calculated according to following formula, based on the generally accepted log-probit model where the cumulative response is a log-normal function of the concentration:

$$P_0 = \frac{1}{\sqrt{2\pi}} \int^{Y0} EXP(-\frac{1}{2}U^2)du (3)$$

With P0 = fraction of biota supposed to die by a Predicted Environmental Concentration (mg/l)

And:

$$Y_\circ = \frac{X_\circ - \mu}{\sigma}$$

With $X_0 = \log_{10}$ (Co); $\mu = \log_{10}$ (LC_{50}) and σ = standard deviation of the response (= 0.83)

In Table 4.12 an overview is given of the direct losses for the different biota groups caused by the worst-case scenario of the crude oil spill.

Table 4.12: Overview direct loss (P-values in%) for the different biota groups (*based on derived ecotox data) (Vandenbroele et al., 1997)

Chemical compound	Phytoplankton	Zooplankton	Invertebrates	Molluscs	Fish
Benzene	1,2	8	5	0,00207	7,2
Toluene	2,8	1,4	7,9	0,0233	16,6
Ethyl benzene	1,8	5,1	1,2	0,00207	1
Xylene (m, p, o)	2	30,9	16,1	0,0233	4
Trimethylbenzene	39,4*	2,9*	2,7	-	9,9*
Naphtalene	14,9	19,2	33,4	0,0483	33
1-methylnapthalene	4,8*	5,5	7,2	0,0483*	0,4
2-methylnapthalene	68,4*	24,8	12,5	12,1*	29,1*
Dimethylnapthalene	34,8*	9,9	1,6*	1,6*	6,4
Trimethylnapthalene	-	-	-	-	-

The calculations give the direct loss per biota for the individual compounds. Oil is however a complex mixture of organic and inorganic compounds of which the ecological impact is the result of the mutual effect of the different compounds. The effect can be additive, synergetic or antagonistic. Therefore it is difficult to predict the total impact. For every biota group the product with the highest impact is considered. This value is seen as the total loss for that biota group (Table 4.13).

Table 4.13: Final loss (%) for the different biota groups

Chemical compound	Biota group	Final loss (%)
2-methylnapthalene	Phytoplankton	68,4
Xylene	Zooplankton	30,9
Naphtalene	Invertebrates	33,4
Dimethylnaphtalene	Molluscs	12,1
Naphtalene	Fish	33

Table 4.13 indicates that the highest short term (4 days) direct impact on the marine environment will be due to the products naphthalene, dimethylnapthalene and xylene.

BIRD LOSS OPEN SEA

For the calculation of the bird loss at open sea as a result of this worst case oil spill scenario the maximum number of birds of the different bird species in the Belgian sea areas have been taken (ship-based surveys 1992-2003) (Seys, 2001; Stienen & Kuijken, 2003; Haelters et al., 2004). The considered impact area has been calculated on the basis of the assumption that the bird population present in a range of 5 km will be attracted by the oil spill (impacted area: approx. 30 km^2).

In Annex 4.10 the maximum density and the percentage mortality in case of contact with oil is represented. The mortality percentage is based on the mortality percentage calculation of Vandenbroele et al. (1997), up dated with the more recent oil vulnerability index (OVI) according to Camphuysen (1998) (in Seys, 2001). Various shadings are used for classes of oil vulnerability (OVI), with: slightly to moderately sensitive (white), sensitive (light grey), highly sensitive (dark grey).

Annex 4.10: Density, oil vulnerability index (OVI) and% mortality –BPNS

The total number of bird casualties is estimated at about 471 birds. Due to seasonal variations in bird densities this number can differ according to the period of the oil accident.

Estimation should however be approached with a certain care. Previous oil spill accidents demonstrate that every accident should be considered individually. The estimated figure in this scenario is much lower than the estimated number of bird casualties in the Erika accident (Bretagne, 1999) (44000 dead birds found; total estimation mortality: 120-300 thousand) despite the comparable spill size of 15000 ton heavy fuel (ICES, 2005). The Tricolor accident (Kanaal, 2003) shows that such a high number (here 20000 casualties found; total estimation 40 – 100 thousand) can also be the result of a small spill (170 ton heavy fuel) (Haelters et al., 2003). In the Braer accident (Shetland, 1996) where crudes were involved (85000 ton) the number of found casualties was 1800, while the total mortality is estimated at 5000 birds (ICES, 2005). These figures are comparable with the case described here.

We can conclude that it is not easy to estimate bird casualties of oil spills. The number will differ according to the spilled quantity, the type of oil, the season and the importance of the location as bird area.

BIRD LOSS BEACH

According to the scenario model, the oil slick will drift away in the direction of the nature reserve the Zwin (Annex 4.9). With a NW wind of 4-5 Bft the spill will reach the coast near the Zwin in 13 hours.

The calculation of bird loss at the Zwin is based on bird surveys during the period 2000-2005. Data were received from Mr. De Scheemaecker, the coordinator of the bird surveys in the area. A distinction has been made between the most important seabirds and water birds of the mud flats and salt marshes characteristic for the nature area.

In case we assume that the oil slick will wash ashore during spring tide, the whole area could be flooded. As a result half (or more) of the total area of mud flats and salt marshes (75 ha) can be covered by oil. Under this assumption the mortality has been calculated for both the sea- and water birds in contact with oil. As in the scenario the accident took place in the winter period (October – March) the maximum numbers of wintering birds have been taken into account. As during winter the number of birds is much higher than during summer, this can be seen as a worst case scenario.

The mortality percentage for seabirds is based on the mortality percentage calculation of Vandenbroele et al. (1997), up dated with the more recent oil vulnerability index (OVI) according to Camphuysen (1998) (in Seys, 2001). Various shadings are used for classes of oil vulnerability (OVI), with: slightly to moderately sensitive (white), sensitive (light grey), highly sensitive (dark grey). No data were available for the mortality percentage of water birds. An average of 50 % has been taken.

From Annex 4.11 the total number of bird casualties is estimated at 741 seabirds and 2595 water bird. The highest mortalities are found for the black-headed gull, herring gull (seabirds) and the mallard, lapwing (water birds), mainly due to their high densities and not due to their sensitivity. In case of an oil spill it is not only the bird population that will be under threat, but the whole value of the nature reserve.

Annex 4.11: Density, oil vulnerability index (OVI) and % mortality – Zwin (winter)

4.4.2 Scenario 2: Worst case scenario of a HNS spill at the BPNS

In this scenario the effect of a HNS spill at open sea (acetone cyanohydrin) is considered. In contrast to the worst case scenario of the oil spill, the impact on land is of minor importance due to the characteristics of the product. The ecological impact assessment will therefore focus on the effects on the aquatic organisms.

4.4.2.1 Exposure assessment

The spill quantity of cargo type 1 products per year for the whole BPNS is estimated at 12,3 ton. If the total cargo spilling accident frequency (calculated over all accident & ship types) is taken into account this means about 8.722 ton per accident, so approximately half of the quantity calculated for crudes. Again the spilled quantity per accident (over all ship types) due to powered groundings (8.920 ton/acc) is comparable with the spilled quantity per accident of the other accident types (7.824 ton/acc) despite the great difference in cargo spilling accident frequency respectively every 82 years and 4.000 years. It should be remembered that it has been assumed that container ships are fully loaded with the class of dangerous goods specified (see 1.3.2.2. – Risk Analysis Methodology). This is likely to be a conservative assumption. In reality different chemical products will be transported. These hazardous products are generally transported as packaged goods (drums, sacks, containers, etc.). In case of an accident, the spilled quantity will depend on the number of damaged packages released at sea. In most cases the spilled quantity will be less than the total amount transported, but as a worst case scenario is taken as point of departure approximately the total amount of cargo spill quantity will be considered in the first place (8000 ton). Secondly the effects of a smaller spill (1000 ton) of acetone cyanohydrin will also be taken into account.

The characteristics and the behaviour of acetone cyanohydrin are summarised in Table 4.14 and in Annex 4.12.

Annex 4.12: Simulation of behaviour of acetone cyaonohydrin (Mackay model)

Out of Annex 4.12 becomes clear that acetone cyanohydrin will dissolve in water for 98.2% and will only evaporate for 1.83%. In water acetone cyanohydrin will decompose producing hydrogen cyanide (HCN) and acetone (C3H6O).

Table 4.14: Chemical characteristics of acetone cyanohydrin (OECD SIDS, 2005; IPCS, 2006)

Name chemical product	Acetone cyanohydrin
CAS registration number	75-86-5
Chemical formula	$(CH_3)_2C(OH)CN$
Physical status	Colourless liquid with characteristic odour
Molar mass (g/mol)	85,1
Density (g/l)	
Vapour pressure (PA)	107 at 20°C
Water solubility (g/m³)	1.00E+06 (miscible in all proportions)
Partition coefficient (Log Pw)	-0,76
Biodegradation (data for hydrogen cyanide)	Complete degradation at < 60 mg/l
Physical danger	Vapour heavier than air
Chemical danger	Rapidly decomposition on heating or on contact with bases or water producing highly toxic and flammable hydrogen cyanide and acetone.
Environmental data	Very toxic to aquatic organisms

In contrast with oil spills (MU-SLICKLETS), a specific operational chemical model estimating the magnitude of the HNS spill does not currently exist in Belgium. The best approach is however been obtained by using the sediment transportation model of the MUMM as a basis for the chemical spilled. Some assumptions had to be taken and therefore the results should be approached with a certain care.

As mentioned acetone cyanohydrin will almost completely dissolve in water and decompose producing hydrogen cyanide (HCN) and acetone (C3H6O). Hydrogen cyanide is a highly toxic substance that will evaporate. During the modelling we assume that no biodegradation will take place as well as no loss to other compartments than water (f.ex. by evaporation). This is a rather conservative assumption but it should be seen in the light of the "worst case" reasoning. Another assumption is that the effects of cyanohydrin, hydrogen cyanide and acetone occur before evaporation of the (decomposed) product. Since HCN is a very rapidly acting toxicant this is a reasonable worst-case assumption.

The approach followed here to estimate the effects of the chemical spill will differ from the one followed for the oil spills as here the spill size and ecological impact area will be estimated based on a critical effect concentration, further described in 4.4.2.2.

To summarize scenario 2 can be described as follows:

• ship type:	Chemical tanker
• cargo type:	Cargo type 1 (acetone cyanohydrin)
• location of accident:	Subarea SA3 (entrance Scheldt estuary)
• cargo spilling accident frequency:	0.001 accident/yr (or every 710 years)
• spill quantity per accident:	8.000 ton/accident (1) & 1.000 ton/accident (2)
• water solubility:	completely dissolving
• eco-toxicological characteristics:	based on acetone cyanohydrin and HCN
• wind condition:	strong northwest (NW) winds
• time of accident:	March (sea water temperature about 6°C)

4.4.2.2 Consequence assessment

For every biota group the LC50 values were determined and corrected for temperature (T) and exposure time (t) according to following formulas (Vandenbroele et al., 1997):

- for temperature: Log10 (LC50T) = log10(LC50To) + a (To - T)
  - With a = 0.07113 for organophosphate compounds and a= 0.04956 for all other compounds;
  - LC50To = selected LC50 value with a temperature of T0
- for time: Log10 (LC50t) = -b (log10t – log10t0) + log10 (LC50t0)
  - With b = 0.8175 for all compounds.

The LC50 values were corrected for a temperature of 6°C (mean sea water temperature in March in subarea SA3) and an exposure time of 4 days.

For some chemical compounds a large set of eco-toxicological data exist, mostly of fresh water organisms. Data for acetone cyanohydrin were rather limited. Due to lack of acetone cyanohydrin data for the biota groups invertebrates, molluscs and fish, data were derived based on ecotox data for hydrogen cyanide. This assumption can be justified as acetone cyanohydrin almost immediately and completely dissolves in hydrogen cyanide and acetone, with hydrogen cyanide as the most toxic component. A selection was then made per biota group of the (marine) species with the lowest LC50 value, as this implies the highest toxicity risk. In Table 4.15 a summary is given of the corrected toxicity data for all the chemical compounds for the different biota groups.

Table 4.15: Corrected eco-toxicological data (LC50 (mg/l) for the different biota groups

Chemical compound	Phytoplankton (F)	Zooplankton (F)	Invertebrates* (M)	Molluscs* (F)	Fish* (M)
Acetone cyanohydrin	1,978	0,365	1,156	3,138	1,396

(*) Derived from eco-toxicological data of hydrogen cyanide

(M) Based on marine species; (F) Based on fresh water species

4.4.2.3 Ecological impact assessment

DIRECT LOSS BIOTA

The direct loss (mortality) for the different biota groups as a result of acetone cyanohydrin was calculated according to formula described in 4.4.1.3.

The approach followed for the calculation of the direct loss caused by a spill of HNS is slightly different from the one followed in case of oil spills. It is generally accepted that a hazardous concentration causing chronic toxicity within 5% of the species population (HC5) is acceptable. As the described formulas are based on acute toxic effects (LC50-values) we have assumed that a 1% loss of the species populations is acceptable.

Starting from this assumption we calculated the Predicted Environmental Concentration (PEC) or the spill concentration corresponding with 1% direct loss. Except for zooplankton, all biota groups have less than 1% direct loss with a PEC < 0.01 mg/l (Table 4.16).

Table 4.16: Direct loss (%) by acetone cyanohydrin spill of the different biota groups for different PEC (0.01; 0.05; 0.1 mg/l)

	0.01 mg/l	0.05 mg/l	0.1 mg/l
Phytoplankton (F)	0,3 %	2,7 %	5,9 %
Zooplankton (F)	3 %	15,2 %	25,1 %
Invertebrates* (M)	0,7 %	5,1 %	10 %
Molluscs* (F)	0,135 %	1,5 %	3,6 %
Fish* (M)	0,5 %	4,1 %	8,5 %

(*) Derived from eco-toxicological data of hydrogen cyanide (based on molecular weight)

(M) Based on marine species; (F) Based on fresh water species

ECOLOGICAL IMPACT AREA

Simulations of the two described sub-scenarios (spill of 8.000 ton/accident and spill of 1.000 ton/ accident) have been carried out over a time-period of 75 days using the sediment transportation model of MUMM. The dispersion of the chemical spill is shown in Annex 4.13 and Annex 4.14.

Annex 4.13: Acetone cyanohydrin simulation of 8.000 ton spill (time period: 75 days) (Executed by MUMM, 2006)

Annex 4.14: Acetone cyanohydrin simulation of 1.000 ton spill (time period: 75 days) (Executed by MUMM, 2006)

Both Annex 4.13 and Annex 4.14 show a similar distribution pattern. The HNS spill has reached acceptable limits (< 0,01 mg/l) respectively after 2 months (8.000 ton) and 1,5 months (1000 ton). In case of a spill of 1000 ton the hazardous substances are almost totally disappeared after 75 days (Annex 4.14), while in the worst-case scenario the spill is at that time still situated around Zeebrugge and the entrance of the Scheldt estuary (Annex 4.13).

In terms of impact it is important to consider all areas where the spill concentration has exceeded the acceptable limit of 0,01 mg/l as this concentration determines the direct loss of biota. In Annex 4.15 the maximum concentration is given for the total modelled area registered between day 1 and day 75 of the simulation. The highest concentrations of the spill caused by an accident in Subarea 3 are situated around Oostende. The spilled area with significant direct loss (> 0.01 mg/l) (all except the dark blue area) is estimated at about 3114 km² in case of 8000 ton spilled or 2127 km² in case of 1000 ton spilled. As illustrated in the figures below, the model covers also partly the French and Dutch part of the North Sea. Deductions to the BPNS results in an ecological impacted area (> 0,01 mg/l or > 1% direct loss of biota) of respectively 70% and 40 % of the BPNS.

Annex 4.15: Maximum concentration (mg/l) acetone cyanohydrine on BPNS (result simulation 75 days) (MUMM, 2006)

As mentioned before, a lot of assumptions have been taken in case of the estimations of the ecological impact from chemical spills. The most important assumption that leads to a severe overestimation of the possible effects is that no loss of the product during the modelling period (75 days) is taken into account. In reality, the product is likely to be lost due to dissociation, breakdown and volatilization. However the results can be interpreted as representing worst case effects of a persistent, toxic compound.

The results above show the possible outcomes of a HNS spill and the magnitude of the spill. It is a first attempt of ecological impact assessment of hazardous products and should be refined when new methodologies become available.

4.4.3 Conclusion

The effect analysis of the selected scenarios is restricted to an ecological impact assessment. The effect analysis is subdivided into three ERA steps: exposure assessment, the consequence assessment and the risk characterisation or ecological impact assessment. Due to lack of quantitative data assumptions have been made in both scenarios (oil & HNS). So the ecological impact assessments can certainly be improved. However the results can be interpreted as representing worst case effects and show the possible outcomes/magnitude of a selected oil and HNS spill. It is a first attempt of ecological impact assessment of both an oil and HNS spill and should be refined when new methodologies become available.

The effect of oil and chemical spills is different. Oil spills have an effect both at open sea and at the beach (stranding), while the effect of a HNS spill is generally be limited to the marine area. In contrast to HNS spills, oil spills have a severe impact on the bird population. In our case study the total number of bird casualties is estimated at about 471 birds (open sea) and 3336 birds (Zwin). Due to the physico-chemical characteristics of the hazardous products the assessment of the ecological impact area is also different. A generalisation of results of a specific spill is thus not possible.

5 RISK ESTIMATION

An overall estimation of the risk can be defined as the multiplication of the consequence for each damage-causing event with the frequency of that event. The frequency of an event is a result of the hazard identification and release step (Chapter 1). The consequence of a damage-causing event is usually defined as casualty probabilities (direct loss (mortality)) (Chapter 4).

Although a quantitative risk assessment approach is preferred, it is rather time consuming and there may be cases where this can not be carried out (e.g. no PEC or PNEC). In this report a quantitative frequency analysis was carried out for different types of accidents, ships, hazardous products and this for several subareas of the BPNS. The consequence assessment has however been executed for only 2 worst case scenarios. The same process could be repeated for all the identified release assessments of the different types of accidents, but this would lead us too far.

Therefore a qualitative risk assessment will be used as an alternative to estimate the overall risk of all types of shipping accidents in the Belgian Part of the North Sea. In this case, the risk characterisation shall entail a quantitative evaluation of the frequency and a qualitative evaluation of the likelihood that an effect will occur under the expected conditions of exposure. The results of the risk characterisation can be used as a base to prioritise risk reduction measures.

5.1 FREQUENCY OF EVENT

Concerning the frequency of event, the following questions can be asked:

- Where do most accidents happen?
- What type of accident?
- Which type of ship is mostly involved?

In Table 5.1 a summary is given of the relative frequency of cargo spill accidents based on the outcomes of chapter 3. First the identified subareas (SA) of the BPNS have been classified by their total cargo spill accident frequency in high, medium and low risk areas (RA). Secondly per RA a frequency classification is given per accident type.

In subarea 3, 5, 6 and 7 most accidents occur (high risk SA) (Max. SA3: every 13 years). These subareas are located closest to the coastline and characterised by either sandbank formations or by the presence of a harbour. More than 90% of the accidents in these high risk areas are due to powered groundings. The subareas 1, 2 and 8 are identified as medium risk areas. Here the main causes of accidents are ship-ship collisions and powered collisions with offshore obstacles. Subarea 1 and 2 are characterised by intense ship traffic but due to traffic separation control (IMO) and/or less abundance of hydro-morphological constraints the frequency of cargo spill accidents is relatively lower. The low risk areas (SA4, 9, 10, 11) follow the same pattern as the medium risk areas with the exception of subarea 10 where powered and drifted collisions with offshore obstacles become important. In this subarea the planned C-Power wind turbines have already been taken into account.

Table 5.1: Cargo spill accident frequency (Subarea (SA) vs accident type)
(1 = high (>25%); 2 = medium (1-25%); 3= low frequency (<1%))

	High risk SA	Medium risk SA	Low risk SA
	SA3; SA5; SA6; SA7	SA1; SA2; SA8	SA4; SA9; SA10; SA11
Collis	2	1	1
Struc	3	2	2
FEX	3	2	2
PGrd	1	3	3
DGrd	2	3	3
PPlat	3	1	3 - (1)
DPlat	3	3	3 - (1)

Table 5.2 gives the relative frequency of ship types involved in cargo spill accidents per subarea. The frequency is a reflection of the shipping transport pattern. In the main shipping lane (Westhinder TSS – Scheur) (SA1, 2, 3, 4 & SA11) oil tankers, RoRO and container ships are each responsible for about 25% of the cargo spill accidents (max. every 30 years SA3). In the high risk areas SA5, SA6 & SA7 most cargo spill accidents (approx. 70%) happen also with RoRo and oil tankers. The share of the other ship types is lower. Subarea 8 (medium RA) is a combination of subarea 9 and 10 (low RA). The proportion of RoRo increases with for SA9 a frequency of accidents with RoRo of 80%.

