Risk Assessment of Pollution due to Shipping Accidents in the North West of Scotland

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Abstract

Following longstanding concerns relating to the risk of pollution associated with shipping traffic in the North West of Scotland, the local councils commissioned a formal risk assessment to identify and evaluate possible risk control options with a view to improve the navigational regime in the area. The study was undertaken by **Safety At Sea Ltd** and **Eagle Lyon Pope Ltd** between November 2004 and April 2005. This paper presents the approach used in the risk analysis and discusses the findings.

1. Introduction

The aim of the study was to assess the effectiveness of current risk prevention measures and identify/recommend additional measures to reduce the risk of a significant pollution incident in the study area. To this end, the following specific objectives were targeted (with respect to the study area):

- Identify the critical hazards that may lead to a significant pollution event and establish their likelihood
- Establish the effectiveness of current preventive measures, and
- Identify and recommend further measures to reduce the likelihood (and hence the risk) of accidental pollution hazards

The study area covers about 12,000 squared nautical miles of the North-West part of Scotland home to the Islands of the Hebrides, a 150 mile-long island chain of beaches, wildlife and a highly indented coastline. The region is internationally important for nature conservation and includes areas designated as a Biosphere Reserve, a World Heritage Site, Ramsar Sites, Special Protection Areas and Special Areas of Conservation. Fishing is a major employer although in recent years, sea fishing has given way to fish farming and shelf fisheries. Coastal recreation and tourism are growing in the region, much of the tourism being based around the heritage of coastal settlements [1].

On the other hand, the geographic area of the study (see Figure 1) has a wide range of shipping types navigating through it and within it. Virtually every type of marine traffic can and does transit through the Minches (red and blue lines, south and north bound ships respectively) or pass west of Hebrides via the Deep Water Route (DWR, green line), as illustrated in Figure 1.

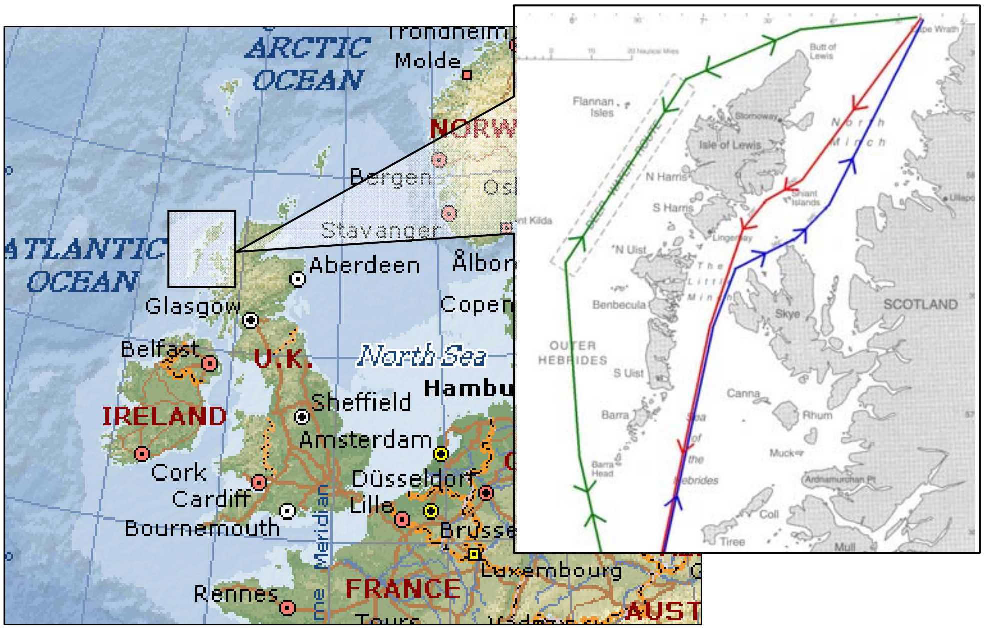

Figure 1: Study Area

The scope of the study was limited to evaluating preventative measures such as traffic routeing, navigation aids, etc. Mitigation (post-incident) measures were not considered explicitly in the study, although a number of such measures (e.g. safe heavens, ETV) were also explored.

