Assessment of Risk and Identification of Environmentally Sensitive Areas

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Abstract

Following the Braer disaster, one of the recommendations published by Lord Donaldson in "Safer Ships Cleaner Seas" was that the UK should look at establishing Marine Environmental High Risk Areas (MEHRA's) to protect the most sensitive areas of the UK coastline and surrounding waters. It was stated that these should consider both the environmental sensitivity of the seas and UK coastline as well as the pollution risk presented by shipping in different areas of the UK Continental Shelf. This paper presents the risk analysis methodology applied to assist the UK Department of Environment, Transport and the Regions (DETR) to determine the Marine Environmental High Risk Areas in the UK.

The paper looks at the different hazards presented by shipping and identifies those, which require to be considered in most detail. Examples are presented of the traffic surveys carried out to determine vessel routeing, as well as the historical frequencies of different types of shipping incidents that have taken place in UK waters. Also described are the factors that are seen to have an influence on the likelihood of shipping accidents.

Following estimation of the shipping risks, details are presented on the methodology applied to rank the environmental sensitivity of the coastline and sea areas, considering ecological, social and economic factors. The methodology relies on a Geographical Information System (GIS) to map different sensitivities, including sites protected by internationally, national, and statutory legislation as well as a number of other unclassified areas.

Following this, the results of these two assessments are combined to identify potential MEHRA's for the UK.

It should be noted that this paper represents the initial research work and further variations and revisions to the methodology which have taken place folowing public consulation are not represented in this paper.

Introduction and Background

Routeing measures are primarily focused on encouraging ships to follow routes where they are less likely to collide with each other, run ashore or get into difficulties. Their second aim is to reduce the scope for disaster if a ship does get into difficulties and thirdly to ensure that, so far as reasonably practicable, ships are kept outwith areas where pollution would cause particular damage to the environment.

With respect to the third aim of environmental protection, the Donaldson Inquiry did not accept a suggestion to place a blanket ban on all large, potentially polluting vessels by requesting they keep a fixed distance from shore during transit: 10 and 50 nm were proposed. This rejection was based on a number of issues including:

- Some channels are too narrow to be able to maintain a set distance.
- Bunching may occur at a fixed distance and increase the likelihood of an accident.
- In some circumstances it may be safest to seek shelter closer to shore.
- By their nature vessels would have to pass within blanket ban distances as they enter/exit ports.
- Although not specifically mentioned by the Inquiry, a blanket ban would not be consistent with International law.

Hence the Donaldson Inquiry proposed an alternative to blanket banning by recommending that Marine Environmental High Risk Areas be established, which are comparatively limited areas of high environmental sensitivity and also at risk from shipping. The basis of the MEHRA's recommendation was that their identification and publication will give the Masters additional information relevant to passage planning that would be more likely to result in the usage of the recommended routeing. It was additionally hoped that ship owners and insurers would, in their own self-interest, regard a MEHRA as an area from which their ships should keep clear and would therefore result in reduction in pollution risk at these sites.

This paper documents the approach adopted by the DETR for identifying MEHRA's and proposes sites which should be considered for classification within this scheme.

Methodology for Identification of MEHRA's

The following figure highlights the methodology which has been devised to determine MEHRA's for the UK.

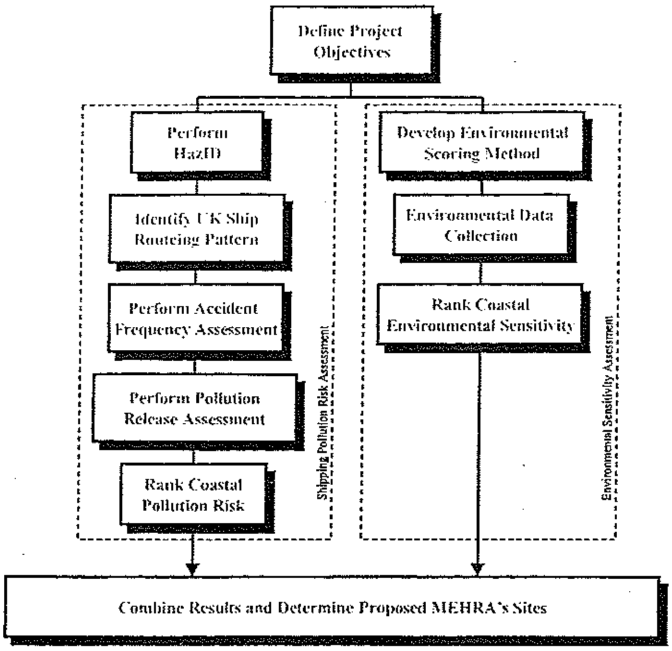

Figure 1 Overview of Methodology

Each of the tasks outlined in Figure 1 is discussed in discussed in the following sections.