Table 5.2: Cargo spill accident frequency (Subarea (SA) vs ship type)
(1 = high (>20%); 2 = medium (5-20%); 3= low frequency (<5%))

	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
SA1	1	2	2	1	3	2	1	3
SA2	1	2	2	1	3	2	1	3
SA3	1	2	2	1	3	2	1	3
SA4	1	2	2	1	3	2	1	3
SA5	1	2	3	1	3	3	2	3
SA6	1	2	3	1	3	3	3	3
SA7	1	2	3	1	3	3	1	3
SA8	2	3	3	1	3	2	2	2
SA9	3	3	3	1	3	3	3	2
SA10	1	3	3	2	3	3	3	3
SA11	1	2	2	1	3	2	1	3

5.2 CONSEQUENCE OF EVENT

Concerning the consequence of event, the following questions can be asked:

- What type of accident results in the highest spill quantity?
- What type of ship results in the highest spill quantity?
- What is the most hazardous spill?

In Table 5.3 a summary is given of the relative cargo spill quantity per year per accident type and risk subarea. The outcome is comparable with Table 5.1. The most important accident types are generally leading to the highest spill quantity respectively powered groundings in the high risk subareas (max. 379 ton/yr SA3) and collisions in the medium risk areas (max. 31,5 ton/yr SA1). In the medium risk SA powered collisions with offshore obstacles (PPlat) (max. 38 ton/yr SA2) were also a main cause of cargo spill accidents, but the quantity released in this type of accidents is identified as "medium". On the other hand in the low risk subareas both collisions and structural failure are responsible for the highest quantities of cargo spills, but with a maximum spill quantity of only 4 ton/yr in SA4. Similar as was mentioned before, powered and drifted collisions are also in terms of spilled quantities important in SA 10.

Table 5.3: Cargo spill quantity (Subarea (SA) vs accident type)
(1 = high (>25%); 2 = medium (1-25%); 3= low frequency (<1%))

	High risk SA	Medium risk SA	Low risk SA
	SA3; SA5; SA6; SA7	SA1; SA2; SA8	SA4; SA9; SA10; SA11
Collis	2	1	1
Struc	3	2	1
FEX	3	3	2
PGrd	1	3	3
DGrd	2	3	3
PPlat	3	2	3-(2)
DPlat	3	3	3-(1)

Table 5.4 gives the relative cargo spill quantity per year per ship type per subarea. In general the most important ship types causing major spills are oil tankers, RoRo and container ships. In the main shipping lane (Westhinder TSS – Scheur) (SA1, 2, 3, 4 and SA11) oil tankers and container ships are jointly responsible for more than 60% of the cargo spilled. In contrast to the frequency results, the share of RoRo is here lower. In the high risk areas SA5 & SA6 the opposite pattern can be seen. Here RoRo (appr. 40 ton/yr) is the most important ship type next to the container ships. Compared to Table *5.2* the share of chemical tankers and general cargo decreases in favour of the bulk carriers.

Table 5.4: Cargo spill quantity (Subarea (SA) vs ship type)
(1 = high (>25%); 2 = medium (5-25%); 3= low frequency (<5%))

	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
SA1	1	3	2	2	3	3	1	3
SA2	1	3	2	2	2	3	1	3
SA3	1	3	3	2	2	3	1	3
SA4	1	3	2	2	3	3	1	3
SA5	2	3	2	1	3	3	1	3
SA6	2	3	2	1	3	3	2	3
SA7	1	3	3	2	2	3	1	3
SA8	2	3	3	1	3	2	1	3
SA9	3	3	3	1	3	3	3	2
SA10	1	3	3	2	2	2	1	2
SA11	1	3	2	2	3	2	1	3

Finally Table 5.5 gives the transport distribution of the different cargo types over the different ship types. Taking further into account the hazardous characteristics of the cargo types (CT1 = high; CT8 = low), the different ship types have been classified in a danger cargo class (dang class) from high (=1), over medium (=2) to low (=3). So oil tankers, chemical tankers and container ships have the highest probability of transporting the most hazardous goods.

Table 5.5: Transport distribution of cargo type per ship type
(1 = high (>10%); 2 = medium (1-10%); 3= low frequency (<1%))

	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
CT1	1	1	3	1	3	2	1	2
CT2	1	3	2	3	3	3	3	3
CT3	1	1	3	2	3	3	3	2
CT4	1	1	3	3	2	3	3	3
CT5	1	1	1	1	2	2	1	3
CT6	2	2	2	1	3	2	1	2
CT7	1	2	1	1	3	2	1	2
CT8	2	2	2	1	2	2	1	3
Dang class	1	1	2	2	3	3	1	3

5.3 RISK ESTIMATION

The overall estimation of the risk is defined as the multiplication of the consequence for each damage-causing event (Table 5.4; danger cargo class classification (Table 5.5)) with the frequency of that event (Table 5.2; high risk area classification (Table 5.1)). The risk estimation should be interpreted as follows: how lower the risk figure, how higher the risk.

Table 5.6: Overall risk estimation

	OilTan	ChemTank	GasTank	RoRo	Bulk	GenCar	Contain	Other
SA1	2	12	16	8	54	36	2	54
SA2	2	12	16	8	36	36	2	54
SA3	1	6	12	4	18	18	1	27
SA4	3	18	24	12	81	54	3	81
SA5	2	6	12	2	27	27	2	27
SA6	2	6	12	2	27	27	6	27
SA7	1	6	18	4	18	27	1	27
SA8	8	18	36	4	54	24	4	36
SA9	27	27	54	6	81	81	27	36
SA10	3	27	54	24	54	54	9	54
SA11	3	18	24	12	81	36	3	81

From Table 5.6 it is clear that

- the highest risk can be found in the high risk subareas SA3, SA5, SA6, SA7 (range once every 13 (SA3) to 43 (SA6) years) characterised by sandbank formations and/or presence of harbour (intense shipping traffic is not the determining factor (see f.ex. SA1 (every 119 yr) & SA2 (every 78 yr)) ;
- in the first place oil tankers and container ships form a high risk for almost the total BPNS due to the fact that they transport the most hazardous cargo types (60% of CT1 and 97% of CT2) and that in case of a spill accident high quantities of dangerous goods are spilled at sea (related to high transported quantities) (Max. cargo spill quantity per year in SA3: 124 ton (oil tankers) & 247 ton (container);
- secondly also chemical tankers and RoRo traffic is risk full, in particular in the high risk subareas, respectively due to the hazardous characteristics of chemical tankers (notice the low spill quantity) and a medium frequency (Max. in SA3: every 150 yr) and quantity (Max. SA3: 24 ton/yr) of accidents with RoRo ships;
- the risk from bulk, general cargo and other (passenger ships & other ships) transport is rather low.

6 EXAMINATION OF AND RECOMMENDATIONS TO EXISTING CONTINGENCY PLANS

As becomes clear from previous chapters, the Belgian maritime area is one of the busiest shipping areas in the world. In addition to the two major shipping lanes (Noordhinder and Westhinder Traffic Separation Schemes), the Belgian Part of the North Sea (BPNS) contains several ferry routes crossing the Southern North Sea. These dense traffic routes running through the often shallow BPNS creates serious risks for collisions and groundings.

To deal with emergencies at sea, a Belgian North Sea disaster plan was designed and refined during the late 1980's and early 1990's. This plan describes the organisation of a rescue at sea and operations combating pollution. The plan covers the mobilisation of all possible support units and the creation of a clear and effective coordination between the different authorities and the rescue services. However necessary, this North Sea disaster plan is limited to a general structure of an operation that is independent of the type of pollution threat. Oil or other dangerous substances are dealt with in the same framework, while guidelines or decision trees for dealing with specific cases or scenarios are not provided.

While acknowledging that a plan is never perfect, an examination and proposal for the improvement of the existing Belgian North Sea disaster plan is an objective in the RAMA project. In addition, the responsible authorities (mainly the Governor of West-Flanders) have recently picked up the idea to design a new contingency plan. This plan will take into account the recently proposed Royal Decree that provides new guidelines and uniformity for all (with a focus on land-based) emergency plans. At the same time, the RAMA risk analysis provides new insights and information that is very valuable for contingency planning for the North Sea and provides an opportunity to move forward towards a more complete plan with extended coverage.

An examination of existing contingency plans by the Maritime Institute, as well as proposals to improve the existing contingency plans, can be found in Annex 6.1.

Annex 6.1: Examination and proposals for improvement of existing contingency plans

In the text of Annex 6.1, the Belgian North Sea disaster plan is studied and compared to sea contingency plans of our neighbouring countries, which are parties to the Bonn agreement to combat pollution in the North sea along with other risks. The Tricolor case made clear that besides scenarios in sea contingency plans, international cooperation can be improved. Other problems, for example, internal cooperation, legal and political issues are also examined. Improvements identified during examination of the existing plan, and related to the results of prior RAMA risk analysis research tasks, are incorporated into a proposal for a new Belgian North Sea disaster plan. This proposal also takes into account some legal aspects that are instructive for the implementation of the plan on the field.

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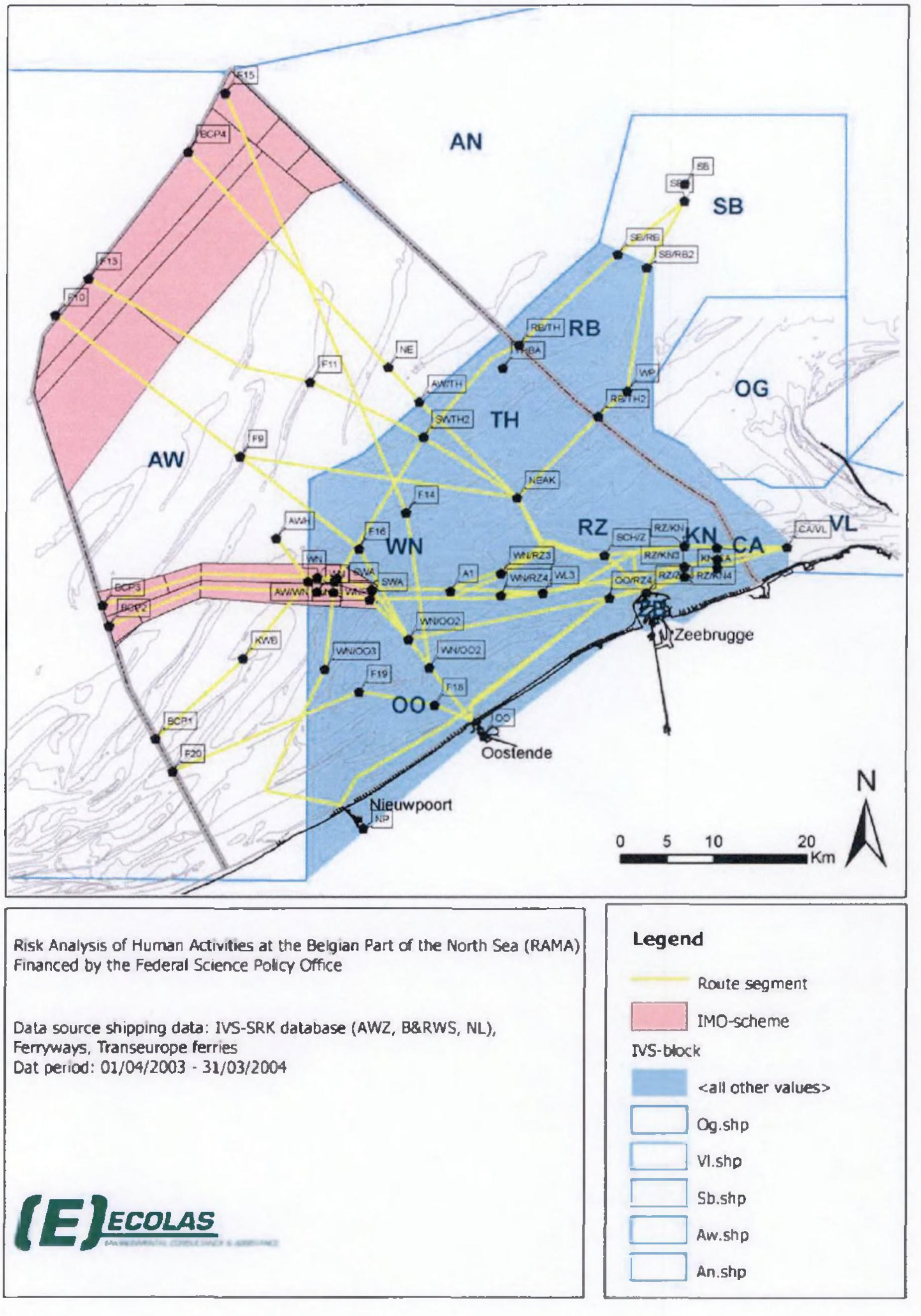
ANNEXES

Annex 2.1: Users of the Belgian Part of the North See (Maes et al, 2005)

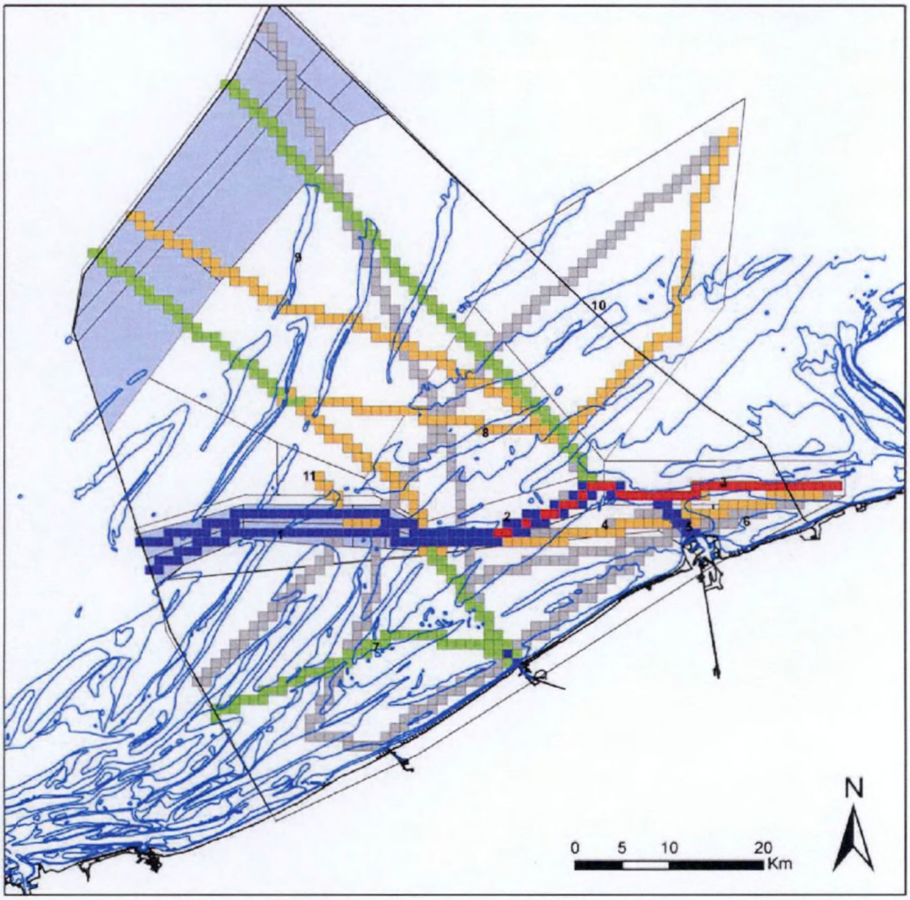
Original data source: cfr. all spatial distribution maps
Map preparation: RCMG - Ghent University

May 2005

Annex 2.2: The identified route segments on the Belgian Part of the North Sea



Annex 2.3: Geographical distribution of the ship movements (per km²) on the BPNS



Risk Analysis of Human Activities at the Belgian Part of the North Sea (RAMA)
Financed by the Federal Science Policy Office

Data source shipping data: IVS-SRK database (AWZ, B & RWS, Nl),
Ferryways, Transeuropa ferries
Data period: 01/04/2003 - 31/03/2004

Legend

Shipmovements (#/km²)

- 1 - 950
- 951 - 3110
- 3111 - 8393
- 8394 - 23880
- 23881 - 56977
- Subareas

Annex 2.4: Quantitative analysis of the different cargo types per ship type

Ship type 1: oil (crude) tankers					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	561,17	940,02	62	76	81,58%
2	39.353,98	40.076,44	1.118	1.191	93,87%
3	865,18	1.736,07	455	474	95,99%
4	9.139,93	29.444,70	12.327	12.735	96,80%
5	9.645,82	16.848,06	2.185	2.245	97,33%
6	14.238,46	128.368,10	859	909	94,50%
7	2.472,17	9.919,32	8.227	9.308	88,39%
8	4.184,98	8.967,77	943	4.366	21,60%
9	0,86	0,35	70	500	14,00%
10	3.518,55	6.247,20	185	5.580	3,32%
Ship type 2: Chemical tankers + refined					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	1.305,60	1.659,26	53	61	86,89%
3	400,67	559,52	110	110	100,00%
4	4.741,99	9.164,92	2.188	2.303	95,01%
5	1.494,78	2.495,06	939	967	97,10%
6	1.355,93	1.244,07	471	495	95,15%
7	1.846,45	2.811,03	4.660	4.934	94,45%
8	1.455,46	1.901,61	555	1.671	33,21%
9	0,96	0,20	24	154	15,58%
10	4.247,31	7.151,67	123	2.648	4,65%
Ship type 3: Gas tankers					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	200,00	0,00	1	1	100,00%
2	1.206,69	200,21	26	26	100,00%
5	880,49	1.192,18	1.011	1.027	98,44%
6	5.780,70	6.983,53	1.078	1.099	98,09%
7	5.361,35	34.499,98	11.565	12.516	92,40%
8	349,44	614,03	52	1.291	4,03%
9	0,00	0,00	0	41	0,00%
10	14,00	0,00	1	1.654	0,06%

Annex 2.4: Quantitative analysis of the different cargo types per ship type (continued)

Ship type 4: RoRo + car carriers + Ropax					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	11,38	18,22	82	97	84,54%
2	2,00	0,00	1	1	100,00%
3	1.800,00	0,00	4	4	100,00%
4	13,52	16,35	9	9	100,00%
5	32,24	404,36	526	714	73,67%
6	215,47	1.932,04	2.624	4.218	62,21%
7	367,05	2.792,49	7.667	19.883	38,56%
8	1.640,22	9.874,46	2.318	16.749	13,84%
9	0,00	0,00	3	26	11,54%
10	0,00	0,00	0	68.559	0,00%
Ship type 5: Bulk carriers					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
4	39.185,16	32.807,37	812	823	98,66%
5	30.282,56	29.417,57	57	57	100,00%
7	31.441,80	36.029,97	237	383	61,88%
8	33.027,03	24.049,64	61	358	17,04%
10	17.194,77	11.979,70	26	15.879	0,16%
Ship type 6: General cargo + reefers					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	291,00	305,56	15	22	68,18%
4	3.783,80	3.291,78	99	99	100,00%
5	211,15	2.412,82	322	332	96,99%
6	10,62	15,27	82	123	66,67%
7	1.632,23	9.993,01	1.527	2.367	64,51%
8	3.402,52	11.330,88	127	5.301	2,40%
9	0,00	0,00	0	1	0,00%
10	2.969,00	431,78	3	75.634	0,00%

Annex 2.4: Quantitative analysis of the different cargo types per ship type (continued)

Ship type 7: Containers					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	167,84	764,64	177	205	86,34%
4	141,51	211,08	28	35	80,00%
5	3.158,94	11.359,45	577	658	87,69%
6	2.537,39	41.066,71	3.319	3.861	85,96%
7	2.812,42	47.293,77	9.858	12.299	80,15%
8	598,14	884,87	515	20.000	2,58%
9	8,50	0,00	7	14	50,00%
10	15.000,00	0,00	1	25.086	0,00%
Ship type 8: Others + passenger ships					
Cargo class	Avg quantity/ CTSMRS (ton)	Stdev quantity/ CTSMRS (ton)	# CTSMRS quantity data	total # CTSMRS	% known data
1	0,40	0,00	7	7	100,00%
3	216,67	125,00	9	9	100,00%
4	2.500,00	0,00	1	1	100,00%
5	12,13	16,57	21	25	84,00%
6	128,87	343,37	44	220	20,00%
7	308,78	1.674,52	263	1.927	13,65%
8	169,00	63,07	8	325	2,46%
10	0,00	0,00	0	28.332	0,00%