The study was conducted in line with the Formal Safety Assessment (FSA) methodology. The FSA is a structured methodology for assessing the risks associated with shipping activity and for evaluating the costs and benefits of the options for reducing these risks. In 2001, the International Maritime Organisation (IMO) approved FSA guidelines for use in the IMO rule-making process as set out in [2]. Since then, the FSA methodology has been used as a tool to help evaluate new regulations or to compare proposed changes with existing standards. The FSA process comprises five basic steps:

- Hazard identification
- Assessment of the risks associated with those hazards (risk analysis)
- Consideration of risk control options (RCOs)
- Cost benefit assessment
- Recommendations for decision-making

Given the objectives of the study, it was decided to follow the FSA approach even if a complete cost benefit analysis was outside of the scope of the study. This paper summarises the work carried out in each step of the process; however, emphasis is placed on the risk analysis work and specifically on the application of a model developed to calculate the risk posed by shipping accidents and evaluate the risk reduction effectiveness of different risk control measures.

2. Hazard Identification

The hazard identification consisted of identifying and reviewing available information pertinent to the study area in relation to present marine activities, shipping traffic data, environmental sensitivity of the study area, pollution response and historical casualty statistics related to shipping accidents leading to pollution (mainly grounding and collisions).

As described in the introduction, the study area is of high environmental and economical sensitivity in Scotland. On the other hand, by virtue of its geographical location, it is unavoidable that the Minches / Hebrides area will always be a salient point for international shipping. Vessels trading between locations within North European ports (Norway, Baltic, Russia), East coast of Scotland, Orkney and Shetland Islands, Northern North Sea offshore oil fields and locations within Ireland, West coast of UK, North Atlantic, South Atlantic (and vice versa) will all be “naturally” drawn to make their passage around the north of Scotland - and thereby via the Minches / Hebrides – for the very valid reason that it is the shortest, and therefore most economical route. A sample of the traffic volume in the study area (summer 2004) is illustrated in Figure 2 (left).

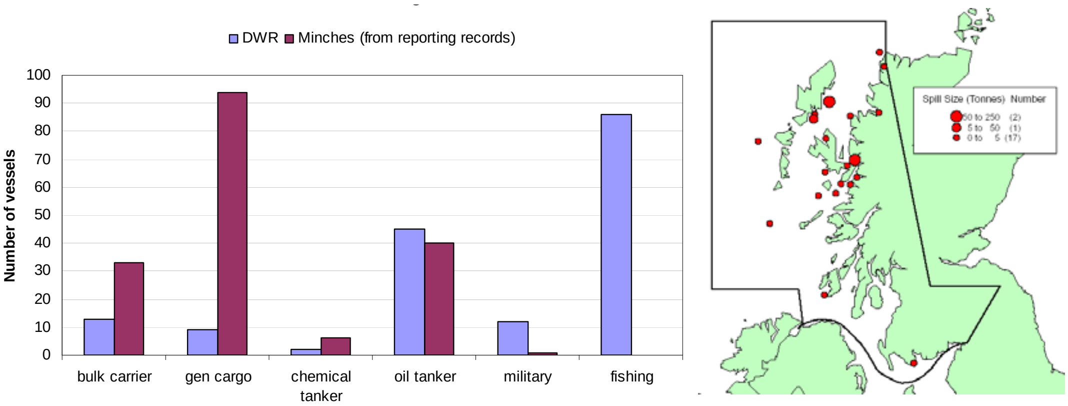

Figure 2: *Left*: Comparison of vessel traffic in the Deep Water Route (DWR) and the Minches. *Right*: Reported oil spills within Western Scotland (1989-1998, [3])

In terms of oil spill statistics, a review of available data [3] and incident reports [4] indicated that within the study area there are about 2 pollution incidents (larger than 1 ton) per year (see Figure 2, right), and these are related to shipping accidents related to grounding and collision.

A brainstorming session involving **experts** representing the concerned stakeholders (ferries and tankers Operators, local Councils, Maritime Coast Guard Agency, Northern Lighthouse Board) was carried out to identify specific hazards and contributing factors related to shipping accidents in the three evaluated routes. The session led to a prioritized list of 29 hazards related to human (navigation errors, organisation failures), technical (vessel breakdown, nav systems failures) and environmental (route-specific) factors, which can be summarized as follows:

- OOW navigational errors (missing course alterations, fatigue, incapacitation, distractions, poor bridge manning and communications)
- Ship systems failure, including vessel breakdown in the Deep Water Route
- Poor passage planning (including contravention of recommended routes)
- Naval/military vessel activity
- Unexpected fishing vessel behaviour
- Others (fire)

With the above information, shipping accident scenarios – related to grounding and collision – were defined and the basis for a quantitative risk analyses were defined, as described next.