Hazard Identification:

The waters around the UK coastline include some of the world's busiest sea lanes. At any one time there are in the order of 5,000 ships operating in the North Sea. There are very few areas of the UK's coastal waters without significant shipping traffic. It is noted that despite this, shipping is responsible for a relatively small proportion of all marine pollution in the UK, compared to that from land-based sources that can be traced back to centres of population and to industrial and agricultural operations. It is however acknowledged that marine accidents generally result in much greater consequences than pollution from land based sources.

Within marine transportation, ships can constitute an environmental hazard to the marine environment through:

- Operational pollution,
- Accidental pollution,
- Physical damage.

The scope of this project was only to look at accidental pollution, given that operational pollution is covered by Marine Pollution (MARPOL) regulations.

Accidental Pollution: Accidents such as collision, and grounding can result in large quantities of pollutant being released into the marine environment. The types of pollutant released following an accident tends to be similar to those associated with operational discharge but as they are more highly concentrated and larger in volume they have a much greater potential to harm the marine environment.

From information reviewed on accidents resulting in pollution within UK waters (Ref. [i]), it was observed that the most common pollutant released to the marine environment is oil. From Lloyds casualty data recorded over a 10 year period (UK - 1989-1998 inclusive) there is only one recorded chemical pollution incident at sea which occurred when two vessels collided in the English Channel and three containers carrying packaged chemicals were lost overboard.

From data presented by the International Tanker Owners Pollution Federation (ITOPF), it was found that most of the operational spills are very small, whereas accidental events result in much larger spills, as presented in Figure 2.

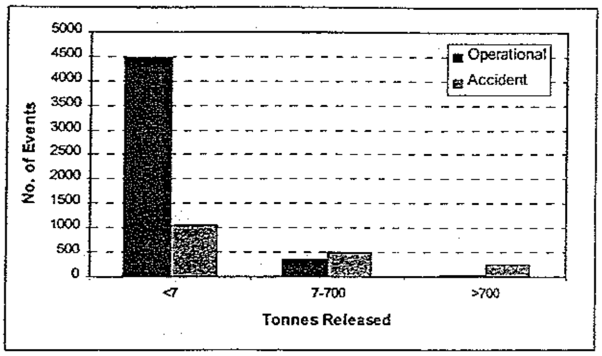

Figure 2 Pollution from Operational & Accidental Events

This supported the conclusion that the assessment should focus on accidental events.

Ship Routeing in UK Waters

One of the first tasks, which required to be carried out, was to identify the routeing patterns and details of the shipping on the routes identified. Within the Donaldson Inquiry it was emphasised that there were a number of factors required to assess the pollution risk associated with a vessel such as:

- the number, type and size of vessels passing and the nature of their cargoes;
- the distance of the usual shipping lanes from the shore;
- any circumstances giving rise to an increased risk of collision such as a significant amount of traffic going across normal flow;

- hydrographical conditions relevant to safe navigation, such as lack of safe anchorage's;

- prevailing meteorological and tidal characteristics

It can be seen from these factors that routeing data was a fundamental input to the analysis. The project used the COAST database (Ref. [ii]) which recognised to be the most comprehensive and up to date data source for ship routeing in UK waters. The main data sources used within the database include:

- Port Callings Data provided by LMIS
- Offshore Traffic Surveys carried out by Standby Vessels (> 200 surveys)
- Platform and Coastal based Radar Systems
- Information from Offshore Operators (Standby/Supply/Shuttle Tanker details)
- Information from Ferry Operators
- Vessel Passage Plans
- Deep Sea Pilot Route Details

An example of a traffic survey used to compile the database is presented in the following figure.

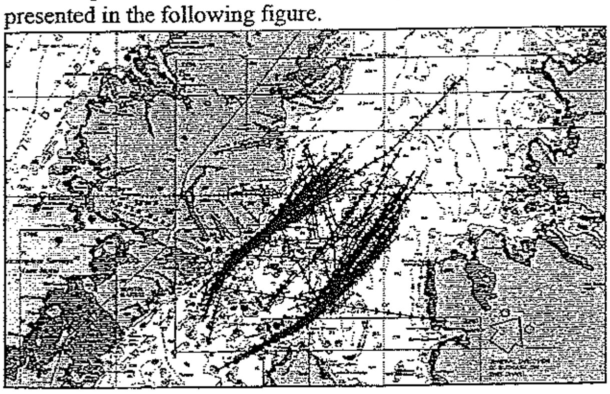

Figure 3 Shippjng Traffic Survey Data in Minches

The main information contained in the database for each route is as follows:

- Port of Departure/Destination
- Route Waypoints
- Number of Vessels per year
- Vessel Type Distribution
- Vessel Size Distribution
- Flag Distribution
- Age Distribution
- Speed Distribution

The main vessel types included within the database are:

- Bulk carriers
- General cargo vessels
- Standby vessels
- Supply vessels
- Oil tankers
- Shuttle tankers
- Ferries
- Gas tankers
- Ro-Ro's
- Chemical tankers

The following figure presents a sample of the routes contained within the database.

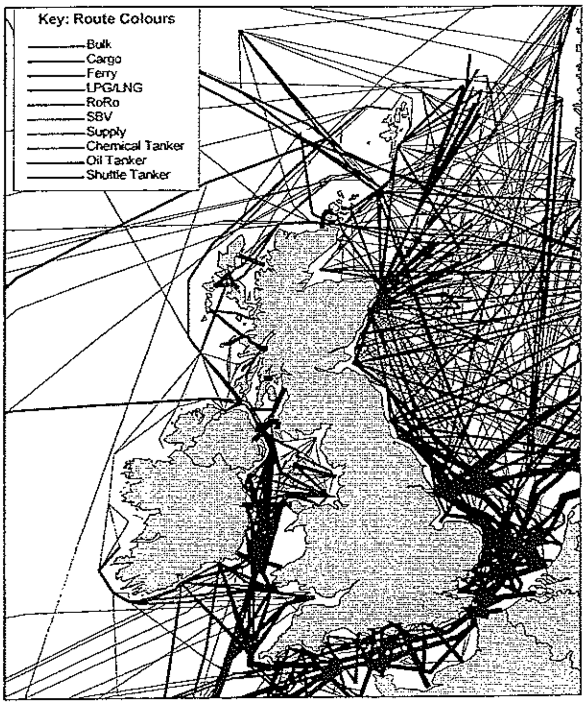

Figure 4 Routes in COAST Database

Shipping Accident Frequency Assessment

Once the ship routeing has been identified, the next stage of the assessment was to determine the frequency of different marine accidents taking place within UK waters which would be followed by the consequence evaluation. These tasks involved the application of several predictive models, which can be categorised as either

- ***Frequency models*** - which determine the likely frequency of accidents within UK waters
- ***Consequence models***- which determined the likelihood of a spill and the volume of the release

Within each of the models developed, it was considered of paramount importance that the results be validated against the best available historical data to ensure an accurate representation of the pollution risks within UK waters.

From a review of historical accident data (UK 1989-1998 incl.), the five main accidental event categories which were identified were:

- Fire & explosion
- Foundering/Structural failure
- Ship to ship collision
- Powered grounding
- Drifting grounding

The following figure presents the distribution of the different accidental events.

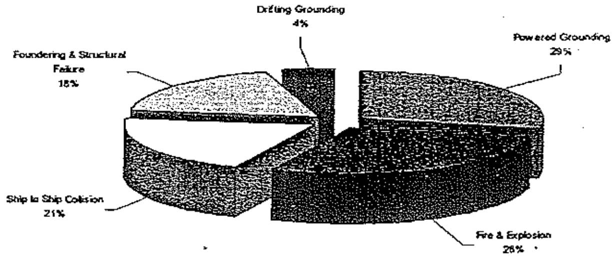

Figure 5 Breakdown of different accidental events

A geographical distribution of a large sample of the accidents is presented in the following figure:.

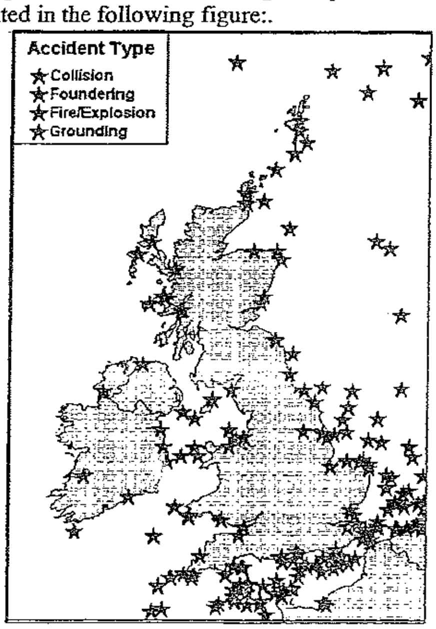

Figure 6 Geographical distribution of accidental events.