Annex 2.5: Average & total quantities (tons) of cargo type 1

Ship type 1	Un nr	IMO	# voyages	total quant/ voyage (ton)	avg quant/ voyage (ton)
Calciumarsenate, calciumarsenite, mixture, solid	1574	6.1	1	3.000,00	3.000,00
Acetone cyanohydrin	1541	6.1	1	1.300,00	1.300,00
Calciumcyanide	1575	6.1	1	624,00	624,00
Linear alkylbenzene		Cat A	1	600,00	600,00
1,2,4-Trichlorobenzen	2321	6.1	1	500,00	500,00
Tetrachloroethylene	1897	6.1	4	358,70	119,57
1-Pentanethiol	1111	3	2	321,00	160,50
Coal tar		9	2	1,00	1,00
(empty)		Cat A	1	1,00	1,00
1,5,9- Cyclododecatriene	2518	6.1	1		
(empty)	1143	3	2		
Ship type 2	Un nr	IMO	# voyages	total quant/voyage (ton)	avg quant/ voyage (ton)
Coal tar		9	3	4.920,00	1.640,00
Butanedione	2346	3	1	1.500,00	1.500,00
Aceton cyanohydrin	1541	6.1	2	1.000,00	500,00
1-Pentanethiol	1111	3	1	750,00	750,00
Trichlorobenzene	2321	6.1	1	500,00	500,00
Motor fuel anti-knock mixture	1649	6.1	1	500,00	500,00
Mercurysulfide, natural	2025	6.1	1	1,00	1,00
Tetrachloroethylene	1897	6.1	2		
Ship type 4	Un nr	IMO	# voyages	total quant/voyage (ton)	avg quant/ voyage (ton)
Chlorine	1017	2.3	18	152,59	10,90
Butanedione	2346	3	1	0,10	0,10
Ship type 7	Un nr	IMO	# voyages	total quant/voyage (ton)	avg quant/ voyage (ton)
Chlorine	1017	2.3	26	4.218,59	162,25
?	3019	non consis tent	1	15,27	15,27
?	1064	2.3	1	5,39	5,39

Annex 2.6: Average & total quantities (tons) of cargo type 2

Ship type 1	Un nr	IMO	# voyages	total quant/voyage (ton)	avg quant/ voyage (ton)
REBCO crude oil	1267	3	2	203.455,00	101.727,50
Crude oil, flashpoint > 60F		oil	1	95.986,00	95.986,00
Crude oil	1202	3	1	89.214,00	89.214,00
Asgard crude oil		oil	1	80.330,00	80.330,00
Crude oil	1267	3	1	63.560,00	63.560,00
Petroleum crude oil with a flashpoint ≥ 23°C & < 0	1267	3	27	1.420.578,00	61.764,26
?	1267	3	61	1.793.452,25	45.985,96
Crude oil		3	13	395.618,00	39.561,80
Petroleum crude oil with a flashpoint < 23°C	1267	3	45	1.409.483,00	37.091,66
Crude		crud e	3	107.117,00	35.705,67
Crude oil (bulk)		oil	1	34.898,00	34.898,00
Crude benzene		crud e	1	3.469,00	3.469,00
Crude oil		3	1	1,00	1,00
Crude oil		3.1	1	1,00	1,00

Annex 3.1: Incidents in the BPNS and neighbouring waters (period 1960-2003)

Name of ship	Year	Country	Chemical product	Spilled quantity (ton)
Esso Wandsworth	1965	Great Britain	fuel oil	5.000
Seestern	1966	Great Britain	Nigerian light crude oil	1.700
Sitakund	1968	Great Britain	bunker and ballast	500
Monte Ulia	1970	Great Britain	crude oil, fuel oil	500
Pacific Glory	1970	Great Britain	Nigerian light crude oil	5.000
Hullgate	1971	Great Britain	oil	600
Texaco Caribbean	1971	Great Britain	bunker and ballast	600
Olympic Alliance	1975	Great Britain	Iranian light crude oil	10.000
Pacific Colocotronis	1975	Netherlands	light crude oil	1.500
Eleni V	1978	Great Britain	heavy fuel oil	5.000
Sindbad	1979	Netherlands	chlorine	30
Mont Louis	1984	Belgium	uranium hexafluoride	0
Herald of Free Enterprise	1987	Belgium	100 different chemicals (TDI, cyanides, hydroquinone, toluene, lead, etc.)	24
Skyron	1987	France	fuel oil	?
Anna Broere	1988	Netherlands	acrylonitrile (DE), dodecylbenzene (F)	700
Serafina	1990	Netherlands	oil	300
Korsnäs Link	1991	Great Britain	sodium chlorate	40
Amer Fuji/ Meritas	1992	Belgium	oil	225
Westhinder 'incident'	1992	Belgium	oil	170
Cast muskox/long lin	1992	France	oil	190
?	1992	Netherlands	chlorhydric acid	?
Ariel	1992	Netherlands	white spirit	?
Davidgas/athos	1992	Netherlands	oil	10
British Trent/ Western Winner	1993	Belgium	unleaded gasoline	5.100
Sherbro	1993	France	pesticides	?
Aya	1993	Netherlands	oil	15
Carina/ MSC Samia	1995	Belgium	oil	45
Spauwer	1995	Belgium	oil	10
?	1996	Netherlands	aluminium phosphate	?
Mundial Car/Jane	1997	Belgium	oil	20
Rosa M	1997	France	hazardous materials	?
Bona Fulmar/ Teoatl	1997	France	gasoline	7.000

Name of ship	Year	Country	Chemical product	Spilled quantity (ton)
Vigdis Knutsen/ Saint Josse	1997	France	risk oil	0
Apus	1998	Netherlands	flammable solids (fire lighters)	?
Ban-Ann	1998	Netherlands	sulfur-phosphine	?
Dart 2	1998	Netherlands	methane sulphon acid	?
European Tideway	1998	Netherlands	detergent agent (alkyl phenol ether phosphate (OLETH 20)	?
Ever Decent/ Norwegian Dream	1999	Great Britain	hazardous materials	?
Adelaide/ Saar Ore	2000	Belgium	oil	10
China Prospect/ Veerseborg	2001	Belgium	coal	?
"Noordpas" incident	2001	Belgium	oil	10
Heinrich Behrman	2001	Belgium	risk oil	?
Music/ Vera	2001	Belgium	oil	20
St Jacques/ Gudermes	2001	Great Britain	oil	100
Tricolor/ Kariba/ Alphonse Letzer	2002	France	fuel (IFO 380)	500
Vicky	2003	Belgium	fuel oil, diesel oil	?

Annex 3.2: Description of the Marcs model

APPENDIX I

DESCRIPTION OF THE MARCS MODEL

Contents

I. DESCRIPTION OF THE MARCS MODEL

I.1 BACKGROUND

Transportation by sea using conventional shipping operations results in both economic benefits and associated ship accident risks, which can result in safety and environmental impacts. Analysis of historical ship accident data indicates that almost all open-water shipping losses (excepting causes such as war or piracy) can be categorised into the following generic accident types:

- Ship-ship collision;
- Powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the *Exxon Valdez*);
- Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the *Braer*);
- Structural failure/ foundering whilst underway;
- Fire/ explosion whilst underway;
- Powered ship collision with fixed marine structures such as platforms or wind turbines (similar definition to powered grounding);
- Drifting ship collision with fixed marine structures such as platforms or wind turbines (similar definition to drift grounding).

These generic accident types effectively represent the results of a high level marine transportation hazard identification (HAZID) exercise and are applicable for most marine transportation systems. However, each marine risk analysis should consider if additional locally specific accident modes apply. For example, in Prince William Sound, Alaska laden oil tankers are tethered to a tug for part of the transit to mitigate grounding accidents. However, the presence of the tug also introduces an extra accident mode (tanker grounds because tug actions are inappropriate). The presence or absence of such additional geographically specific accident modes should be verified on a project specific basis.

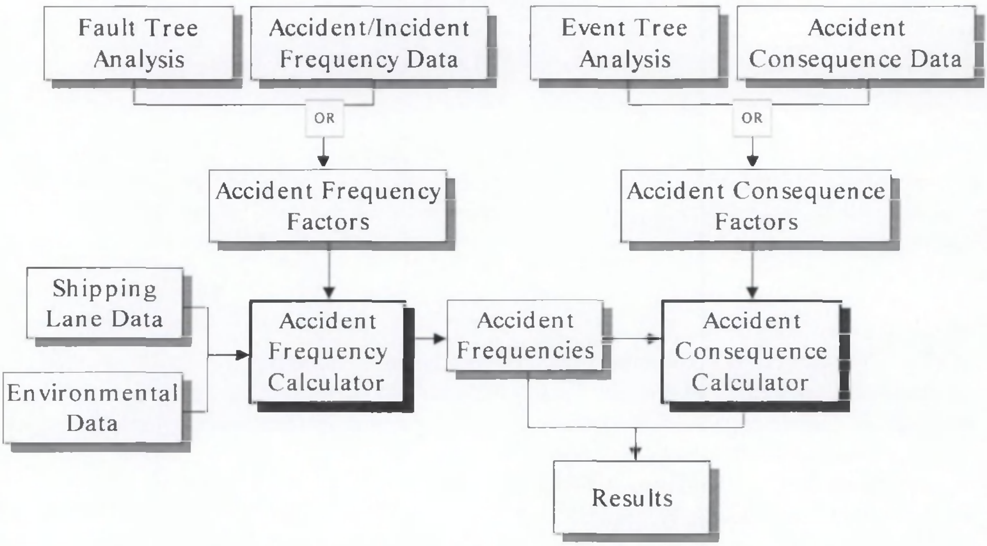
Marine transport risk analysis can be performed by assessing the frequency of the above accident types, followed by an assessment of the accident consequences, typically in terms of cargo spill, lives lost or in financial terms. DNV has developed the MARCS model to perform such marine transport risk analyses in a structured manner. The risk analysis results can then be assessed to determine if the estimated risks are acceptable or if risk mitigation is justified or required (risk assessment).

I.2 Introduction to MARCS

1.2.1 Overview

The Marine Accident Risk Calculation System (MARCS) was developed by DNV to support our marine risk management consultancy business. The MARCS model provides a general framework for the performance of marine risk calculations. A block diagram of the model is shown in Figure I.1.

Figure I.1 Block Diagram of MARCS



The MARCS model classifies data into 4 main types:

- Shipping lane data describes the movements of different marine traffic types within the study area;
- Environment data describes the conditions within the calculation area, including the location of geographical features (land, offshore structures etc) and meteorological data (visibility, windrose, currents and seastate);
- Internal operational data describes operational procedures and equipment installed onboard ship – such data can affect both accident frequency and accident consequence factors;
- External operational data describes factors external to the ship that can affect ship safety, such as VTMS (Vessel Traffic Management Systems), TSS (Traffic Separation Schemes), and the location and performance of emergency tugs – such data can affect both accident frequency and accident consequence factors.

As indicated in Figure I.1, accident frequency and consequence factors can be derived in two ways. If a coarse assessment of accident risk is required, the factors may be taken from worldwide historical accident data. Alternatively, if a more detailed study is required, these factors may be derived from generic fault trees or event trees which have been modified to take account of specific local factors.

I.2.2 Critical Situations

MARCS calculates the accident risk in stages. It first calculates the location dependent frequency of critical situations (the number of situations which could result in an accident – "potential accidents" – at a location per year; a location is defined as a small part of the study area, typically about 1 nautical mile square, but depending on the chosen calculation resolution). The definition of a critical situation varies with the accident mode, see Section I.4. MARCS then assesses the location dependent frequency of serious accidents for each accident mode via "probability of an accident given a critical situation" parameters. A "serious accident" is defined by Lloyds as any accident where repairs must be made before the ship can continue to trade. Finally, the location dependent accident consequence, and hence risk, is assessed.

Analysis of these results for a specified area or trade enables the derivation of conclusions and recommendations on topics such as risk acceptability, risk reduction measures and cost-benefit analysis of alternative options.

I.2.3 Fault Tree Analysis

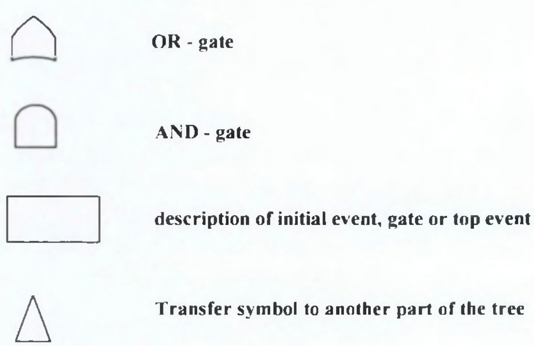
Fault tree analysis (see, for example, Henley E.J. and Kumamoto H., 1981 or Cooke R.M., 1995) can be described as an analytical technique, whereby an undesired state of a system is specified, and the system is then analysed in the context of its environment and operation to find all credible ways in which the undesired event can occur. This undesired state is referred to as the top event of the fault tree. It expresses the frequency or probability for the occurrence of this event or incident.

The basic events of a fault tree are those events that make up the bottom line of the fault tree structure. To perform calculations of the top frequency or probability of a fault tree, these basic events needs to be quantified.

The fault tree structure is built up by basic events, and logical combinations of these events which are expressed by AND and OR gates. The output of these gates are new events, which again may be combined with other events/basic events in new gates. The logic finally results in the top event of the fault tree. For example, fire occurs if combustible material AND air/oxygen AND an ignition source is present.

The different symbols in the fault tree are defined in Figure I.2.

Figure I.2 Fault tree symbols

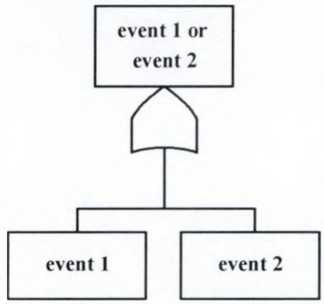


The OR gate, see Figure I.3, expresses the probability of occurrence of event 1 or event 2, and is calculated as the sum minus the intersection of the two events;

$$P(\text{event 1 OR event 2}) = P1 + P2 - P1*P2$$

Usually the intersection probability can be neglected, as it will be a very small number (if P1 = P2 = 10^{-2}, then P1*P2 = 10^{-4}).

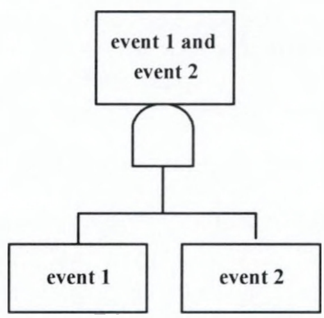
Figure I.3: OR - gate



The AND gate, see Figure I.4, expresses the probability that event 1 and event 2 occur simultaneously, and is calculated as the product of the two events;

$$P(\text{event 1 AND event 2}) = P1*P2$$

Figure I.4: AND - gate



It should be emphasised that the quality of the results produced by fault tree analysis is dependent on how realistically and comprehensively the fault tree model reflects the causes leading to the top event. Of course, it is never possible to fully represent reality, and therefore the models will always only represent a simplified picture of the situation of interest. The top event frequencies will generally be indicative, and hence relative trends are more secure than the absolute values.

Fault tree models have been constructed to assess a number of parameters within MARCS, including collision per encounter probabilities (collision model) and failure to avoid a powered grounding given a critical situation probabilities (powered grounding model) (SAFECO I; SAFECO II).

I.3 Data used by MARCS

I.3.1 Traffic Image Data

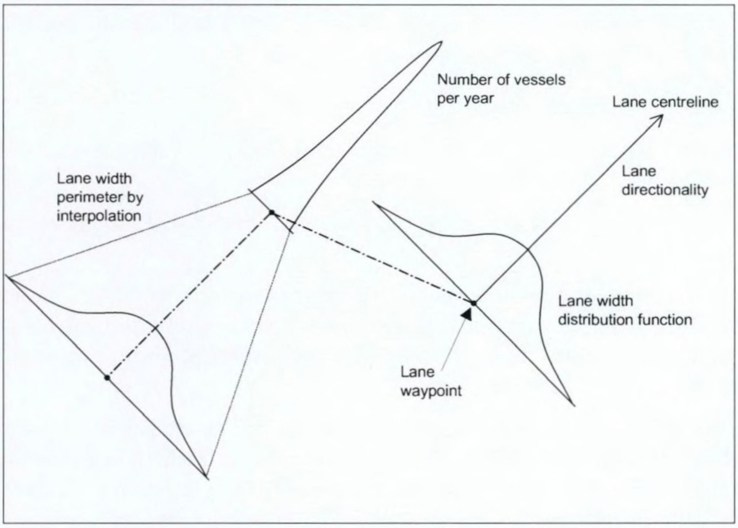
The marine traffic image data used by MARCS is a representation of the actual flows of traffic within the calculation area. Marine traffic data is represented using lane data structures. Different traffic types are divided into separate marine databases in order to facilitate data verification and the computation of different types of risk (for example, crude oil spill risk versus human safety).

A typical traffic lane is shown in Figure I.5. The following data items are defined for all lanes:

1. The lane number (a unique identifier used as a label for the lane);
2. The lane width distribution function (Gaussian or truncated Gaussian);
3. The lane directionality (one-way or two-way);
4. The annual frequency of ship movements along the lane;
5. A list of waypoints, and an associated lane width parameter at each waypoint;
6. The vessel size distribution on the lane.

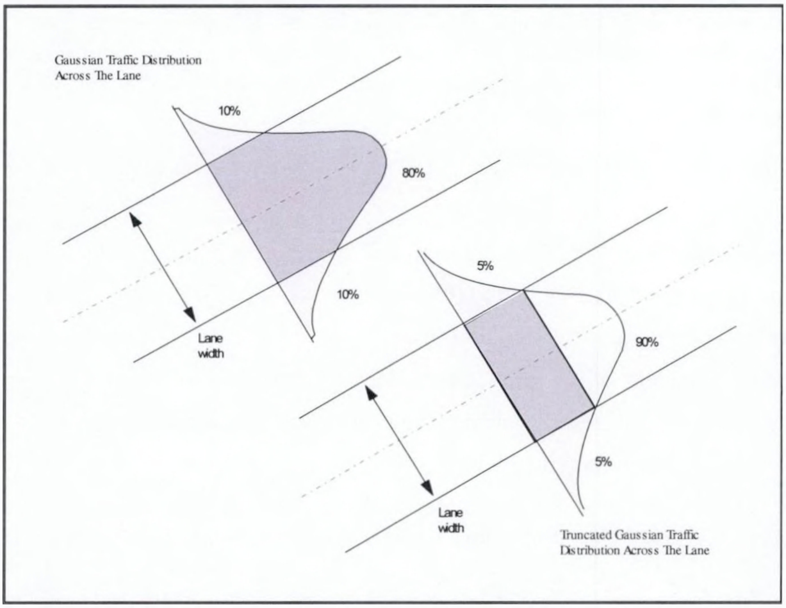
Additional data may be attached to the lane, such as: the hull type distribution (single hull, double hull, etc) for tankers; the loading type (full loading, hydrostatic loading) for tankers; ship type etc.

Figure I.5 Shipping Lane representation used in MARCS



Detailed surveys of marine traffic in UK waters in the mid 1980s (e.g. HMSO, 1985) concluded that commercial shipping follows fairly well defined shipping lanes, as opposed to mainly random tracks of individual ships. Further detailed analysis of the lanes showed that the lateral distribution across the lane width was approximately Gaussian, or truncated Gaussian for traffic arriving in coastal waters from long haul voyages (e.g. from the US or Canada). The shipping lane distributions used in MARCS are shown in Figure I.6.

Figure I.6 Shipping Lane Width Distribution Functions used in MARCS



The marine traffic description used by MARCS is completed by the definition of four additional parameters for each type of traffic:

1. Average vessel speed (generally 8 to 18 knots);
2. Speed fraction applied to faster and slower than average vessels (generally plus/minus 20%);
3. Fraction of vessels travelling faster and slower than the average speed (generally plus/minus 20%);
4. Fraction of vessels that exhibit "rogue" behaviour (generally set to 0%, though historical accident data in many geographical areas shows a small proportion of (usually) smaller vessels undergo accidents through lack of watch keeping (bridge personal absent or incapacitated)).

A rogue vessel is defined as one that fails to adhere (fully or partially) to the Collision Avoidance Rules (Cockcroft, 1982). Such vessels are assumed to represent an enhanced collision hazard. These four parameters can be specified as a function of location within the study area for each traffic type.