3. Risk Analysis

The focus of the risk analysis work in the study was to quantify the current risk level of pollution and the effectiveness of possible routing and other measures aimed at reducing that risk. Since routing measures are mainly related to prevention of shipping accidents, a probabilistic model of collision and grounding was developed, including the elements outlined next.

Probability of a hazardous situation

The probability of a hazardous situation (course to shore, drift, collision course) along the routes was calculated on the basis of available traffic characteristics and its geographical/environmental conditions. The evaluated routes were discretised into 5nm sectors and each sector evaluated independently taking into account the associated hazard information such as water depth, grounding hazards (rocks, shore proximity, etc) and collision hazards (crossing ships, local traffic, etc).

Probability of a shipping accident

The probability of the OOW actions in the presence of a grounding or collision hazard at any point in the route and the associated probability of a shipping accident relate to both human factors (OOW's ability, awareness, decision-making, etc) and technical reliability of the ship (navigational equipment, steering, propulsion, etc).

To this end a probabilistic model based on Bayesian Networks (BN) technology was developed. Bayesian networks are today widely used as a sound and intuitive formalism for reasoning under uncertainty. Bayesian networks (also called belief networks or causal networks) are acyclic directed graphs representing and illustrating the interactions among the set of variables that it models. Numerically, it represents the joint probability distribution among them. The structure and the numerical parameters of a Bayesian network are provided by a mixture of expert knowledge and measurements and objective frequency data.

Using the above described model, the annual probability of a collision and/or grounding accident with the potential to cause significant pollution in the study area was estimated. Actual traffic information on the evaluated routes was utilised to calculate the exposure to the hazards on an annual basis and per ship types. The results indicated that:

- In average, 11 accidents/incidents every year can be expected in the Minches route, and 11 accidents/incidents every year in the Deep Water Route involving all types of vessels. These include mainly fishing vessels.
- In average, one accident involving a large laden tanker (over 10,000 GRT) can be expected every 26 years in the Minches and every 1.1 year in the Deep Water Route (see Figure 3, illustrating the "basis" risk level).

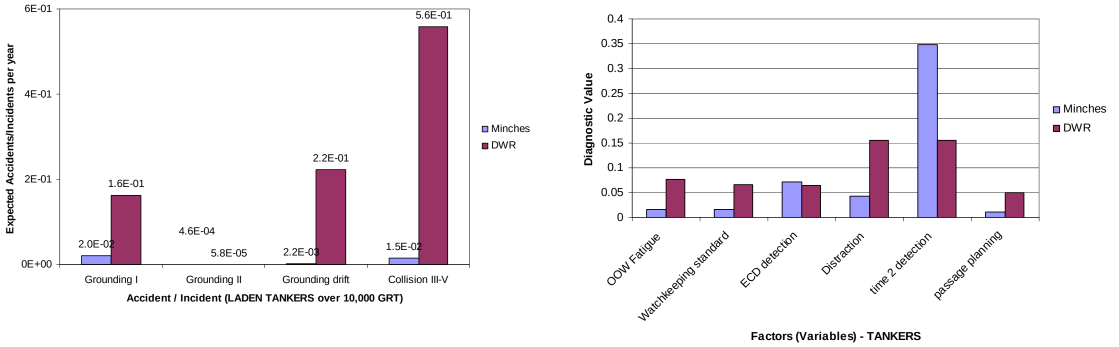

Figure 3: Expected number of accident / incidents per year involving laden oil tankers over 10,000 GRT (left).

A sensitivity analysis of all influencing factors indicated that in general (i.e. when considering all shipping traffic) the most significant factors were OOW fatigue, the quality of the passage planning and watchkeeping standards. However, a more detailed analysis of the oil tanker fleet indicated that due to the already high standards relative to other shipping traffic, the "time to detection" (of the grounding or collision hazard) was the more critical factor, as can be seen on the right hand side of Figure 3. The model was then utilised to evaluate various risk control measures aimed mainly at preventing shipping accidents and hence, the probability of occurrence of a significant pollution event, as described in the next Section.

4. Assessment of Risk Control Options

The findings of the risk analysis indicated that as far as (oil and chemical) tankers were concerned, there was evidence that the risk of a significant collision/grounding accident involving a large laden oil tanker in the Minches routes was lower than in the Deep Water Route. This was related to the fact that the Minches routes had a number of inherent risk reduction measures for ships (natural shelter from weather, more choice of safe anchorages if required), and a number of imposed risk reduction measures (voluntary routeing and reporting, ability to deploy an emergency towing vessel). Such an accident in the Minches could be expected once every 26 years; in the Deep Water Route such an event could be expected once every year.