These major accident groups were isolated within the database to allow further, more in-depth analysis to be carried out. Within this analysis various factors such as ship age, size and type were assessed as well as the environmental conditions at the time of each incident to establish if any underlying trends exist which could influence the likelihood of each type of accident occurring. The findings of the analysis were then incorporated into the predictive models for the different types of shipping accident.

The following two graphs provide a sample of the findings of this review. Figure 7 presents a breakdown of the weather conditions that were reported at the time of each ship collision incident. The graph shows that collisions are most likely to occur in poor visibility.

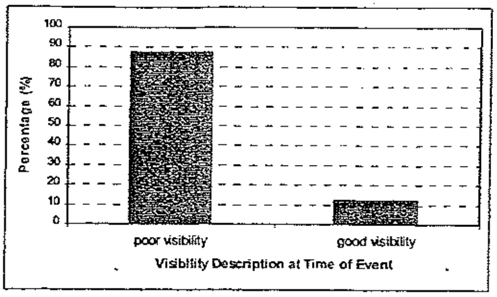

Figure 7 Visibity at Time of Accident

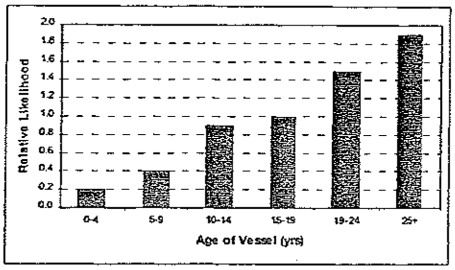

Figure 8 Age of Vessels at Time of Accident

From Figure 8 it can be seen that there is a relationship between the age of vessels and the likelihood of foundering or structural failure. This is as expected and is considered to be a result of deterioration of hull due to corrosion stresses and fractures.

Models have been developed and utilised to calculate the geographical distribution of accidental events in UK Waters. The following table summarises the factors covered within each of the models.

Table 1 Factors Considered in Models

Models	Parameters Used Within Models
Ship to ship collision	Route positions, visibility, encounter angle, VTS areas, vessel type and size, vessel speed, and number of vessels on route.
Powered grounding	No of vessels on route, proximity of route to coastline, coastal rockiness, vessel size, VTS areas, sea state, vessel type, geometrical probabilities, navigational error probabilities.
Drifting grounding	Vessel type and size, wind strength & direction, sea-conditions, self-repair probabilities, mechanical failure probabilities, drift speeds.
Fire and explosion	Vessel type and size, traffic densities.
Foundering	Vessel type and size, traffic densities and probability of severe weather in different geographical locations.

In order to present the collision frequency results in a manner that could be viewed alongside the UK coastline, a GIS system was developed with different sized cells generated depending on proximity to the shoreline. The different cell sizes applied are as follows:

- 7.5 nm x 4 nm (shoreline cells)
- 15 nm x 8nm (sea cells)
- 30 nm x 16 nm (sea cells)
- 60 nm x 32 nm (sea areas remote from UK coastline)

The following figure presents the incident frequencies predicted by the models.

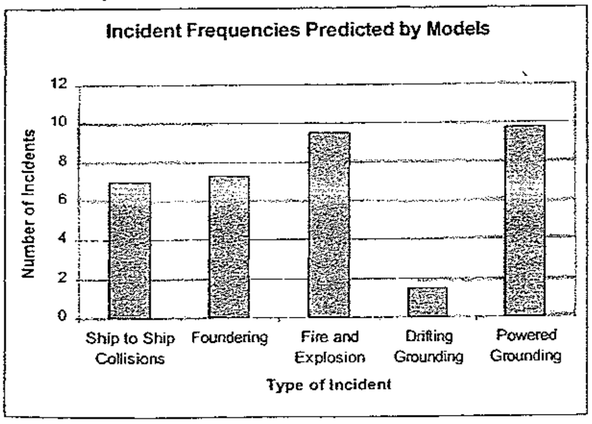

Figure 9 Incident Frequencies Per Annum in UK Waters Predicted by Modelling

This figure shows that powered groundingis the most likely type of marine accident on the UKCS, closely followed by fire and explosion. The following figure presents the geographical distribution of incidents for all accidents and all vessel sizes & types.