The marine traffic image is made up by the superposition of the defined traffic for each contributing traffic type.

I.3.2 Internal Operational Data

Internal operational data is represented within MARCS using either worldwide data or frequency factors obtained from fault tree analysis or location specific survey data. Fault tree parameters take into consideration factors such as crew watch-keeping competence and internal vigilance (where a second crew member, or a monitoring device, checks that the navigating officer is not incapacitated by, for example, a heart attack). Examples of internal operational data include:

1. The probability of a collision given an encounter;
2. The probability of a powered grounding given a ship's course is close to the shoreline;
3. The frequency (per hour at risk) of fires or explosions.

Internal operational data may be defined for different traffic types and/ or the same traffic type on a location specific basis.

I.3.3 External Operational Data

External operational data generally represents controls external to the traffic image, which affect marine risk. In MARCS it relates mainly to the location of VTS zones (which influence the collision and powered grounding frequencies by external vigilance, where external vigilance means that an observer external to the ship may alert the ship to prevent an accident) and the presence and performance of emergency towing vessels (tugs) which can save a ship from drift grounding.

I.3.4 Environment Data

The environment data describes the location of geographical features (land, offshore structures etc.) and meteorological data (visibility, wind rose, sea currents and seastate).

Poor visibility arises when fog, snow, rain or other phenomena restricts visibility to less than 2 nautical miles. It should be noted that night-time is categorised as good visibility unless fog, for example, is present.

Windrose data is defined within 8 compass points (north, north-east, east etc) in 4 wind speed categories denoted: calm (0 – 20 knots); fresh (20 to 30 knots); gale (30 to 45 knots); and storm (greater than 45 knots). Seastate (wave height) within MARCS is inferred from the windspeed and the nature of the sea area (classified as sheltered, semi-sheltered or open water).

Sea currents are represented as maximum speeds in a defined direction within an area.

I.4 Description of Accident Frequency Models

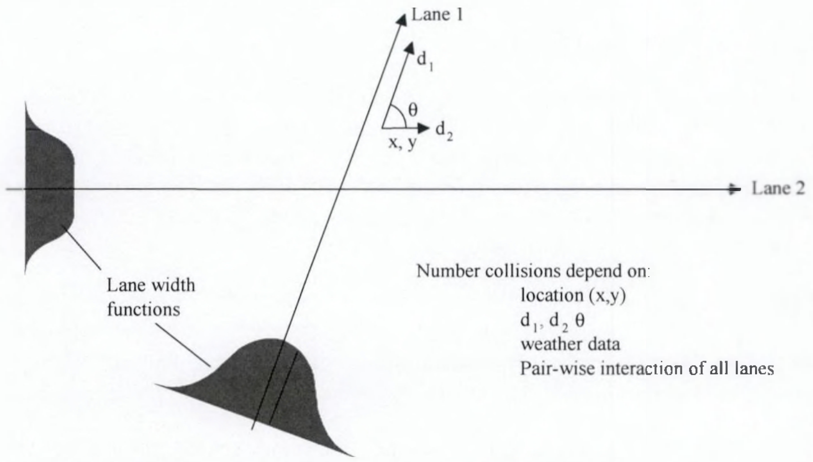
The section describes how MARCS uses the input data (traffic image, internal operational data, external operational data and environment data) to calculate the frequency of serious accidents in the study area.

I.4.1 The Collision Model

The collision model calculates the frequency of serious inter-ship powered collisions at a given geographical location in two stages. The model first estimates the frequency of encounters (critical situations for collision - when two vessels pass within 0.5 nautical miles of each other) from the traffic image data using a pair-wise summation technique, assuming no collision avoiding actions are taken. This enables the calculation of either total encounter frequencies, or encounter frequencies involving specific vessel types.

The model then applies a probability of a collision for each encounter, obtained from fault tree analysis, to give the collision frequency. The collision probability value depends on a number of factors including, for example, the visibility or the presence of a pilot. Figure I.7 shows a graphical representation of the way in which the collision model operates.

Figure I.7 Graphical representation of the collision model



Frequency = (Frequency of encounters) x (probability of collision given an encounter)

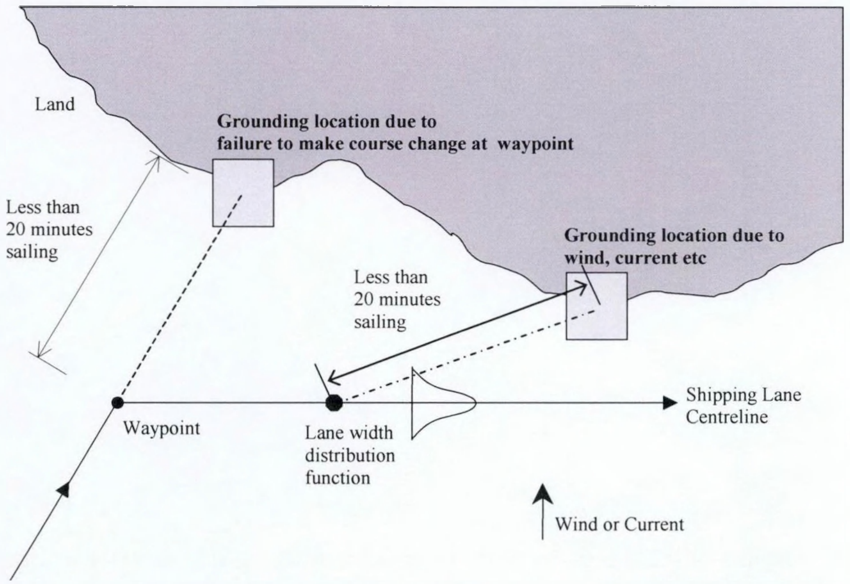
In Figure I.7, d_1 refers to the density of traffic associated with lane 1 at the location x,y. The frequency of encounters at location x,y through the interaction of lanes 1 and 2 is proportional to the product of d_1, d_2 and the relative velocity between the lane densities.

I.4.2 The Powered Grounding Model

The powered grounding frequency model calculates the frequency of serious powered grounding accidents in two stages. The model first calculates the frequency of critical situations (sometimes called "dangerous courses" for powered grounding accidents). Two types of critical situation are defined as illustrated in Figure I.8. The first critical situation arises when a course change point (waypoint) is located such that failure to make the course change would result in grounding within 20 minutes navigation from the planned course change point if the course change is not made successfully. The second critical situation results when a grounding location is within 20 minutes navigation of the course centreline. In this case crew inattention combined with wind, current or other factors could result in a powered grounding.

The frequency of serious powered groundings is calculated as the frequency of critical situations multiplied by the probability of failure to avoid grounding.

Figure I.8 Graphical representation of the powered grounding model



The powered grounding probabilities are derived from the fault tree analysis of powered grounding. The powered grounding fault tree contains 2 main branches:

1. Powered grounding through failure to make a course change whilst on a dangerous course. A dangerous course is defined as one that would ground the vessel within 20 minutes if the course change were not made.
2. Powered grounding caused by crew inattention and wind or current from the side when the ship lane runs parallel to a shore within 20 minutes sailing.

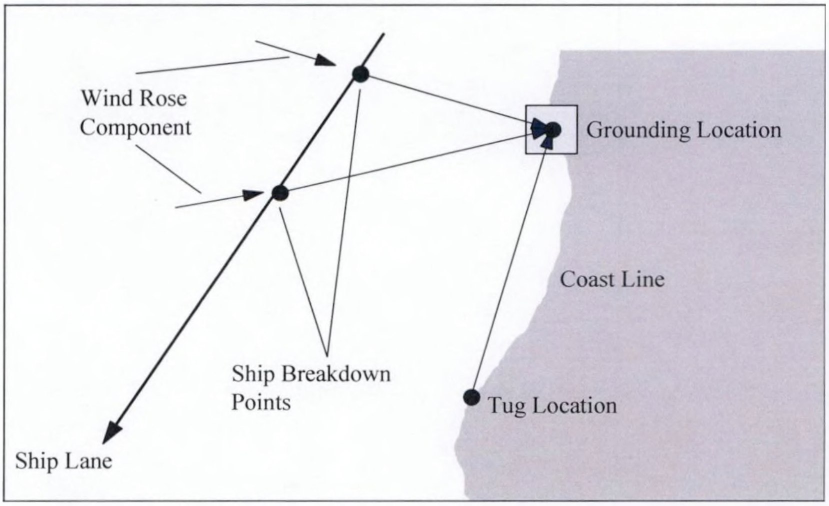
Both these branches are illustrated in Figure I.8. The powered grounding frequency model takes account of internal and external vigilance, visibility and the presence of navigational aids (radar) in deducing failure parameters.

I.4.3 The Drift Grounding Model

The drift grounding frequency model consists of two main elements as follows: first, the ship traffic image is combined with the ship breakdown frequency factor to generate the location and frequency of vessel breakdowns; second, the recovery of control of drifting ships can be regained by one of 3 mechanisms: a) repair, b) emergency tow assistance, or c) anchoring. Those drifting ships that are not saved by one of these three mechanisms (and do not drift out into the open sea) contribute to the serious drift grounding accident frequency results.

The number and size distribution of ships which start to drift is determined from the ship breakdown frequency, the annual number of transits along the lane and the size distribution of vessels using the lane. The proportion of drifting vessels which are saved (fail to ground) is determined from the vessel recovery models. The drift grounding frequency model is illustrated in Figure I.9.

Figure I.9 Graphical representation of the drift grounding model

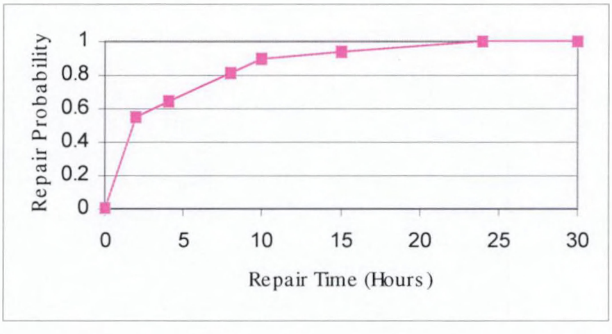


Implicit in Figure I.9 is the importance of the time taken for the ship to drift aground. When this time is large (because the distance to the shore is large and/or because the drift velocity is small) then the probability that the ship will recover control before grounding (via repair or tug assistance) will be increased.

Repair Recovery Model

Vessels which start to drift may recover control by effecting repairs. For a given vessel breakdown location, grounding location and drift speed there is a characteristic drift time to the grounding point. The proportion of drifting vessels which have recovered control by self-repair is determined from this characteristic drift time and the distribution of repair times.

Figure I.10 Graphical representation of the self repair save mechanism



Recovery of Control by Emergency Tow

Drifting vessels may be brought under control (saved from grounding) by being taken in tow by an appropriate tug. It should be noted that the tug save model assumes a save is made when the ship is prevented from drifting further towards the shoreline by the attachment of a suitable tug. In practice, two or more tugs would be required to complete the ship save, by towing the vessel to a safe location, but this aspect of the save is not modelled in MARCS.

Two types of tug can be represented within MARCS. Close escort tugs move with ships through their transit, thus their time to reach a drifting ship is always small. Pre-positioned tugs are located at strategic points around the study area. The model works by calculating for each tug:

- If the tug can reach the drifting vessel in time to prevent it grounding. This time consists of the time to reach the ship (almost zero when close escorting) and the time to connect and take control of the ship (which is a function of seastate);
- If the tug can reach the ship before it grounds, then the adequacy of the tug with regard to control of the ship is evaluated. (The presence of several tugs of differing power is assumed to be represented by the presence of one tug of the largest power. This is because only one tug is usually used to exert the main "saving" pull. Other tugs present are used to control the heading of the disabled ship, and to bring the ship to a safe location.)
- When several tugs of various capabilities can reach the drifting ship in time, then the tug with the best performance is assumed to be connected to the ship and takes control of the largest proportion of the drifting vessels.

The tug model contains parameters to take explicit account of:

- The availability of the tug (some tugs have other duties);
- The tugs response time (delay before assistance is summoned);
- The tug speed (as a function of seastate);
- The time to connect a line and exert a controlling influence on the ship (as a function of seastate);
- The performance of the tug (identified as the maximum control tonnage for the tug) as a function of wind speed and location (since the wind speed and the fetch control sea state).

Tug performance parameters can take account of ship wind and wave resistance, tug wind and wave resistance and tug length and propulsion arrangement (open versus nozzle) which influences the propulsion efficiency.

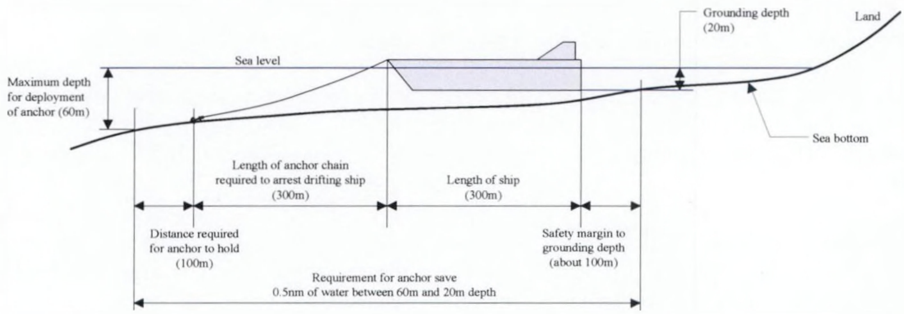
Recovery of Control by Anchoring

The anchor save model is derived with reference to the following reasoning:

1. Anchoring is only possible if there is a sufficient length of suitable water to prevent the ship running aground. Suitable water is defined as a depth of between 30 fathoms (about 60m - maximum for deployment of anchor) and 10 fathoms (about 20m - minimum for ship to avoid grounding). Sufficient length is calculated as 100m for anchor to take firm hold of the seabed + 300m to stop ship + 300m for length of ship + 100m for clearance = 800m, or 0.5 nautical miles (to be slightly conservative).

2. If such a track exists, then the probability that the anchor holds is calculated as a function of the wind speed and the sea bottom type (soft sea beds consist predominantly of sands, silts and muds). If the anchor hold, then an anchor save is made.

Figure I.11 Graphical representation of the Anchor save mechanism



The anchor save model is conservative in that it under-predicts the effectiveness of this save mechanism for average and smaller ships.

I.4.4 The Structural Failure Model

The structural failure/foundering accident frequency model applies accident frequency parameters derived from accident data or fault tree analysis with calculations of the ship exposure time to obtain the serious accident frequency. The structural failure/foundering parameters take account of the greater structural strength of some hull designs, such as double hulled vessels.

The total ship exposure time (number of vessel hours) in any area for a given wind speed category (used by MARCS to infer the seastate) can be calculated from the traffic image parameters (locations of lanes, frequencies of movements and vessel speeds) and the local wind speed parameters. The serious structural failure/foundering frequency is then obtained by multiplying these vessel exposure times by the appropriate structural failure frequency factor for the wind speed (seastate) category.

I.4.5 The Fire and Explosion Model

The fire/explosion accident frequency model applies the accident frequency parameters derived from accident data or fault tree analysis with calculations of the ship exposure time to obtain the serious accident frequency. The total ship exposure time (number of vessel hours) in any area can be calculated from the traffic image parameters (locations of lanes, frequencies of movements and vessel speeds). The fire/explosion serious accident frequency is then obtained by multiplying these vessel exposure times by the appropriate fire/explosion frequency factor (accidents per ship-hour). It should be noted that fire/explosion frequency factors assumed to be independent of environmental conditions outside the ship.

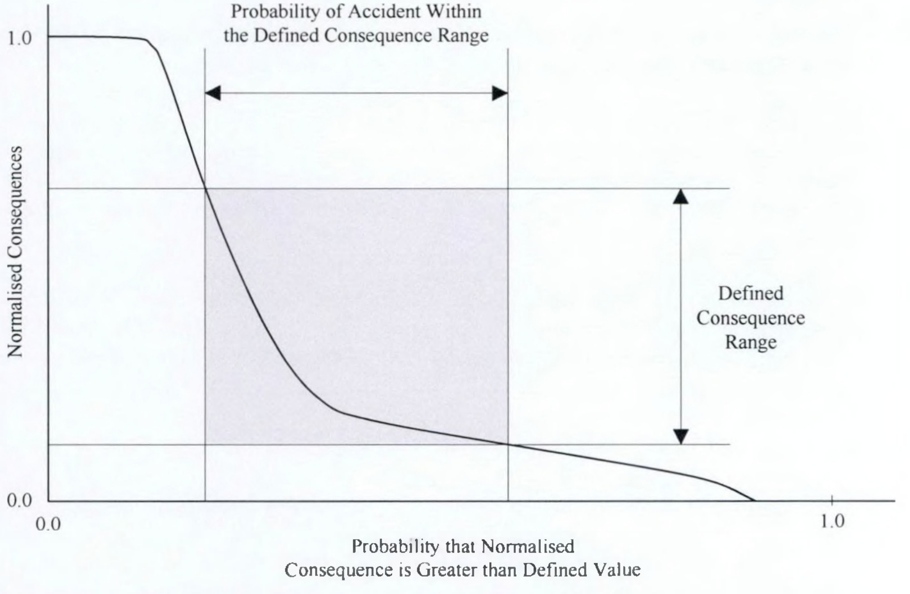
I.5 Generic Description Of Accident Consequence Models

Marine transport risks are estimated by combining the frequencies of serious accidents with the accident consequences, given a serious accident. Marine accident consequences are typically expressed in terms of cargo spilled, lives lost or financial loss.

Previous projects performed by DNV have developed crude oil outflow models for different accident types (collision, fire/explosion etc) and different hull configurations (single hull, double hull etc). These models (normalised cumulative probability distributions) take the generic form shown in Figure I.12. The curve shows the normalised consequence (in terms of, for example, cargo mass outflow into the environment) versus the probability that the consequence is greater than this value. Thus the normalised consequence of 1.0 (equal to total loss of all cargo carried) occurs for relatively low probabilities, whereas the probability that the normalised consequence is greater than a small fraction of the cargo carried generally approaches 1.0 for single hulled ships.

DNV has also developed bunker fuel oil spill models for all ship types, using a similar form to that shown in Figure I.12. It should be noted that, in general, double hulled ships do not have "double skin" protection for their bunker fuel.

Figure I.12 Generic Accident Consequence versus Probability Curve



I.6 Model Ehancements Made For The RAMA Project

In order to meet the objectives of the RAMA project DNV has made the following changes and enhancements to the MARCS model.

- MARCS has been amended to better represent areas of shallow water and the grounding behaviour of mixed lanes of deep and shallow draft ships;
- MARCS has been amended so that different cargo types can be transported by ships of the same ship type;

- The need for revised and extended cargo spill models has been considered.

These amendments are described in this section.

In the calculation control file a new location descriptor has been introduced to represent the shallow water grounding line. Only ships of draft greater than the depth of the shallow water can ground on a shallow water location, whereas all ships will ground on a coastal location (assuming that the sea bottom rises sufficiently fast that a shallow water location cannot be represented separately).

A new label has been attached to each shipping lane to represent the cargo type that is transported by the lane. This label is used by the accident consequence calculation so that the consequence calculation can be performed on for each cargo type separately (10 types of cargo are defined, see Appendix II. Bunker fuel oil spills directly from the fuel tanks are also calculated separately).

During previous studies (SAFECO I, SAFECO II) DNV has established oil outflow models for spillage of hydrocarbon products from tanker ships, and for spillage of bunker oil from bunker fuel tanks. The bunker fuel outflow models are assumed to be directly applicable to all ship types without modification.

DNV's current outflow of hydrocarbon cargo from tankers are assumed to be directly applicable to oil tankers and chemical tankers (ship types 1 and 2).

DNV do not have specific gas outflow models for gas tankers (ship type 3). Such tankers are less likely to release cargo compared to conventional tankers because of the pressure vessel, but if a puncture does occur then more cargo will be released because of the excess pressure. On balance gas outflows are calculated from the liquid hydrocarbon models for double hulled crude tankers.

DNV do not have specific cargo loss models for the remaining ship types (ro-ro/ car ferry, bulk carrier, general cargo, container ships, passenger ships/ other). It is anticipated that for each of these ship types the liquid hydrocarbon outflow models will over-estimate the cargo loss for the following reasons:

- Liquid cargos will "flow" more than the cargos in ship types 4 to 8;
- The proportion of dangerous cargo relative to the deadweight capacity in a ro-ro, container ship etc is likely to be less than for a crude oil tanker (data for container ships suggests that only 10% of all containers carry dangerous goods).