The model developed for risk calculation was then utilised for evaluating the risk reduction effectiveness of the following risk control options (RCO):

RCO 1. Improved routeing
RCO 2. Improved navigation aids
RCO 3. Improved reporting
RCO 4. Pilotage
RCO 5. Tug escorting and intervention
RCO 6. Safe heavens

RCO 7. AIS
RCO 8. VTS
RCO 9. Improved Chart Coverage
RCO 10. Denial of ROIP
RCO 11. Reconfiguration of existing DWR

In relation to the risk posed by oil tankers, the results are illustrated in Figure 4

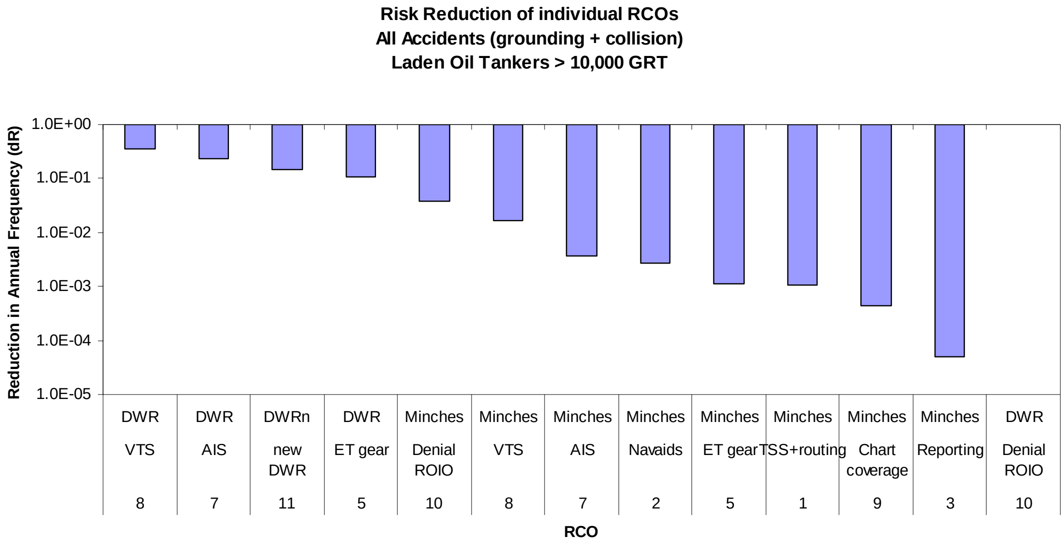

Figure 4: Estimated risk reduction of various risk control options

5. Conclusions

Acting on concerns about the impact that a serious pollution incident could have on the local environment and environment-based economies such as tourism and aquaculture, the local Authorities commissioned a risk assessment dealing mainly with the evaluation of traffic routing measures aimed at preventing shipping accidents in the study area.

A Formal Safety Assessment approach was adopted. The risk assessment was based on the development of a Bayesian Network model of collision and grounding utilised to calculate the probability of a significant shipping accident in the study area as a function of actual shipping traffic, prevalent weather conditions, and traffic routing arrangements, among others. The model was successfully used to estimate the basis (as is) risk and to evaluate the risk reduction effectiveness of various preventative measures.

Although a complete cost-benefit analysis of these measures was outwith the scope of the study, the quantitative results and eventual recommendations made were utilised by the relevant authorities to support decision-making on the type and extent of measures required to achieve a level of risk that is consistent with the As Low As Reasonably Practical (ALARP) principle.

The combination of practical navigation knowledge and state-of-the-art probabilistic modelling and analysis contributed greatly to the successful realisation of this study.

6. References

[1] SNH-8 (2001), *Marine and Environment Issues in Scotland*, Scottish Natural Heritage, Data Support Scotland, Sheet 8, November 2001.

[2] IMO (2002), *Guidelines for Formal Safety Assessment (FSA) for Use in the IMO Rule-Making Process*, MSC/Circ 1023 – MEPC/Circ 392

[3] DOVRE SAFETEC (1999), *Identification of Marine Environmental High Risk Areas (MEHRA) in the UK*, Department of the Environment, Transport and the Regions, December 1999.

[4] ACOPS (2001-2004), *Annual survey of reported discharges attributed to Vessels and offshore oil & gas installations Operating in the United Kingdom Pollution control zone – Years 2001 to 2004*. London.