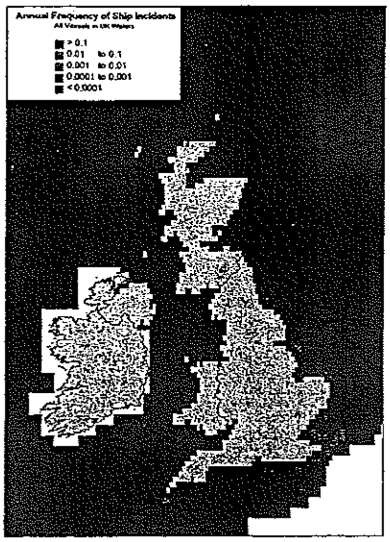

Figure 10 Annual Frequency of Incidents in UK

The following table presents the frequencies generated by the models for a cell in the Dover Strait.

Table 2 Incident Frequencies for Dover Strait

Location	Incident Category	Frequency
Dover Strait	Ship to ship collision	0.15
(Non- coastal cell)	Fire & explosion	0.06
	Powered grounding	Not applicable
	Drifting grounding	Not applicable
	Foundering	0.04
Total		0. 25

The results generated using the models were validated for the entire UKCS based on the historical accident frequencies. The following figure presents an example of the validation exercise.

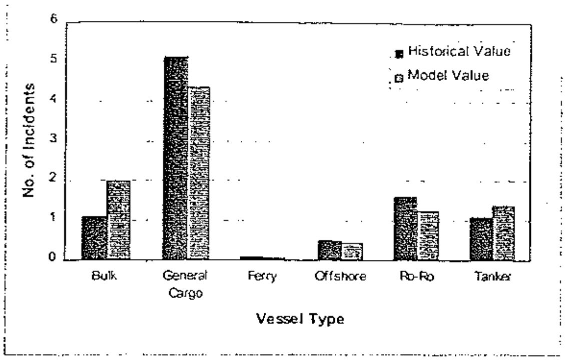

Figure 11 **Model vs Historical Frequencies**

The above graph shows that there is a good comparison between model predictions and the actual number of historical occurrences for fires and explosions.

Spill Probabilities: A large amount of data was reviewed for the different incident types to investigate the likelihood of a spill occurring should an accident occur. This involved investigating the likelihood of either bunkers or cargo being spilt. The following graph presents the probability of a spill occuring (bunker or cargo) for the different types of accident.

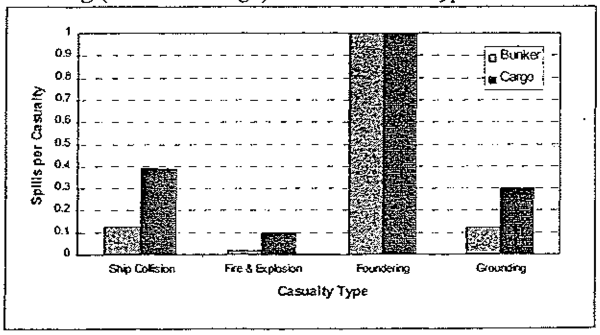

Figure 12 Probability of Spill resulting from Casualty

The potential spills were divided into different size categories for each accidental event.

Table 3 **Spill Size Categories**

Spill Size Category	Spill Size (tonnes)
1	0 to 1,000
2	1,000 to 10,000
3	10,000 to 50,000
4	50,000 to 100,000
5	Over 100,000

The spill probability and size varies with ship size and design as well as the type of accidental event. The following figure presents on a geographical basis the frequency of spills >1,000 tonnes.

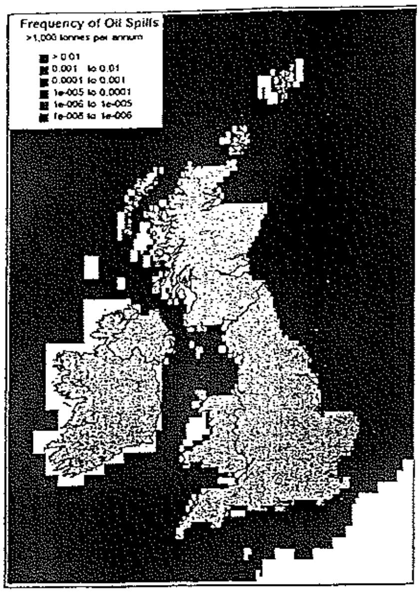

Figure 13 **Frequency of Spills >1,000 Tonnes**

Average spill quantities were estimated for each size category based on historical data. A model was also developed to estimate the likelihood of a spill in a sea area reaching a coastal area. Estimates were then made of the tonnage spilt per annum in each cell. The following figure presents the pollution risk estimated for the UK coastline.