However, in the absence of better alternative data, DNV apply the liquid hydrocarbon cargo outflow models to ship types 4 to 8 as a conservative assumption.

I.7 References

Cockcroft, 1988: "A guide to the collision avoidance rules", Cockcroft, A N and Lameijar J N F, Stanford Maritime, 1982.

Cooke R.M., 1995: "Methods and Code for Uncertainty Analysis", UNICORN, AE Technology, TUDelft,

Henley E.J., Kumamoto H., 1981: "Reliability Engineering and Risk Assessment", Prentice-Hall Inc.

HMSO, 1985: "Shipping routes in the area of the UK continental shelf: Offshore technology report", OTH 85 213, HMSO, March 1985.

SAFECO I: "Safety of Shipping in Coastal Waters (SAFECO I) Summary Report", DNV 98-2038, 1998.

SAFECO II: "Safety of Shipping in Coastal Waters (SAFECO II) Summary Report", DNV 99-2032, 1999.

Annex 3.3: Data used by the Marcs model

APPENDIX II

DATA USED BY THE MARCS MODEL

Contents

II DATA USED BY THE MARCS MODEL

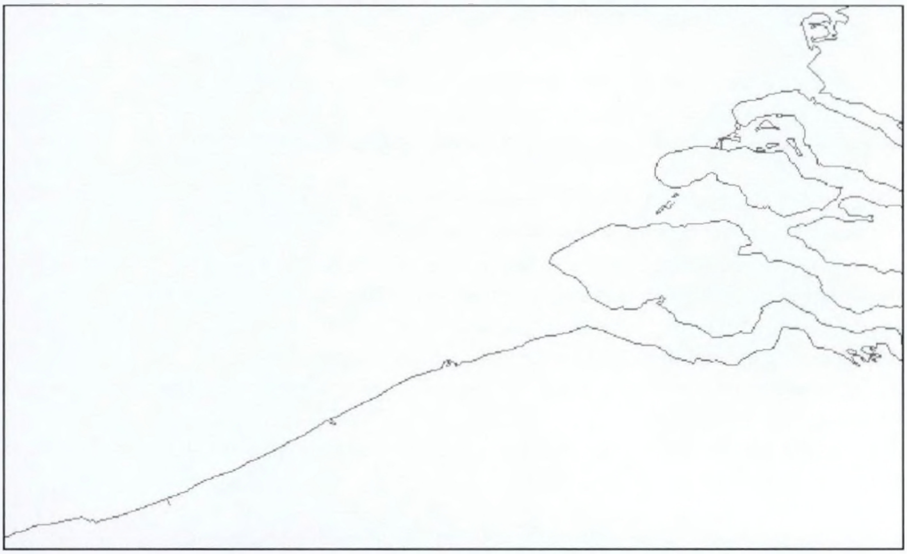
This appendix describes the data and reasoning behind the risk analysis parameters used to generate the marine risk results used in this project.

II.1 Risk Modelling Approach

This section describes the overall approach to the modelling of the risks posed by the marine traffic trading off the coast of Belgium. The marine risk model (MARCS, or Marine Accident Calculation System) is described in detail in Appendix I.

The study area is shown in Figure II.1. This has been chosen so that all ship routes within 50nm (nautical miles) of the Belgian coast are included within the study area. This limit is selected because in previous marine projects performed by DNV it has been judged that 50nm is the highest credible drift distance for a mechanically disabled ship. It should be noted that any ships outside the defined study area cannot influence the marine risk analysis, or the risk results obtained.

Figure II.1 Definition of the Project Study Area



The co-ordinates of the study area are between 52° and 51° north to south and between 2° 10' and 4° 15' west to east. The calculation resolution is 0.10 minutes (185m) by 0.20 minutes (236m); each small area defined by the calculation resolution is called a calculation location, see Appendix I.

Other inputs that contribute to the definition of the project study area, such as the location of offshore wind turbines and the location of the 5m depth grounding line, are described in Section II.4 below.

II.2 Marine Traffic Image Data

II.2.1 Traffic Characteristics

MARCS represents marine traffic in terms of up to 8 traffic types and traffic routes for each traffic type. For most projects, traffic types are defined in terms of the similarity of risks that each ship type poses and other similarities (for example, ferries tend to trade faster so may be grouped separately from general cargo ships). Non-hazardous traffic types, such as general cargo ships, container ships and ferries will also be defined. This is because these non-hazardous ships can collide with hazardous cargo ships, and because all ships carry bunker oil. In this study Ecolas were responsible for the collection of ship traffic data.

The traffic types defined in this study are as follows:

- Type 1: Oil (crude) tankers;
- Type 2: Chemical tankers and refined product tankers;
- Type 3: Gas tankers;
- Type 4: RoRo and Car carriers;
- Type 5: Bulk carriers;
- Type 6: General cargo and reefers;
- Type 7: Containers;
- Type 8: Passenger ships and other ships.

For each ship lane defined it is necessary to define a range of parameters which describe:

- The lane number and ship type (as above);
- The cargo type that is being transported (see below);
- The annual frequency of ship movements along the lane (ships/year);
- The lane type (all lanes in this study are one-way Gaussian – see Appendix I);
- Any tug escorts that may be present (none in this study);
- The type of ship loading (characterised by 3 parameters);
- The proportion of ships on the lane in each ship size (DWT) and hull type (single hull, double hull etc) category;
- The number of waypoints, the location of each waypoint and the lane width (twice the standard deviation) at each waypoint.

These parameters are provided in the spreadsheet InputDataSummary v0.xls, sheet Traffic Data.

The cargo type carried by each vessel type is defined by the IMO Dangerous Goods classes as follows:

- Class 1: Marine Pollutants + Bulk Cat A;
- Class 2: Crude oils;
- Class 3: Bunkers and heavy fuels;
- Class 4: Other oil products;
- Class 5: Potential Marine Pollutants + Bulk Cat B & C;
- Class 6: Toxic Products (IMO-code 6.1 & 2.2);
- Class 7: Other identifiable dangerous goods or HNS;
- Class 8: Dangerous goods, with insufficient product information;

- Class 9: Empty but with leftover fractions from dangerous goods;
- Class 10: No dangerous goods.

In addition, it is assumed that all ships carry bunker fuel oil in their bunker fuel oil tanks (distinct from bunker fuel oil as a cargo).

Cargo Classes 9 and 10 are not included in the risk analysis (see Section 2.3 of main report).

II.2.2 Internal Operational Data

In DNV's previous marine risk analysis projects we have derived internal operational data, such as ship-ship collision probabilities given an encounter, from North Sea fleet data. This is assumed to apply to marine traffic in Belgian waters. Table II.1 shows the internal operational data which DNV normally applies for North Sea average ships [DNV, 1997; DNV, 1998].

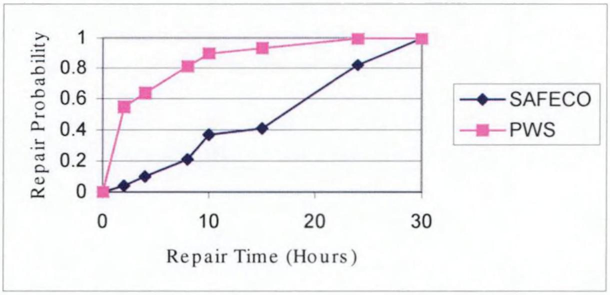
Table II.1 Risk Parameters for North Sea Average Ships

Risk Parameter			**Average ship probability (all ship types)**
Accident Type	**Pilot**	**Visibility**	
Collision	No	Good	8.48e-5
Collision	No	Poor	5.80e-4
Collision	Yes	Good	6.83e-5
Collision	Yes	Poor	4.64e-4
Powered Grounding	No	Good	3.07e-4
Powered Grounding	No	Poor	8.57e-4
Powered Grounding	Yes	Good	2.47e-4
Powered Grounding	Yes	Poor	6.87e-4

Accident Type and Parameter Description	**Ship Type**	**Average ship frequency (per hour)**
Drift Grounding Ship breakdown frequency per hour	Type 1: Oil (crude) tankers; Type 2: Chemical tankers; Type 3: Gas tankers; Type 4: RoRo; Type 5: Bulk carriers; Type 6: General cargo; Type 7: Containers; Type 8: Passenger and other ships.	3.60e-4 3.60e-4 3.60e-4 5.00e-4 3.00e-4 5.00e-4 5.00e-4 1.30e-5
Structural Failure Structural failure frequency per hour in calm/ fresh, gale and storm seastates respectively	Type 1: Oil (crude) tankers; Type 2: Chemical tankers; Type 3: Gas tankers; Type 4: RoRo; Type 5: Bulk carriers; Type 6: General cargo; Type 7: Containers; Type 8: Passenger and other ships.	1.85e-7 1.85e-7 4.62e-7 1.85e-7 1.85e-7 4.62e-7 1.85e-7 1.85e-7 4.62e-7 6.92e-7 4.62e-7 4.62e-7 4.62e-7 4.62e-7 9.23e-7 6.92e-7 4.62e-7 4.62e-7 6.92e-7 4.62e-7 4.62e-7 1.85e-7 1.85e-7 4.62e-7
Fire/Explosion	Type 1: Oil (crude) tankers; Type 2: Chemical tankers, Type 3: Gas tankers; Type 4: RoRo; Type 5: Bulk carriers; Type 6: General cargo; Type 7: Containers; Type 8: Passenger and other ships.	4.08e-7 4.08e-7 4.08e-7 1.00e-7 1.00e-7 1.00e-7 1.00e-7 1.00e-7

Figure II.2 shows the distribution of self-repair times derived from these two projects (Prince William Sound Risk Assessment and SAFECO respectively). As shown in Figure II.2, there is considerable uncertainty regarding the time required to repair mechanical failures onboard ship. In the current project the SAFECO curve is assumed to apply to all ships, though we note that this assumption is likely to result in conservative (higher) risk results for drift grounding and drifting obstacle collision results.

Figure II.2 Self Repair Distribution Function for Average (SAFECO) and Above Average (Prince William Sound - PWS) Ships



II.2.3 Traffic speeds

Table II.2 shows the average speed of each vessel type in the study area as used in the risk calculation.

Table II.2 Average Vessel Speed (knots) applied in the Study Area

Ship Type	All Locations
Type 1: Oil Tanker	12
Type 2: Chemical tankers	12
Type 3: Gas tankers	12
Type 4: RoRo	12
Type 5: Bulk carriers	12
Type 6: General cargo	10
Type 7: Containers	14
Type 8: Passenger and other ships	16

II.3 External Operational Data For Study Area

The use of pilots within certain areas reduces the frequency of collision, powered grounding and powered collision with fixed obstacles due to the improved local knowledge of the pilot compared with the ship's normal crew. The location of piloted areas in this study is shown in Figure II.4. Within these areas the reduced probability of accidents, as shown in Table II.1, are applied.

Figure II.4 Location of Piloted Areas

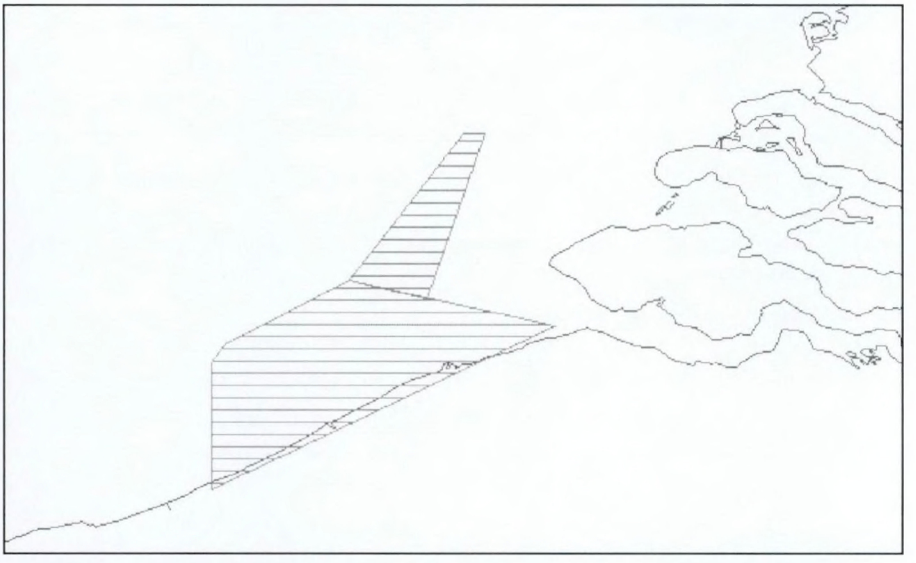


Table II.3 summarises the emergency tows which are potentially available (data from Ecolas, see InputDataSummary v0.xls, sheet TugData).

Table II.3 Locations and Performances of Emergency Tows

Location	North	East	Number	Bollard Pull (te)
Terneuzen	51° 22'	3° 48'	2	55, 55
Zeebrugge	51° 20'	3° 12'	7	45 to 66, 95
Antwerpen	51° 22'	3° 48'	12	40 to 66
Gent – Terneuzen	51° 22'	3° 48'	14	30 to 40
Oostende	51° 15'	2° 58'	1	30

Due to the high levels of traffic in the area, it is possible that other tugs or salvage vessels might fortuitously be in the vicinity of a drifting vessel and therefore be able to offer assistance. This eventuality has not, however, been included in the drift grounding frequency calculator within MARCS, to ensure that a conservative approach to the risk modelling is maintained throughout the study.

The tug input data to the MARCS model is shown in Table II.4. Each tug type in Table II.3 is assigned to a tug performance class by reference to previous tug performances characterised by DNV. The availability of each tug is determined by assuming that each individual tug is available for only 10% of the time. Thus the availability for controlling a drifting vessel is estimated from the equation:

$$\text{Availability} = 1.0 - 0.9^{(\text{number of tugs of similar performance at the location})}$$

Table II.4 Tug Input Data

Tug Class	Availability	North	East	Comment
1	0.19	51.3667	3.8000	2 tugs at Terneuzen
2	0.47	51.3333	3.2000	6 tugs at Zeebrugge
4	0.10	51.3333	3.2000	1 powerful tug at Zeebrugge
2	0.71	51.3667	3.8000	12 tugs at Antwerpen

Tugs less than 40 tons of bollard pull are judged to be ineffective in open water.

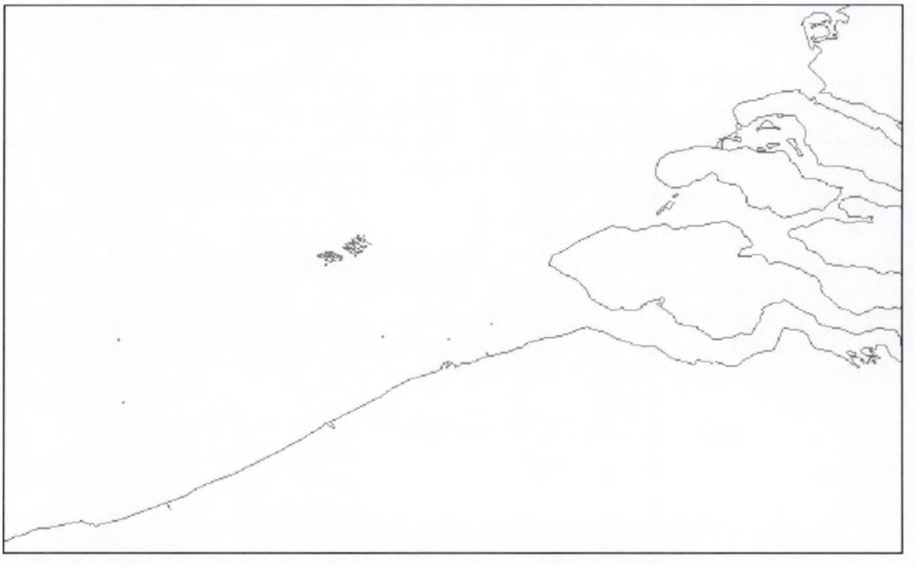
The performance (speed of the tug and the maximum size of ship it can control in kdwt) of each tug type, taken from previous work by DNV, is shown in Table II.5.

Table II.5 Tug Performance Data for a Semi-Sheltered Location – see wave height data below (Save = Maximum size of ship in kdwt that can be controlled by the tug in the specified conditions)

Wind	Calm		Fresh		Gale		Storm	
	Speed kts	Save	Speed kts	Save	Speed kts	Save	Speed kts	Save
Type 1	14	999	11	999	8	0	5	0
Type 2	14	999	11	999	8	62	5	0
Type 3	14	999	11	999	8	138	5	0
Type 4	14	999	11	999	8	262	5	34
Type 5	14	999	11	999	8	999	5	264

The location of offshore wind turbines (installed and approved but not yet installed) plus other obstacles are shown in Figure II.5. The data is recorded InputDataSummary v0.xls, sheet Obstacles.

Figure II.4 Location of Offshore Wind Turbines (installed and approved) and other Obstacles



II.4 Environmental Data For The Study Area

Visibility data was obtained from two local data sources as indicated in Table II.7. Typical values for the North Sea from a previous project are shown for comparison.

Table II.7 Visibility Data for the Study Area and Data used in this Project

Sea Area	Good Visibility (time fraction greater than 2 nm)	Poor Visibility (time fraction less than 2 nm)	Data Source
North Sea Average	0.95	0.05	DNV, 1998
Goeree	0.9516	0.0484	NL, 2001
Europlatform	0.9448	0.0552	Ecolas, 2004a
Ostend Airport	0.959	0.041	Ecolas, 2004b
Data applied in this study	0.95	0.05	

The local data shown in Table II.7 are not significantly different from the North Sea average, therefore the North Sea average data was applied to this study. That is, visibility of less than 2nm occurs 5% of the time.

Windrose data from four local measuring locations are shown in Table II.8 and compared to North Sea average data.

Table II.8 Windrose Data for the Study Area (First 4 Tables from Ecolas, 2004c, Final Table DNV, 1998)

Wind State	Wind Speed	Wind Direction - MOW0 Wandelaar H19.2m. jun86-sept01							
		N	NE	E	SE	S	SW	W	NW
Calm	0-20 kts	0.06737	0.10510	0.07776	0.06661	0.10566	0.11616	0.08536	0.05780
Fresh	20-30 kts	0.01873	0.02401	0.01841	0.01311	0.04649	0.08559	0.04455	0.02370
Gale	30-45 kts	0.00160	0.00207	0.00193	0.00089	0.00632	0.01564	0.00989	0.00393
Storm	>45 kts	0.00001	0.00000	0.00000	0.00000	0.00016	0.00060	0.00049	0.00006

Wind State	Wind Speed	Wind Direction - MOW7 Westhinder H25.25m maa94-sapt01							
		N	NE	E	SE	S	SW	W	NW
Calm	0-20 kts	0.06079	0.08483	0.07655	0.07093	0.08747	0.11701	0.07895	0.05206
Fresh	20-30 kts	0.02696	0.03576	0.02468	0.01061	0.02941	0.09983	0.05057	0.03124
Gale	30-45 kts	0.00339	0.00359	0.00292	0.00057	0.00504	0.02748	0.01166	0.00601
Storm	>45 kts	0.00004	0.00003	0.00000	0.00000	0.00017	0.00107	0.00035	0.00004

Wind State	Wind Speed	Wind Direction - MOW5 Droogte van 't Schooneveld periode ? Waarschijnlijk 86-91)							
		N	NE	E	SE	S	SW	W	NW
Calm	0-20 kts	0.08322	0.09093	0.07829	0.05491	0.09107	0.10554	0.08856	0.06428
Fresh	20-30 kts	0.02998	0.02466	0.01345	0.00815	0.04954	0.08359	0.05771	0.02656
Gale	30-45 kts	0.00317	0.00208	0.00026	0.00085	0.00813	0.01706	0.01269	0.00354
Storm	>45 kts	0.00002	0.00000	0.00001	0.00002	0.00021	0.00070	0.00070	0.00011

Wind State	Wind Speed	Wind Direction - VR Vlakte vd Raan, H416.5m, nov88-mei98							
		N	NE	E	SE	S	SW	W	NW
Calm	0-20 kts	0.08027	0.09256	0.08185	0.06938	0.09218	0.12576	0.09481	0.06428
Fresh	20-30 kts	0.02346	0.02392	0.01445	0.00763	0.03851	0.08797	0.04819	0.02656
Gale	30-45 kts	0.00152	0.00114	0.00030	0.00015	0.00334	0.01054	0.00730	0.00357
Storm	>45 kts	0.00000	0.00000	0.00000	0.00000	0.00003	0.00015	0.00016	0.00005

Wind State	Wind speed	Wind Direction - North Sea Average (DNV, 1998)							
		N	NE	E	SE	S	SW	W	NW
Calm	0–20 kts	0.058	0.028	0.042	0.053	0.090	0.090	0.08	0.08
Fresh	20–30 kts	0.029	0.014	0.021	0.027	0.045	0.045	0.04	0.04
Gale	30-45 kts	0.023	0.011	0.017	0.021	0.036	0.036	0.032	0.032
Storm	> 45 kts	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002

Analysis of these windrose tables indicates that the wind directions, irrespective of windspeed, are very similar for each dataset (mostly within 10% and always within 16%). Windspeeds however are highest for the second windrose (MOW7 Westhinder H25.25m maa94-sapt01). High windspeeds result in higher marine accident risk results, thus this second data set has been applied across the entire study area, since this will give the more conservative risk result. (Note, it is considered that there is insufficient difference between the windroses to justify use of multiple windroses in defined sub-areas, though the MARCS model is capable of using such data.)

The significant wave height observed is a function of the windspeed, the time for which that windspeed has been observed and the "fetch" of the location (the sea distance over which the wind acts and the wave heights are built). In previous work (DNV, 1997), DNV defined 3 types of sea location and approximate significant wave heights as a function of wind speed, as shown in Table II.9. Within Table II.9, the "Open Ocean" location considered was the northern Pacific Ocean (i.e. a large body of water with some very large waves).

Table II.9 Approximate Significant Wave Height as a function of Wind Speed and Location Characteristics

Wind State	Wind Speed	Sheltered Wave Height	Semi-Sheltered Wave Height	Open Ocean Wave Height
Calm	20 kts	1.2m	1.6m	2m
Fresh	30 kts	2.4m	3.2m	4m
Gale	45 kts	4.2m	5.6m	7m
Storm	58 kts	5.4m	7.2m	9m

Examination of wave height data for various locations within the study area (Ecolas, 2004d) indicate that the study area is between sheltered and semi-sheltered (the maximum 100% percentile wave height in large detailed datasets across all wind conditions was 4.5m, but the 90th percentile waveheight was generally less than 2 to 2.5m, depending on the dataset). The study area in this project has, therefore, been characterised as semi-sheltered in order to provide conservative risk results.

The navigation charts were examined for sea current data but no significant currents were found (excluding tidal currents which cannot be represented adequately by a statistical model such as MARCS) and so none were included in the risk analysis calculations.

The grounding line for the marine traffic is defined to be the 5m depth line shown in Figure II.5. Such sand banks would result in contacts with deeper draft ships. However the soft sea bottom and the depth of water (that helps to support the weight of the ship) is likely, in most cases, to allow grounding without significant damage to the ship or loss of bunker oil or ship's cargo.

Figure II.5 Location of the 5m Grounding Line

The sea bottom and shoreline that predominates within the study area is mainly soft mud or sand. Thus, in the case of a grounding, the probability of a cargo or fuel oil release is relatively low compared to a more rocky sea-bottom or shoreline. Thus a uniform probability of a cargo spill given a grounding of 0.1 is applied throughout the study area.

A drifting ship can save itself from grounding by deploying its anchoring systems, provided that the sea bottom geometry is suitable. For anchor saves to be effective, the sea depth should lie between 60 and about 20m for a distance of half a nautical mile, see Appendix I. Anchor saves are more effective at low wind speeds and for softer sea bottoms.

The water depth throughout the study area is generally shallow and suitable for saving a drifting ship using the anchor save mechanism. Thus the anchor save mechanism has been applied throughout the study area.

II.5 References

DNV, 1997: "Prince William Sound Risk Assessment", Final Report to the Prince William Sound risk assessment steering committee, December 1996.

DNV, 1998: "Demonstration of risk analysis techniques for ship transportation in European waters", Report 98-2021, Final report to SAFECO project.

Ecolas, 2004a: Spreadsheet "zichtbaarheid-in-nl.xls" supplied by Ecolas.

Ecolas, 2004b: Spreadsheet "Zichtb_IRM-bd.xls" supplied by Ecolas.

Ecolas, 2004c: Spreadsheet "winddata 3Estudie c-power.xls" supplied by Ecolas.

Ecolas, 2004d: Spreadsheets "golfhoogte.xls", "presentsignifgolfh79-98.xls" and "wave height Akkaert, MP7westhinder.xls", supplied by Ecolas.

Annex 3.4: Risk results of the Marcs model

APPENDIX III

RISK RESULTS FROM THE MARCS MODEL

Contents

III. RISK RESULTS FROM THE MARCS MODEL

III.1 Introduction

This Appendix presents the results of the risk analysis of marine traffic in Belgian waters. The results presented are based upon the modelling methodology shown in Appendix I and the model input data described in Appendix II.

The format and keys for the results described below are shown in Section 2.4 of the main report.

III.2 Marine Traffic Analysis

The geographical distribution of shipping traffic for each vessel type is shown in the bitmap files L1.bmp to L8.bmp for vessel types 1 to 8 respectively.

The sub-area analysis of the number of vessel miles is included in the Excel sheet Results v0.xls, sheet "Traffic".

III.3 Modelling Results

III.3.1 Accident Frequency Results

The total frequency of serious accidents is shown as a function of accident type, ship type, cargo spill type and sub-area in the Excel sheet Results v0.xls, sheet "Results D1", rows 8 to 138.

The geographical distribution of accident frequency results are shown in the files map1_x.bmp, where x=0 for all cargo spill, 1 to 10 is for cargo classes 1 to 10 respectively and 20 is for bunker spills.

III.3.2 Cargo Spilling Accident Frequency Results

The total frequency of serious accidents is shown as a function of accident type, ship type, cargo spill type and sub-area in the Excel sheet Results v0.xls, sheet "Results D1", rows 140 to 270.

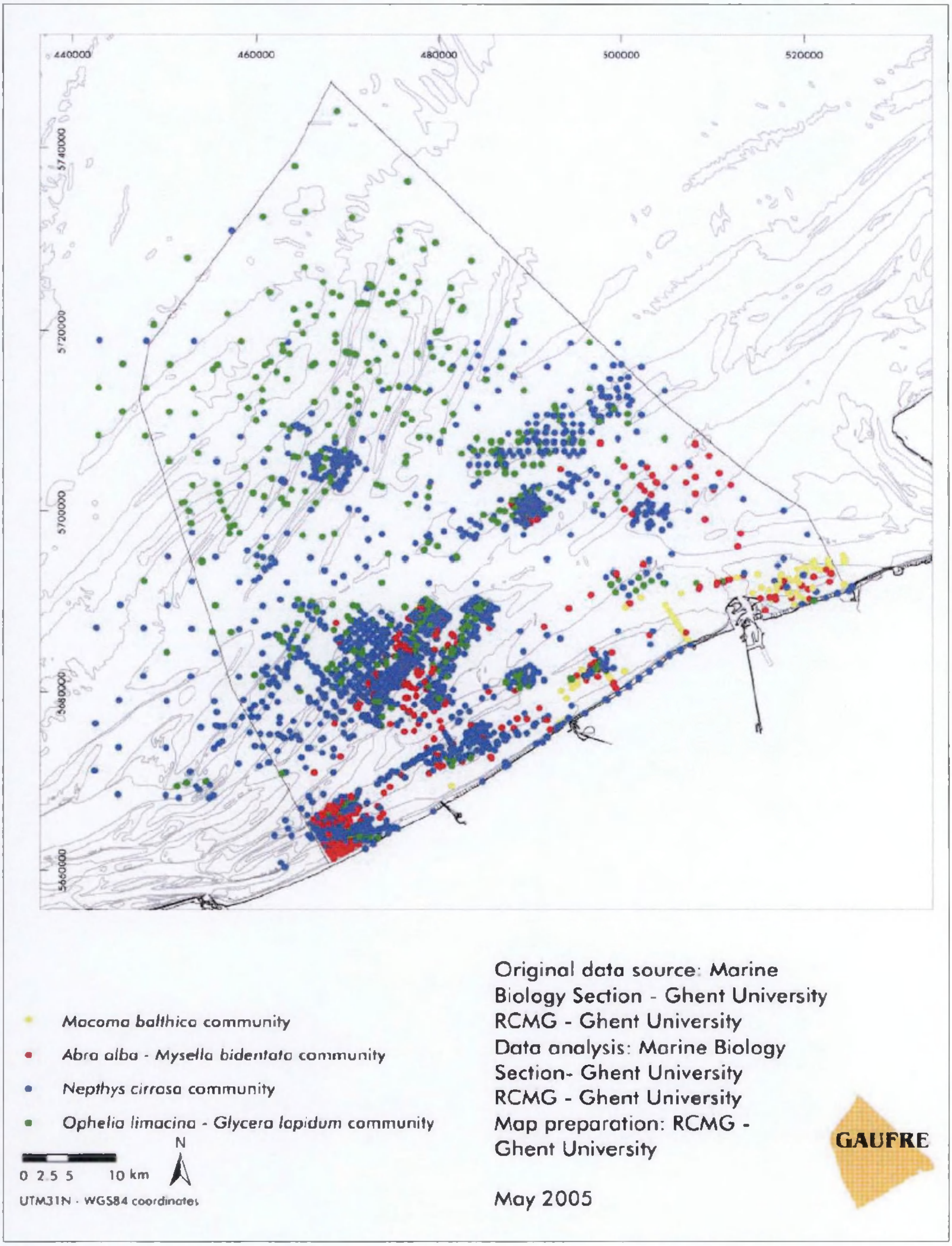
The geographical distribution of accident frequency results are shown in the files map2_x.bmp, where x=0 for all cargo spill, 1 to 10 is for cargo classes 1 to 10 respectively and 20 is for bunker spills.

III.3.3 Cargo Spilling Risk Results

The total frequency of serious accidents is shown as a function of accident type, ship type, cargo spill type and sub-area in the Excel sheet Results v0.xls, sheet "Results D1", rows 272 to 402.

The geographical distribution of accident frequency results are shown in the files map3_x.bmp, where x=0 for all cargo spill, 1 to 10 is for cargo classes 1 to 10 respectively and 20 is for bunker spills.

Annex 4.1: Spatial distribution of benthic communities at BPNS (Maes et al., 2005)



Annex 4.2: Importance for biographical population, protection status (BD= bird directive, BE= Bern Convention, BO= Bonn Convention) and function BPNS (R= resting place (winter; M= migration corridor, F= fouraging area (breading seaon)) of the most important bird species (Stienen & Kuijken, 2003)

Bird species (English name)	Bird species (scientific name)	Importance for biogeographical population	Protection	Function PPNS
Common scoter	Melanitta nigra	low	-	R,M
Red throated diver	Gavia stellata	low	BD, BE, BO	R
Great crested grebe	Podiceps cristatus	medium	-	R, M
Little gull	Larus minutus	high	BE	M
Common tern	Sterna hirundo	high	BD, BE, BO	F, M
Sandwich tern	Sterna sandvicensis	high	BD, BE, BO	F, M
Razorbill	Alca torda	low	-	R
Guillemot	Uria aalga	low	-	R
Northern gannet	Morus bassanus	low	-	M
Lesser black-backer gull	Larus fuscus	medium	-	F, M
Fulmar	Fulmar glacialis	low	-	R
Great skua	Stercorarius skua	high	-	M
Black-headed gull	Larus ridibundus	low	-	R, M
Common gull	Larus canus	low	-	R
Herring gull	Larus argentatus	low	-	R, F, M
Great black-backed gull	Larus marinus	low	-	R, M
Kittiwake	Rissa tridactyla	low	-	R
Little tern	Sterna albifrons	low	BD, BE, BO	F, M
Arctic tern	Sterna paradisaea	negligible	BD, BE	
Black throated diver	Gavia arctica	negligible	BD, BE, BO	
Mediterranean gull	Larus melanocephalus	negligible	BD, BE, BO	

Annex 4.3: Determination of the sensitivity scores for the ecological and socio-economical parameters of the BPNS

GENERAL

A sensitivity analysis is set up to identify vulnerable areas in the marine and coastal zone of Belgium. The analysis consists of three important steps:

1. Criteria or parameters should be considered based on the characteristics that influence or describe the possible sensitivities best.
2. Scenarios should be identified to meet the temporal differences of the sensitivity analysis.
3. An objectively as possible sensitivity scoring (from zero to five) should be worked out for all parameters.

During a restricted public participation (PP) with the end-users of the RAMA project these three steps were treated to get a broader public platform for the sensitivity analysis. All end-users could evaluate the proposed parameters and add new parameters (ecological, socio-economical). They could give their opinion about possible scenarios. Finally all the parameters were scored by the different users. An average was taken of the different scores and divided (percentile) into a sensitivity class (5= high; 3= medium; 1= low) (PP).
A comparison of the results of the PP with the preliminary results of the RAMA project (Original) has led to the final identification of the scenarios and the ecological/ socio-economical parameters and their scoring used for the sensitivity analysis of the marine and coastal area of Belgium. In this final decision the results of the public participation (PP) has as much as possible been taken into account, but adapted where needed on the basis of expert judgement (PP + expert).

SENSITIVITY SCORING

		Original	PP	PP+expert
Ecological parameter				
Nature status	RAMSAR sites	5	5	5
	EC - Special Protected Areas (SPA) (in framework of habitat or bird directive)	5	5	5
	EC - Habitat Directive Area (Natura 2000)	5	5	5
	EC- Bird directive Area (Natura 2000)	5	3	5
	Marine Protected Areas (MPA)	3	3	3
	Strict nature reserve	3	3	3
	National park	3	1	1
	Beach (nature) reserves	1	3	3
	Nature reserve	1	1	1
	Natural monument	1	1	1
	Landscape reserve (classified landscape)	1	1	1

Others		Original	PP	PP+expert
Socio-economische parameters				
Recreation	Global tourist factor (beach recreation)	3	5	5
	Garded swimming zones	1	3	1
	Marinas	1	1	1
Fisheries	Spawning sites		5	5
	Concentration of fish		5	5
Shipping	Port	2	5	5
	Local port	1	1	1
	Anchorage area/ Shipping lane	0	1	0
Economical aspects	Touristal value coast	2	3	3
	Concession zone aggregate extraction at sea	1	1	1
	Concession zone wind energy at sea	1	1	1
Social aspects	High population (inh/km²)	1	3	1
	Overnight stays per month summer		3	3
	Overnight stays per month winter		1	1

SCENARIOS

During the public participation the end-users focused on the aspect that the interests of the different users of the BPNS vary in time. The tourist sector is mainly summer dependent, while for example some nature areas are of important value for wintering birds. Three different scenarios leading to different sensitivity maps have been identified through the public participation:

General scenario: scenario in which all parameters are evenly important or with other words have received the same weight factor (=1);

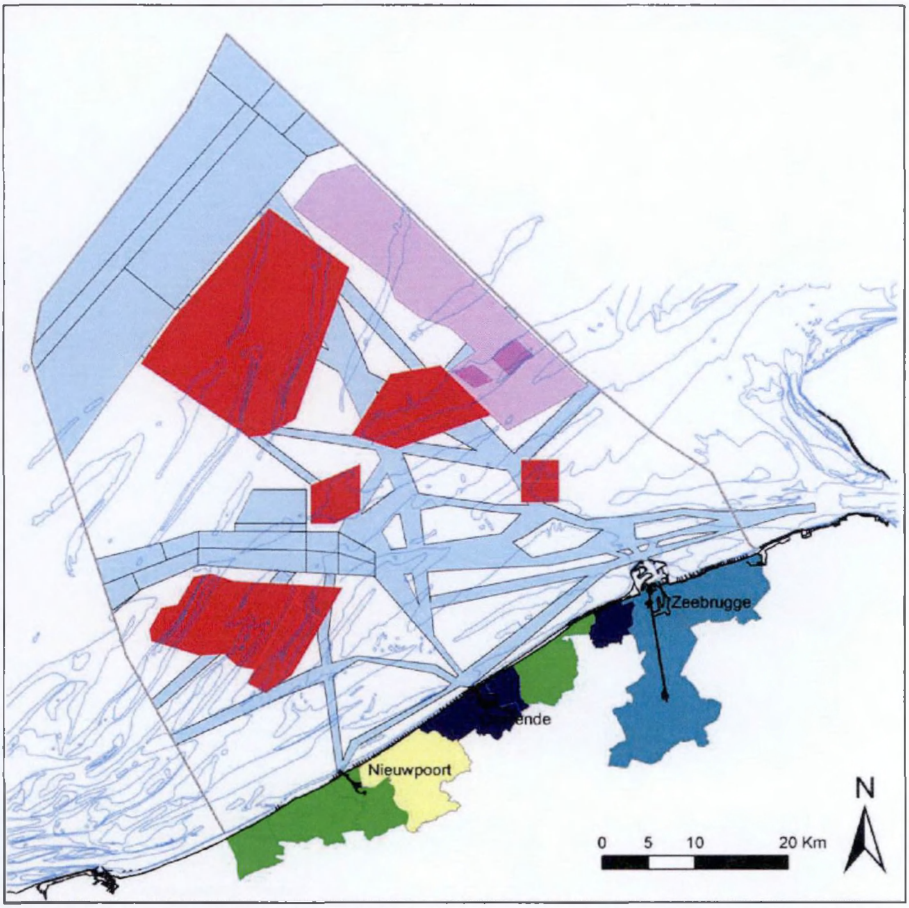
Summer scenario: scenario in which the tourist and recreational values of the coastal and marine areas have been given special attention (weight factor= 2), while the other factors have received a weight factor of 1;

Winter scenario: scenario in which the nature values (wintering-, foraging- and spawning areas) of the coastal and marine areas have been given special attention (weight factor= 2), while the other factors have received a weight factor of 1.

TOTAL SENSITIVITY SCORE

Taking into account the intensity of a parameter (absent/present (ecological); qualitatively (socio-economical), the sensitivity scoring and the weight factor, a total sensitivity score per cell (1 km²) could be calculated.