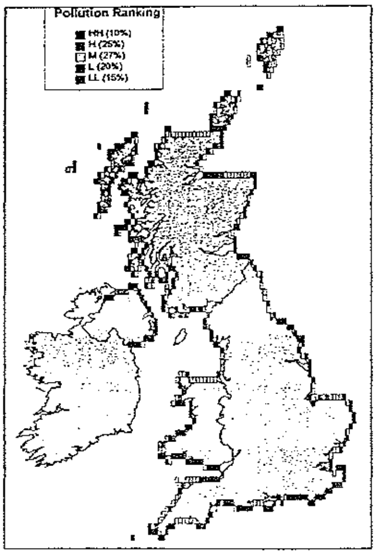

Figure 14 **Pollution Sensitivity of UK Coastline**

The results of the spill analysis were then compared with 10 years of oil spill data (ACOPS) for UK waters. This date presented in the following figure gives an annual spill volume of 16,200 tonnes per annum, with the model predicting 12,500 tonnes per annum (i.e. same order of magnitude)

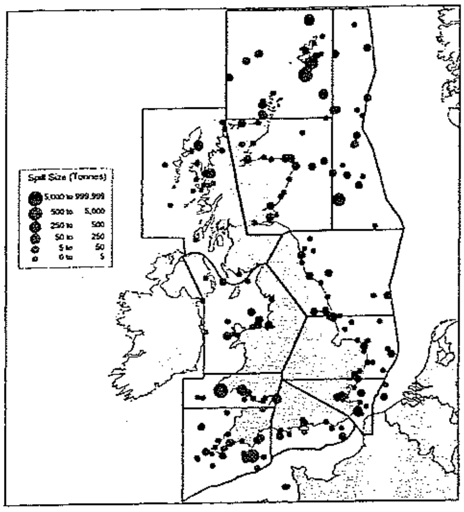

Figure 15 Oil Spills in the UK (1989-1998)

Environmental Sensitivity of UK

The environmental sensitivity of the UK coastline and surrounding waters required to be estimated. This was carried out by using GIS to map different sites covered by different designations. The sites were placed under the following general categories:

- Wildlife
- Landscape
- Geology
- Fishing
- Vulnerability of seabirds to oil pollution
- Economy/Amenity

Typical designations considered under wildlife include:

- World heritage sites
- Biosphere reserves
- Special Protection Area
- Ramsar sites
- Sites of Special Scientific Interest
- National Nature Reserves etc. etc.

In total in the order of 30-40 different types of designation were mapped in the assessment. An example of the mapping of a shellfish production area is presented in the following figure:

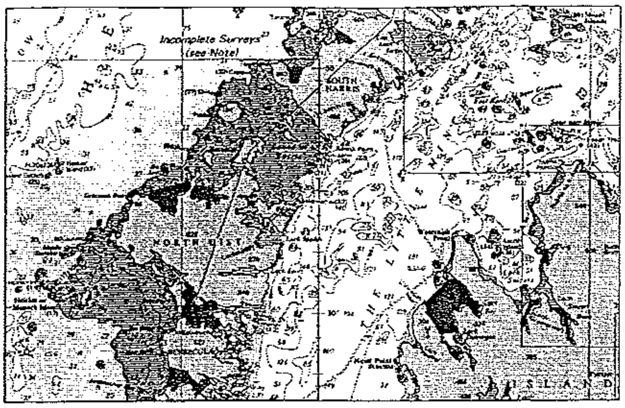

Figure 16 GIS Maping of Shellfish Production Areas

An assessment was carried out by the Joint Nature Conservation Committee (JNCC) on the sensitivity of sites to marine pollution. Once the sensitive sites were identified a scoring methodology was developed to allow for the ranking of environmental sensitivity. The GIS software identifies the number and type of different sites located within a cell and calculates the sensitivity. If multiple sites of the same type (e.g. 2 blue flag beaches) were located within a cell, then only 1 will be counted in the sensitivity score. The following table summarises the scoring methodology:

Table 4 Scoring Methodology for Coasal & Sea Area Environmental Sensitivity

Nature of Importance	Methodology	Example Sites Within a Cell	Cell Score
Wildlife	Only the highest scoring site located within a cell scores.	1 WHS (ecological), 1 SPA, 1 SSSI, 1 LNR.	5
Seabird Vulnerability	One score per cell.	High ranking	5
Fishing	Each criteria identified within a cell scores and scores are added.	High density fish farming, and shellfish waters.	4
Amenity/Economy	Each criteria identified within a cell scores and scores are added.	2 blue flag beaches, 1 blue flag marina and 1 country park	3
Landscape	Only the highest scoring site located within a cell scores.	1 AONB, 1 NP and 1 ESA.	3
Geological	Only the highest scoring site located within a cell scores.	1 WHS (geological) & 1 ESCR site.	3
Total	N/A	N/A	23

The following figure presents the results of the environmental sensitivity. For coastal areas. Sea areas cannot score as highly as coastal areas (not as many criteria apply), therefore they do not enter the top 10% of the coastal scores.