Annex 4.4: Socio-economical parameters of the Belgian coast and marine waters



Risk Analysis of Human Activities at the Belgian Part of the North Sea (RAMA)
Financed by the Federal Science Policy Office

Data source shipping data: IVS-SRK database (AWZ, B&RWS, NL), Ferryways, Transeurope ferries
Data source wind concessions: EIA C-power & Cabinet North Sea
Data source aggregate concession: EIA Zeegra
Data source inhabitants: NIS statistics (2005)

[E] ECOLAS

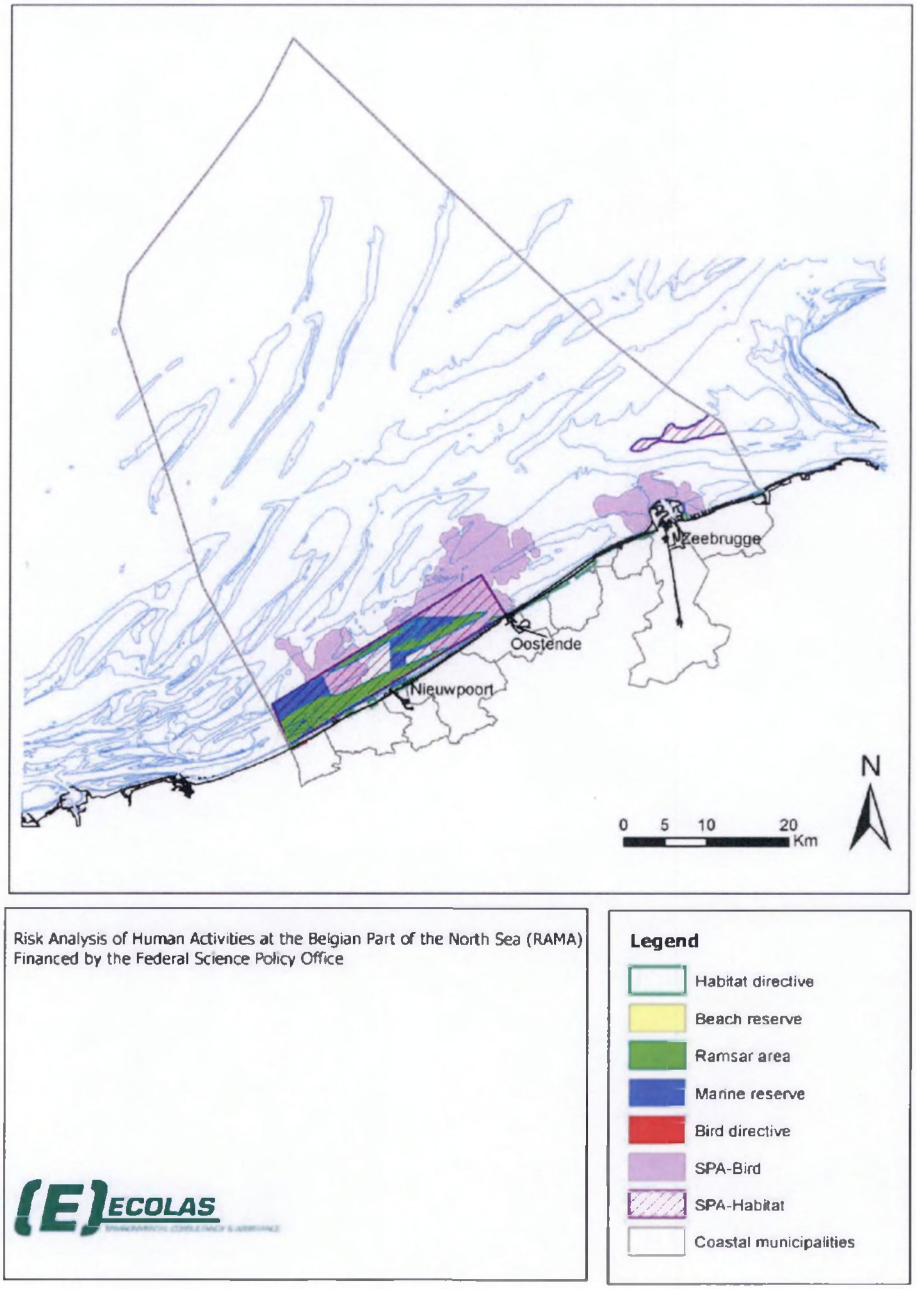
Legend

- C-power concession
- Wind concession
- Shipping lanes
- Aggregate concession

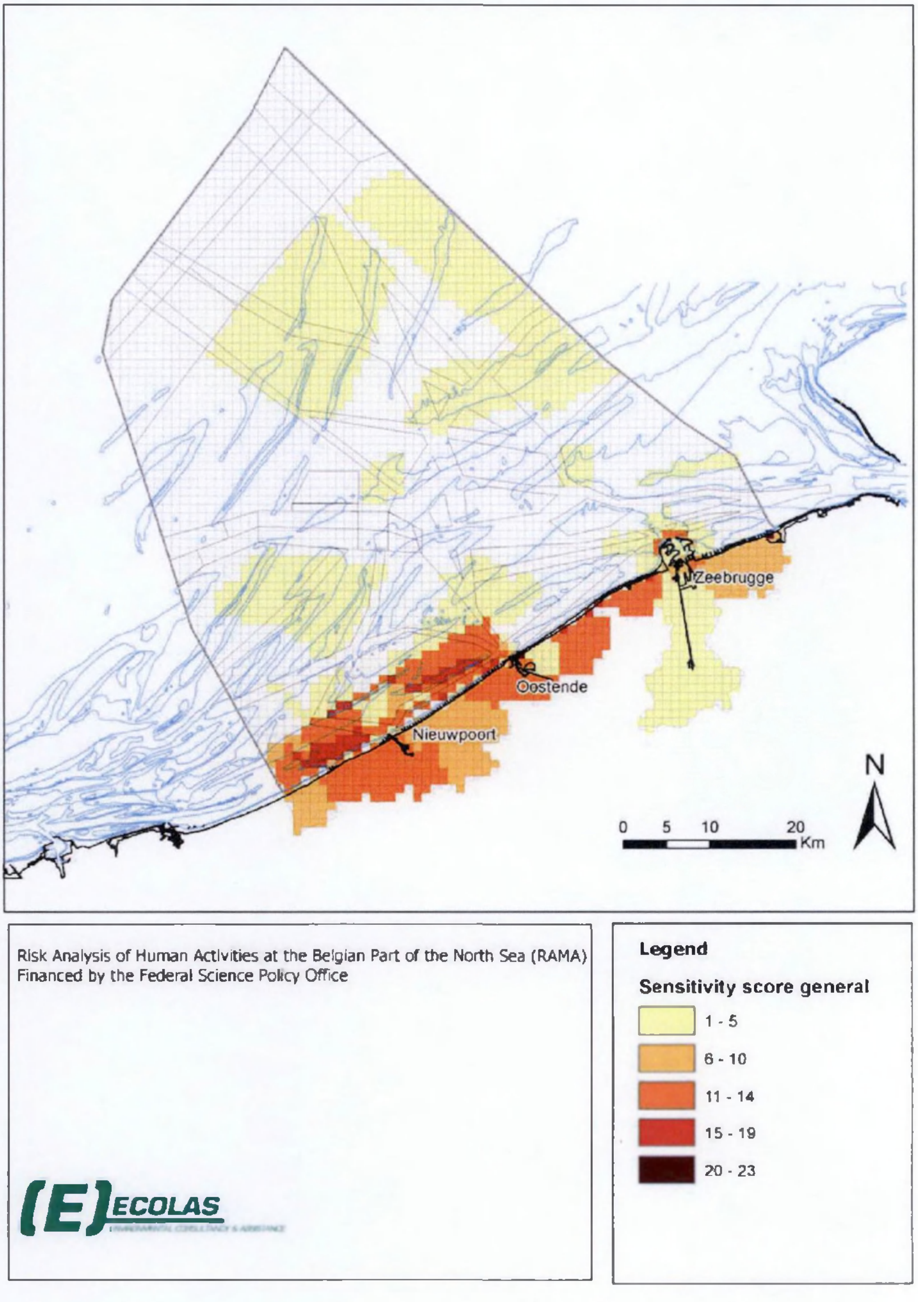
Coastal municipalities (Inhabitants/km²)

- < 250
- < 500
- < 1000
- < 2000

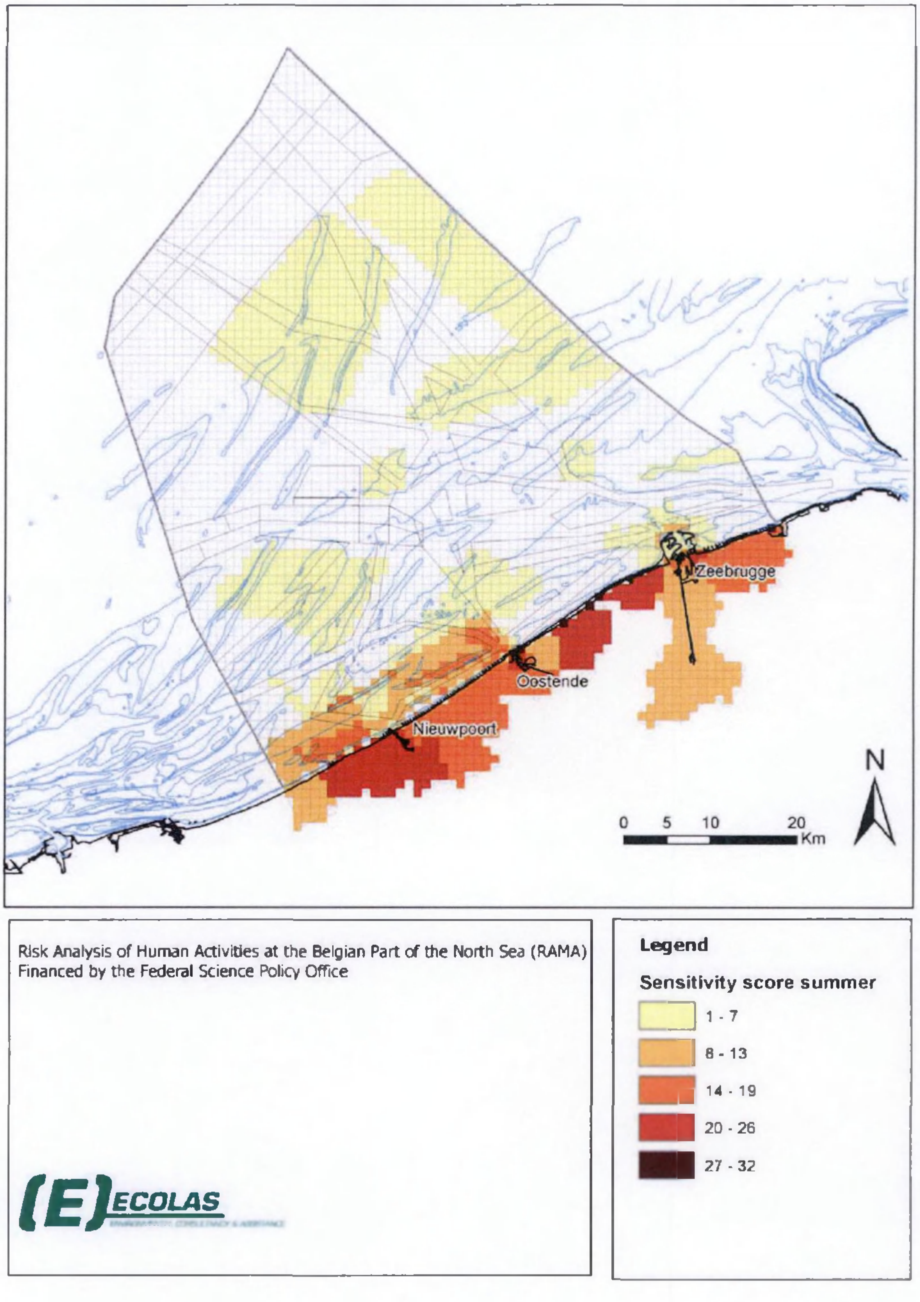
Annex 4.5: Ecological parameters of the Belgian coast and marine waters



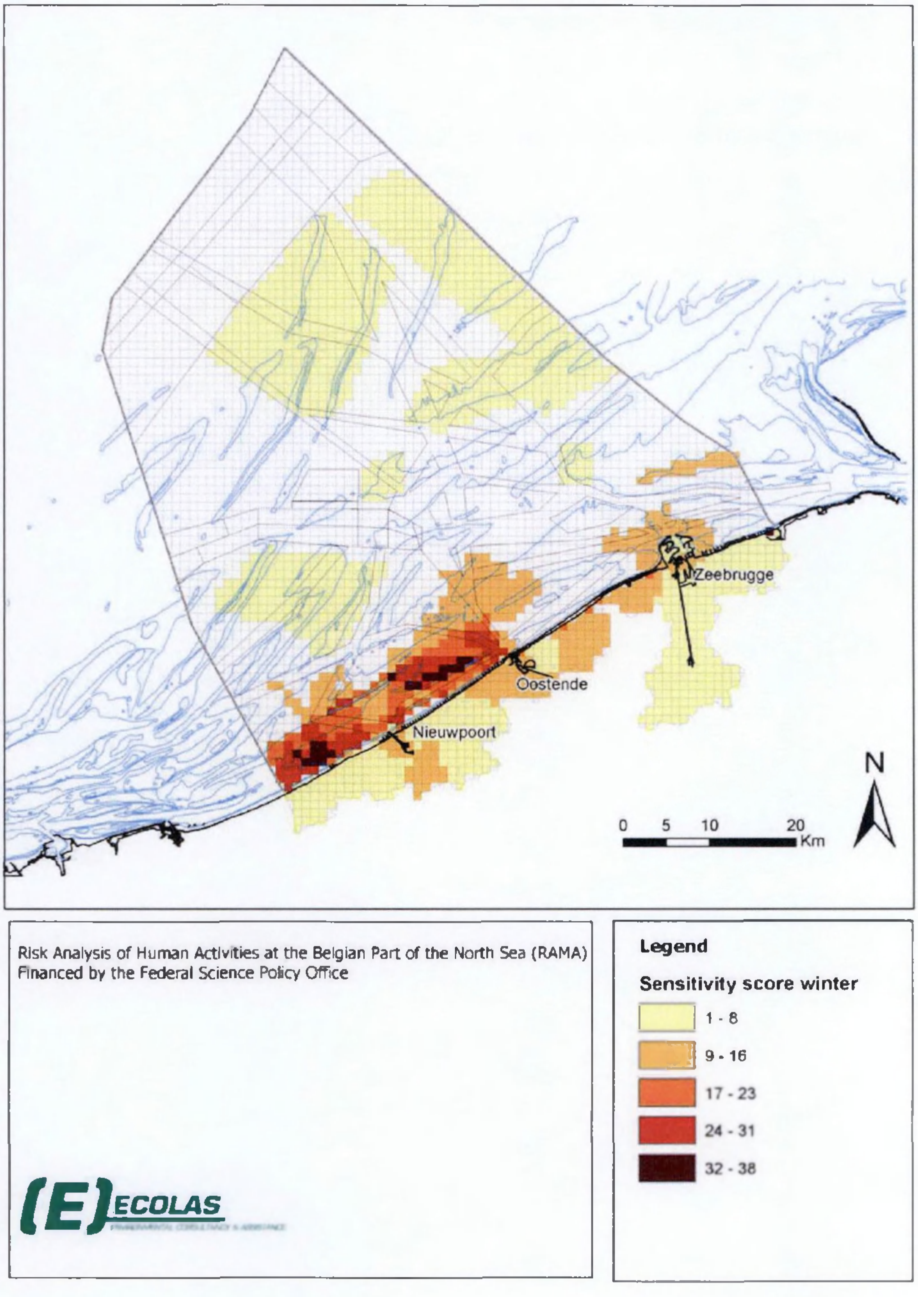
Annex 4.6: Sensitivity map (general scenario) of the Belgian coastal & marine area



Annex 4.7: Sensitivity map (summer scenario) of the Belgian coastal & marine area



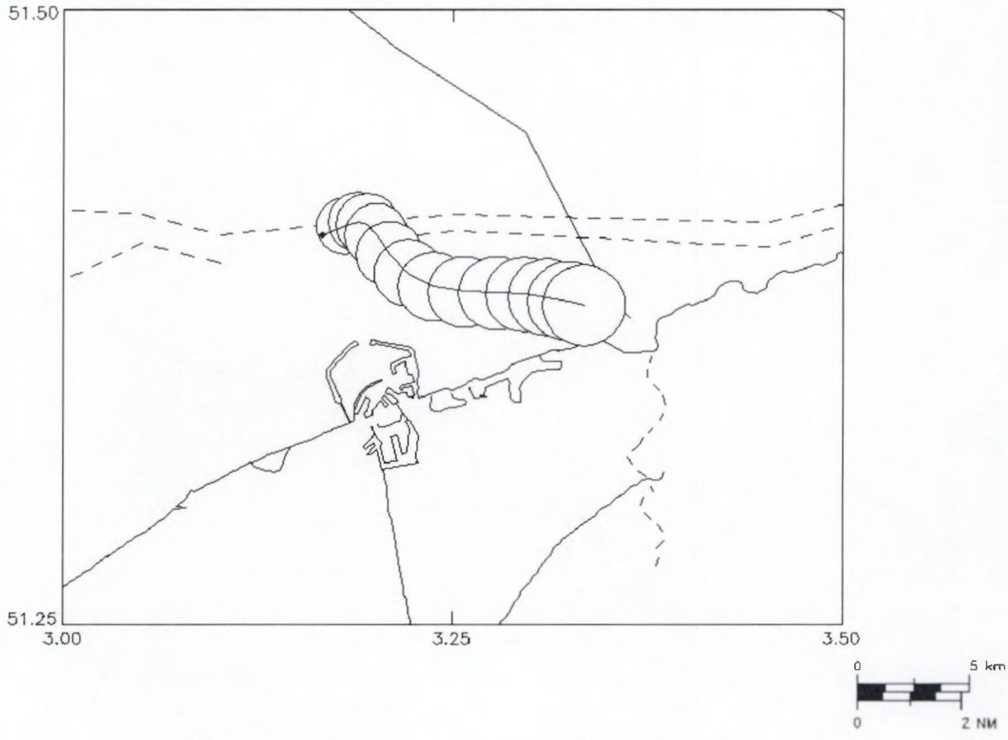
Annex 4.8: Sensitivity map (winter scenario) of the Belgian coastal & marine area



Annex 4.9: Modelling result of oil scenario (performed by MUMM, 2006)

Detailed description results MU-SLICKLETS model:

- Starting point in subarea SA3 (51°24'30"N, 3°10'00"E)
- Spill quantity: 19550 m³ heavy fuel 2
- Surface slick: 12,6 km² (Ø 4 km)
- Oil slick layer: 1 mm
- Time before coast (Zwin) is reached: 13 hours.



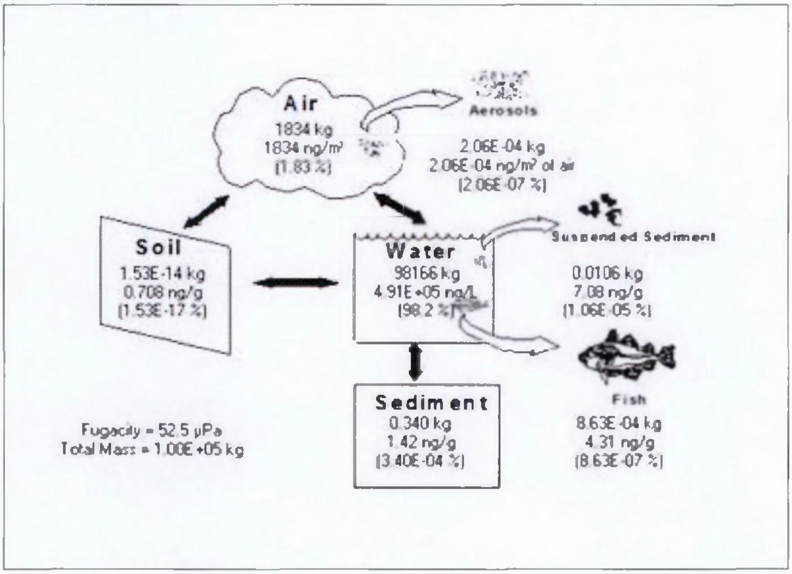
Annex 4.10: Density, oil vulnerability index (OVI) and% mortality –BPNS

Seabirds		Max. density at BCP	Density per km²	Density per 30 km²	OVI	Mortality (%)	Mortality (#)
Common scoter	Melanitta nigra	5846	2	49	52	62,97	31
Red throated diver	Gavia stellata	1382	0	12	50	60,55	7
Great crested grebe	Podiceps cristatus	3736	1	31	45	54,49	17
Little gull	Larus minutus	3670	1	31	46	55,70	17
Common tern	Sterna hirundo	7605	2	63	35	42,38	27
Sandwich tern	Sterna sandvicensis	4950	1	41	35	42,38	17
Razorbill	Alca torda	3791	1	32	64	77,50	24
Guillemot	Uria aalge	13163	4	110	62	75,08	82
Northern gannet	Sula bassana	3714	1	31	54	65,39	20
Lesser black-backed gull	Larus fuscus	15608	4	130	46	55,70	72
Fulmar	Fulmarus glacialis	1441	0	12	50	60,55	7
Great skua	Stercorarius skua	519	0	4	48	58,13	3
Black-headed gull	Larus ridibundus	2102	1	18	36	43,59	8
Common gull	Larus canus	11084	3	92	36	43,59	40
Herring gull	Larus argentatus	6094	2	51	42	50,86	26
Great black-backed gull	Larus marinus	5727	2	48	52	62,97	30
Kittiwake	Rissa trdactyla	6462	2	54	54	65,39	35
Little tern	Sterna albifrons	1275	0	11	35	42,38	5
Arctic tern	Sterna paradisaea	255	0	2	35	42,38	1
Black throated diver	Gavia arctica	101	0	1	50	60,55	1
Mediterranean gull	Larus melanocephalus	270	0	2	36	43,59	1