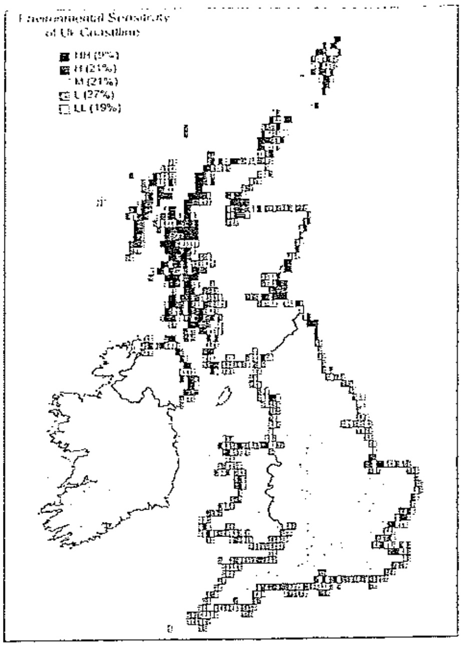

Figure 17 Environmental Sensivity of UK Coastline

From the figure it can be seen that the main areas of very high environmental sensitivity around the UK coastline are mainly around the West Coast of Scotland, with the highest scoring cell being near the Isle of Mull. The following table presents how the score has been calculated for this particular cell.

Table 5 Environmental Ranking for Cell

Category	Sites Within Category or Ranking	Score
Wildlife	1 Special Protection Area (SPA) 1 Site of Special Scientific Interest (SSSI)	5
Seabird Vulnerability	Ranking is high	5
Fishing	Fish farm density is medium	2
	Nephrops fishing area	3
	Shellfish production area	1
	Shellfish waters	1
Amenity/Economy	1 Preferred Conservation Zone (PCZ)	1
Landscape	1 National Scenic Area (NSA) 1 Environmentally Sensitive Area (ESA)	3
Geological	1 Geological Conservation Review Site (GCR)	1
Total		22

A sample plot the sensitivity for the West Coast of Scotland is presented in the following figure.

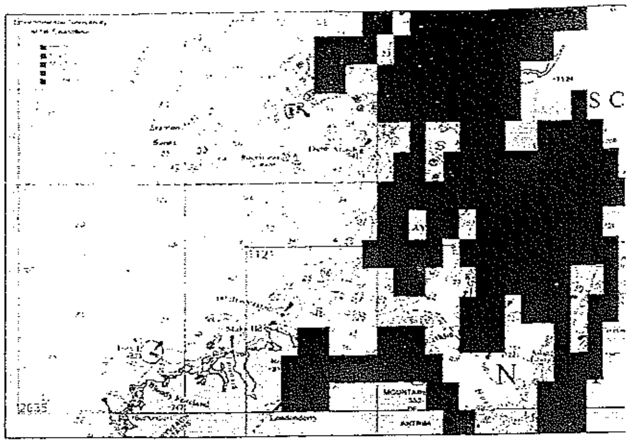

Figure 18 Sample Plot of West Coast of Scotland

Identification of MEHRA's

Following the assessment of both the pollution risk and the environmental sensitivity, the results were re-calibrated so that both sets could be combined with equal weighting to establish the MEHRA's ranking. To identify candidates for Marine Environmental High Risk Areas, these new values were combined as follows:

MEHRA's Score = Environmental Sensitivity x Pollution Risk

Using this formula ensures that coastal cells have to qualify on both sets of criteria to obtain a high overall score The following figure presents the ranking of the UK Coastline with the top 10% shaded in black identified as being the most likely candidates for MEHRA's

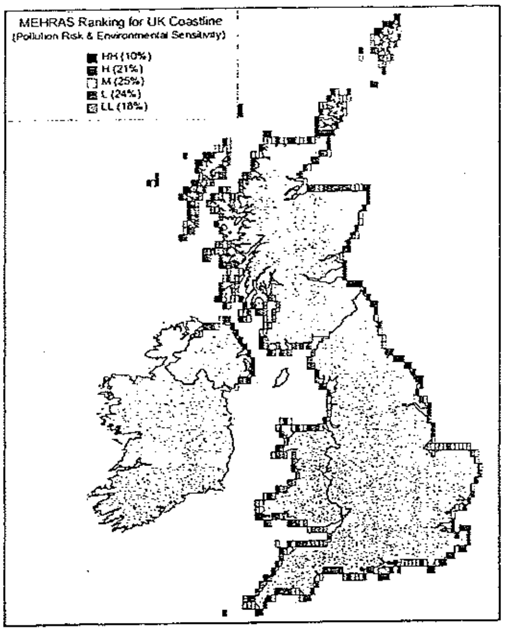

Figure 19 MEHRAS's Ranking for UK Coastline

The following table presents an example of the top scoring sites based on both pollution risk and environmental sensitivity.

Table 6 Top Scoring MEHRA's Sites

Location	Score
Muckle Flugga (North Coast of Unst in Shetland)	224
West of Yell (Shetland)	210
Bass Rock (Adjacent to Firth of Forth)	208
Isle of May (Adjacent to Firth of Forth)	196
Holy Island near Berwick Upon Tweed	192
West Coast of Hoy (Pentland Firth, Orkney)	182
Near Carloway (West Coast of Lewis)	182
Rathlin Island (North Coast of Northern Ireland)	182
Near Larne (East Coast of Northern Ireland)	169
Farne Islands (North East Coast of England)	169
South Foreland (South East Coast of England)	168
Muckle Flugga (North Coast of Unst in Shetland)	168
Duncansby Head (Pentland Firth, North Coast of Scotland)	168
Near Berwick Upon Tweed (South East Coast of Scotland)	168
St. Abbs Head Near Berwick Upon Tweed (South East Coast of Scotland)	160
Flamborough Head (East Coast of England)	156
Rhinns of Islay (West Coast of Scotland)	156
Skomer & Skokholm Island (West Wales)	156
Saint Kilda (West Coast of Scotland)	156
Near Bangor (East Coast of Northern Ireland)	156

The following figure presents a plot of the MEHRA's ranking for the North West coast of Scotland.

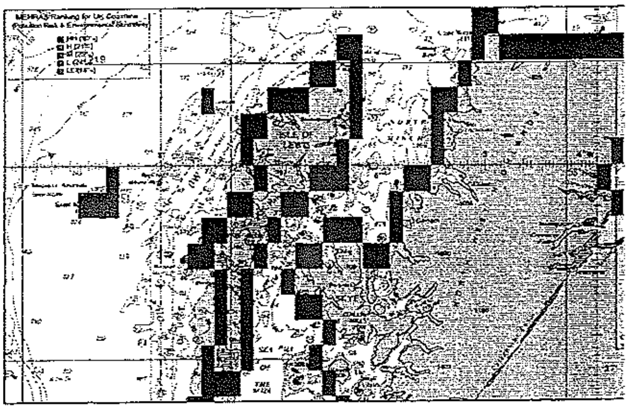

Figure 20 MEHRA's Ranking for NW Coast of Scotland

Conclusions

It is concluded that a non-subjective methodology has been developed to assist in the identification of MEHRA's. The methodology developed gives account to both the shipping pollution risk and coastal environmental sensitivity as recommended by Lord Donaldson and is both transparent and traceable.

It is further concluded that the methodology gives account to all the parameters highlighted within the Donaldson Inquiry as having the potential to influence MEHRA's plus others. These include:

- the number, type and size of vessels passing and the nature of their cargoes;
- the distance of the usual shipping lanes from the shore;
- any circumstances giving risk to an increased risk of collision such as a significant amount of traffic going across normal flow;
- prevailing meteorological characteristics;
- existence of wildlife feeding or breeding sites of international significance or the presence of biological

communities of either flora or fauna or both or particular interest or rarity: designation as a Special Protection Area under the EC Birds Directive or any area of special conservation under the Habitats Directive will normally be regarded as evidence of this.

- the existence of commercially exploitable biological resources and mariculture sites; and the extent to which the area provides a public recreational amenity.

Future Work:

In the further assessment of MEHRA's consideration requires to be given to the following:

1. Consideration should be given to the inclusion at a later date for the inclusion of marine benthic sensitivity data for sea areas in the assessment of environmental sensitivity.
2. The persistence of the coastline should be integrated to take into account residence times for different coastal morphology.
3. Different scoring methodologies could be investigated for assessing the environmental sensitivity of the coastline.

Acknowledgements

The author wishes to express his thanks to the DETR for allowing the presentation of this paper.

References

i Lloyds casualty data 1989-1998.

ii Safetec UK Ltd, "Development of a UK Shipping Database (COAST)" Final Report to the Health and Safety Executive, UK Offshore Operators Association and Department of Transport – 1996/7.