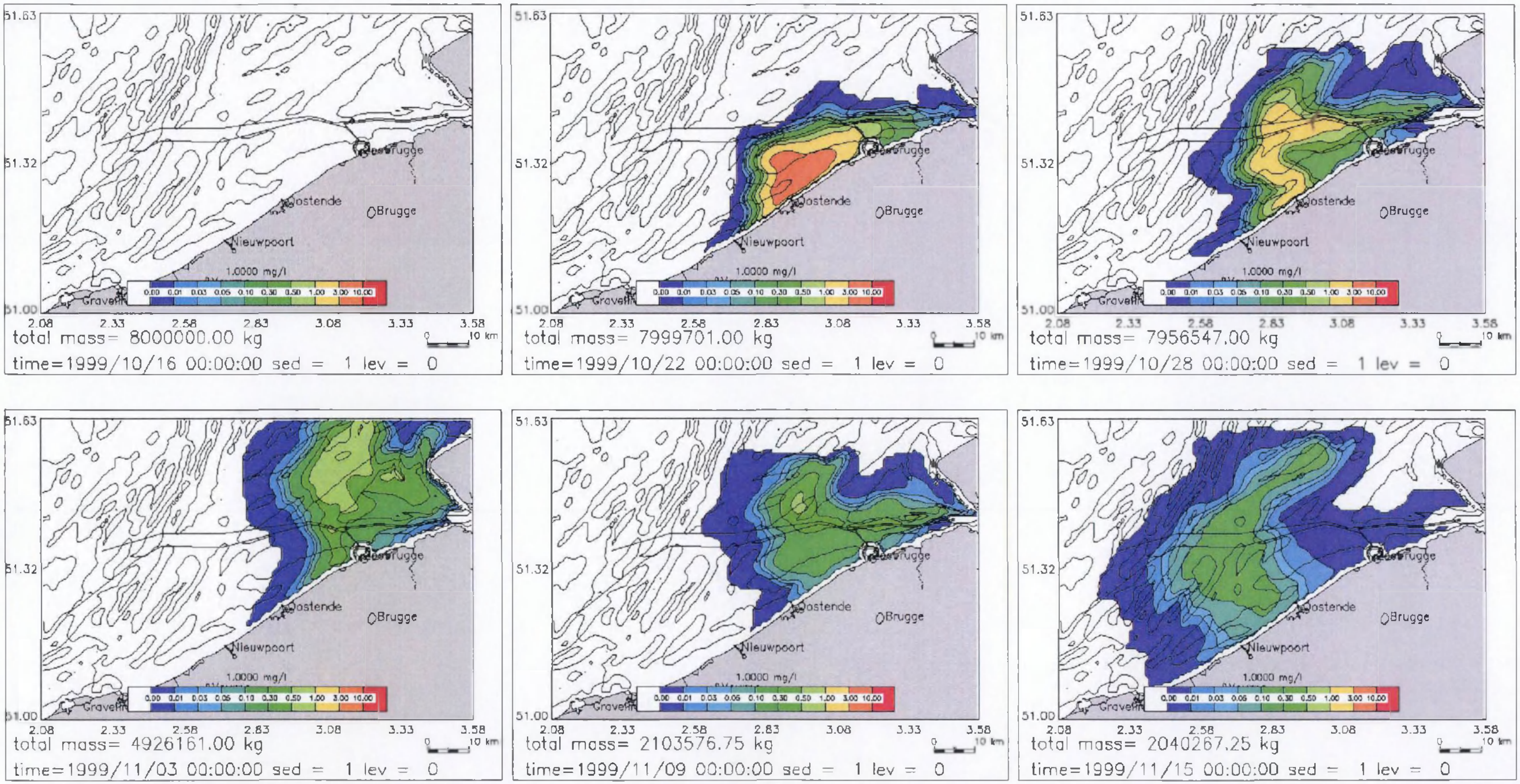
Annex 4.11: Density, oil vulnerability index (OVI) and% mortality – Zwin (winter)

Seabirds		#/ha	#/75 ha	OVI	Mortality (%)	Mortality (#)
Great crested grebe	Podiceps cristatus	0,15	12	45	54,49	6
Common goldeneye	Bucephala clangula	0,12	9	50	60,55	5
Mediterranean gull	Larus melanocephalus	0,07	5	36	43,59	2
Little gull	Larus minutus	0,01	1	46	55,70	0
Black-headed gull	Larus ridibundus	16,67	1250	36	43,59	545
Common gull	Larus canus	0,40	30	36	43,59	13
Lesser black-backed gull	Larus graellsii	0,01	1	46	55,70	0
Herring gull	Larus argentatus	3,50	263	42	50,86	134
Great black-backed gull	Larus marinus	0,04	3	52	62,97	2
Kittiwake	Rissa tridactyla	0,01	1	54	65,39	1
Sandwich tern	Sterna sandvicensis	0,00	0	35	42,38	0
Little tern	Sterna albifrons	0,00	0	35	42,38	0
Arctic tern	Sterna paradisaea	0,00	0	35	42,38	0
Common tern	Sterna hirundo	0,01	1	35	42,38	0
Guillemot	Uria aalge	0,00	0	62	75,08	0
Great cormorant	Phalacrocorax carbo	0,57	43	62	75,08	32
Northern gannet	Morus bassanus	0,00	0	54	65,39	0
Great skua	Stercorarius skua	0,00	0	48	58,13	0
Waterbirds		#/ha	#/75 ha	OVI	Mortality (%)	Mortality (#)
Mallard	Anas platyrhynchos	31,67	2375		50	1188
Lapwing	Vanellus vanellus	14,67	1100		50	550
Wigeon	Anas penelope	7,00	525		50	263
Dunlin	Calidris alpina	3,73	280		50	140
Oystercatcher	Haematopus ostralegus	1,65	124		50	62
Shelduck	Tadorna tadorna	1,11	84		50	42
Curlew	Numenius arquata	2,93	220		50	110
Golden plover	Pluvialis apricaria	2,93	220		50	110
Grey plover	Pluvialis squatarola	1,22	92		50	46
Teal	Anas crecca	2,27	170		50	85

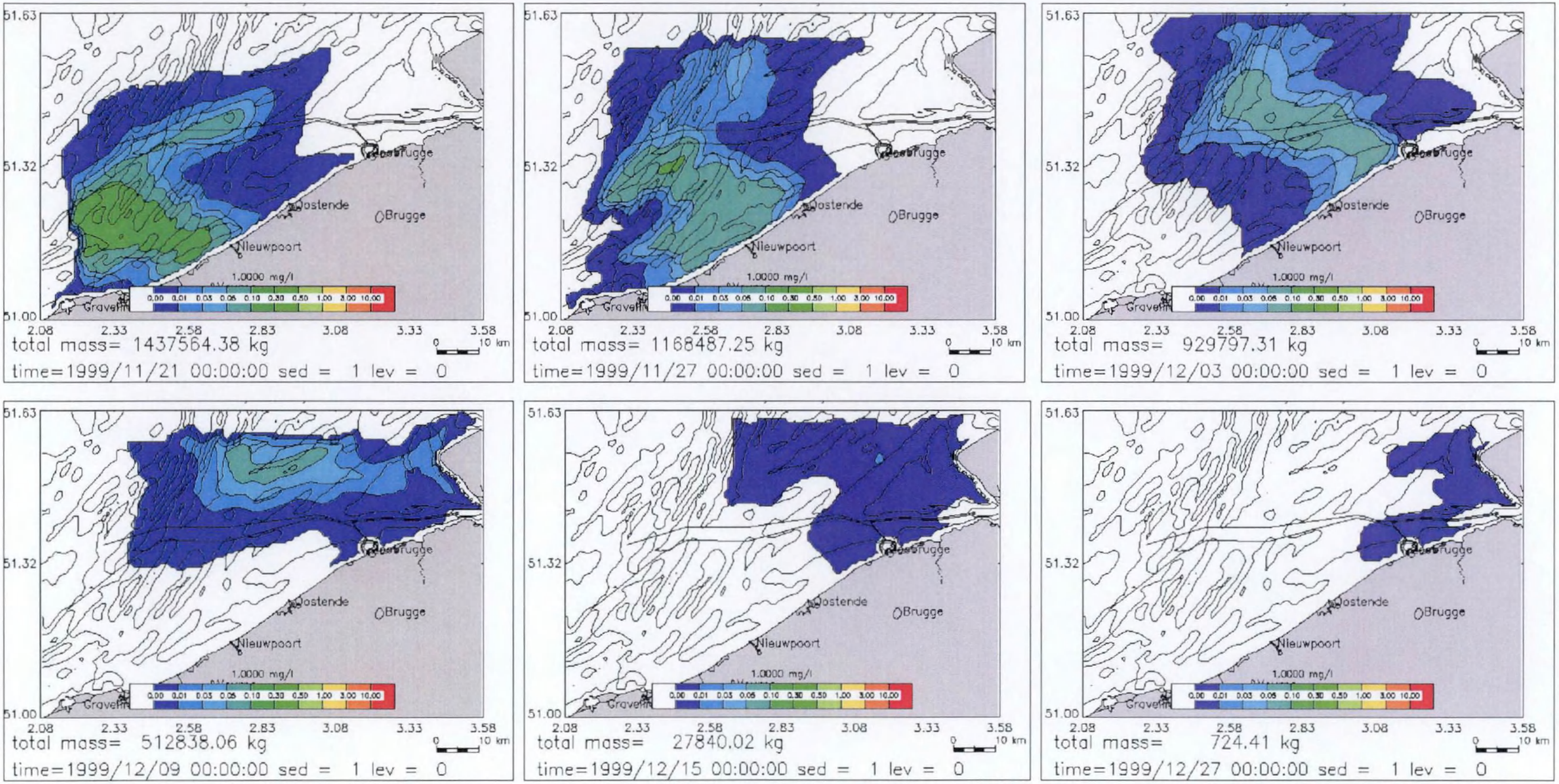
Annex 4.12: Simulation of behaviour of acetone cyaonohydrin (Mackay model)



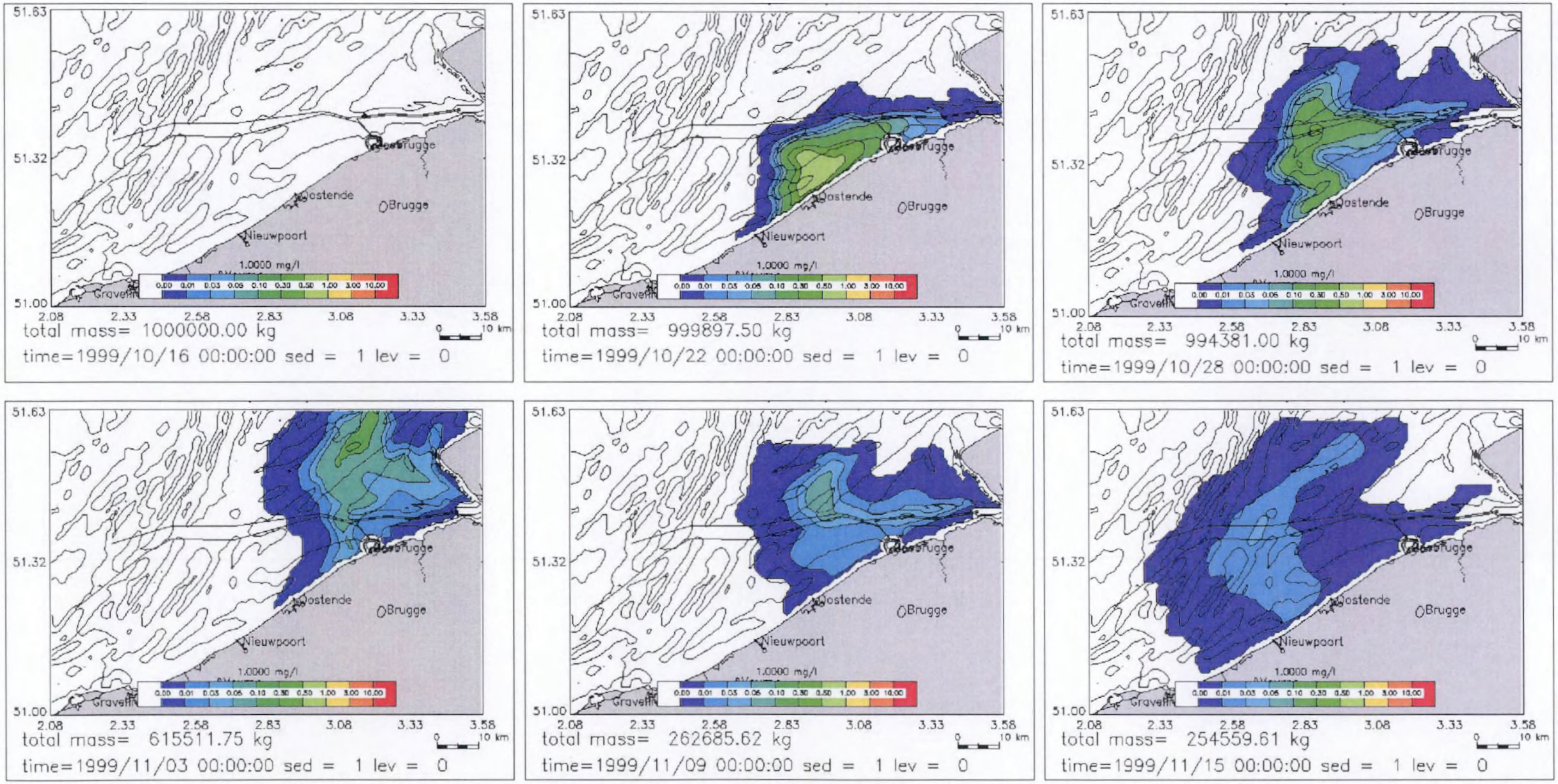
Annex 4.13: Acetone cyanohydrin simulation of 8.000 ton spill (time periode: 75 days)
(Executed by MUMM, 2006)



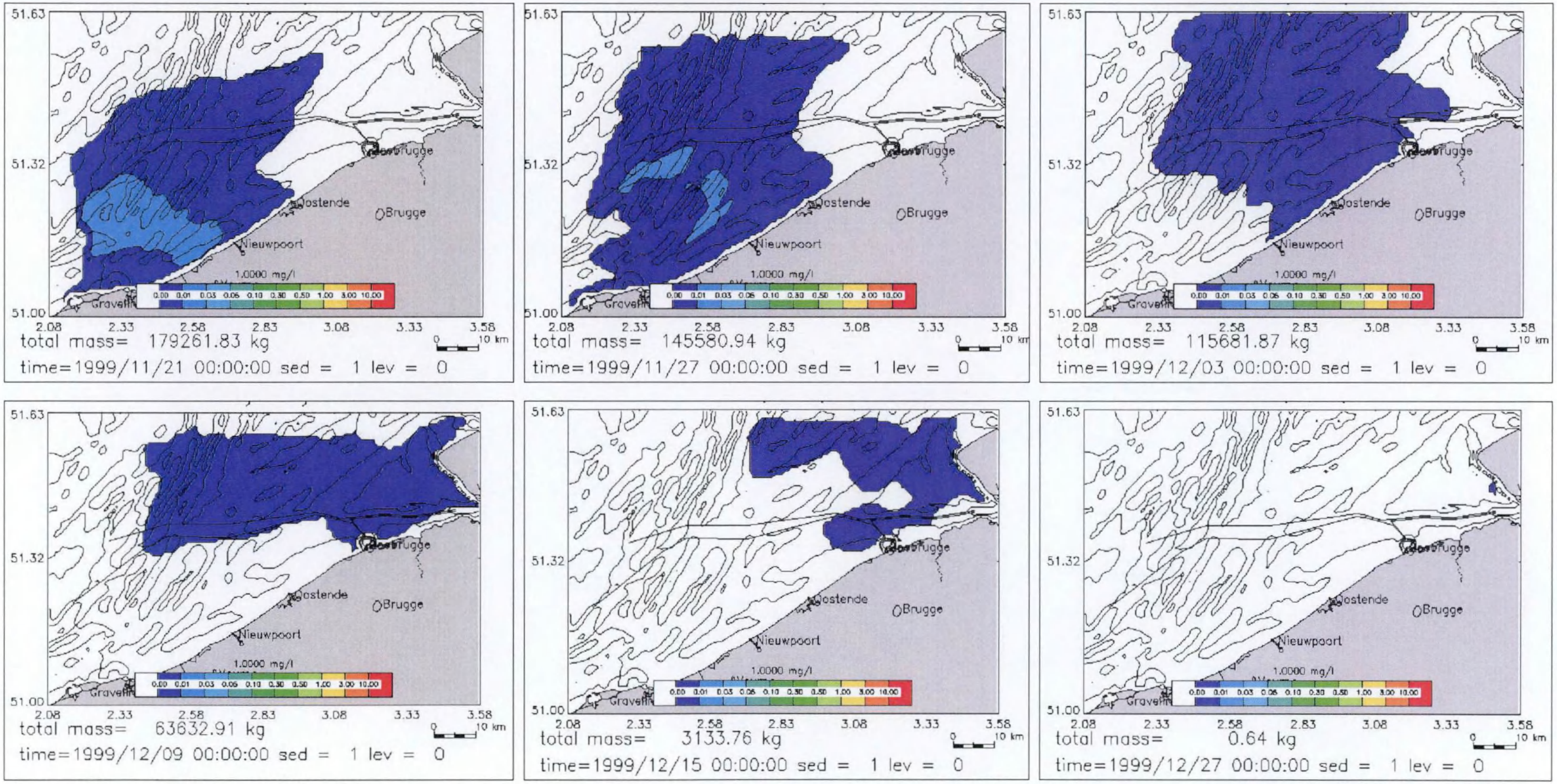
Annex 4.13: Acetone cyanohydrin simulation of 8.000 ton spill (time periode: 75 days)
(Executed by MUMM, 2006) (continued)



Annex 4.14: Acetone cyanohydrin simulation of 1.000 ton spill (time periode: 75 days)
(Executed by MUMM, 2006)

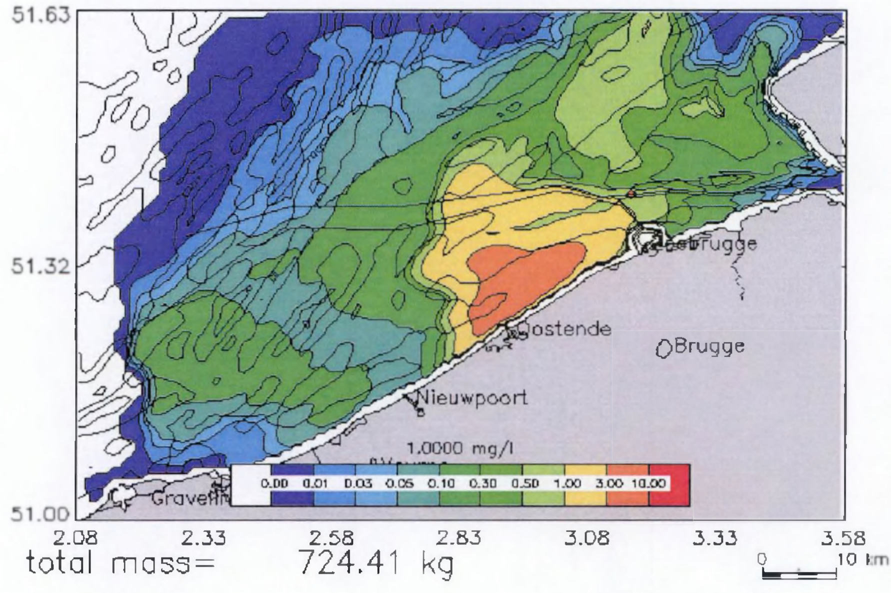


Annex 4.14: Acetone cyanohydrin simulation of 1.000 ton spill (time periode: 75 days)
(Executed by MUMM, 2006) (continued)

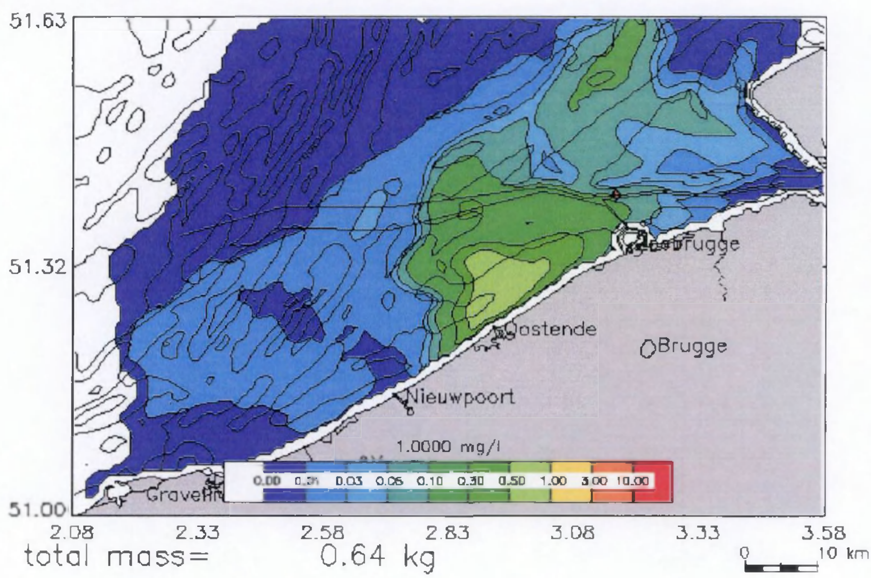


Annex 4.15: Maximum concentration (mg/l) acetone cyanohydrine on BPNS (result simulation 75 days) (MUMM, 2006)

Result of simulation of 8.000 ton/accident



Result of simulation of 1.000 ton/accident



Annex 6.1: Examination and proposals for improvement of existing contingency plans

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