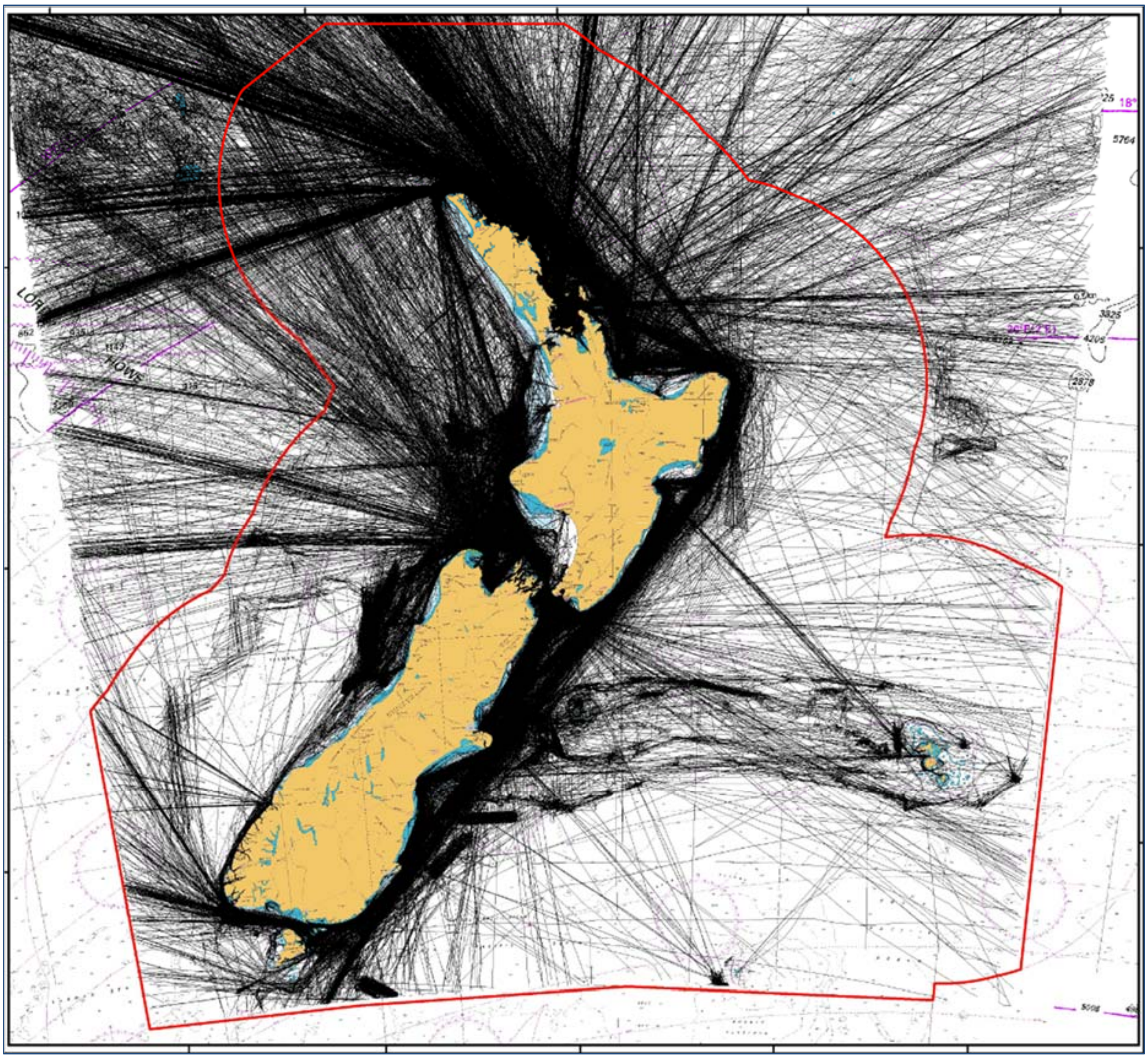
Hydrographic Authority

LAND INFORMATION NEW ZEALAND

NEW ZEALAND HYDROGRAPHIC RISK ASSESSMENT - NATIONAL OVERVIEW



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LAND INFORMATION NEW ZEALAND

NEW ZEALAND HYDROGRAPHIC RISK ASSESSMENT - NATIONAL OVERVIEW

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ABBREVIATIONS

Abbreviation	Detail
ATBA	Area To Be Avoided. An IMO approved routeing tool, which is printed on the chart, where a sea area is close to SOLAS traffic in accordance with agreed criteria. ATBAs are normally used in sea areas of high ecological value to a coastal state, such as a marine reserve.
AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
AtoN	Aid to Navigation
b	Billion
CATZOC	Category of Zone of Confidence in data, an IHO S57 attribute of the MQUAL object
CPZ	Cable Protection Zone
DG	Dangerous Goods
DOC	Department of Conservation
DQWG	Data Quality Working Group
DUKC	Dynamic Under Keel Clearance
DWT	Deadweight, a measure of a vessel's weight carrying capacity
ECDIS	Electronic Chart Display Information System
EEZ	Exclusive Economic Zone
ENC	Electronic Navigational Chart
FIGS	Freight Information Gathering System
FSA	Formal Safety Assessment
GDP	Gross Domestic Product
GIS	Geographic Information System
GRT	Gross Registered Tonnage
GT	Gross Tonnage
ha	Hectare
HW	High Water
IHO	International Hydrographic Organization
IMO	International Maritime Organisation
ISS	International Space Station
ITU	International Telecommunications Union (Marine communication standards)
km	Kilometre

kt	Knot (unit of speed equal to one nautical mile per hour)
LAT	Lowest Astronomical Tide
LOA	Length Overall
LW	Low Water
m	Metre
M	Million
ML	Most Likely
MMSI	Maritime Mobile Service Identity. A series of nine digits, uniquely identifying a vessel, sent in digital form by an AIS transponder.
MNZ	Maritime New Zealand
MPI	Ministry for Primary Industries
MQUAL	Accurate quality of data, an area within which a uniform assessment of the quality of the data exists.
nm	Nautical Mile
NtoM	Notice to Mariners
PEC	Pilotage Exemption Certificate
POAL	Ports of Auckland Limited
RoRo	Roll-on / Roll-off vessel
S-AIS	Satellite (received) Automatic Identification System
SBM	Single Buoy Mooring
SOLAS	The International Convention for the Safety of Life at Sea
STCW	Standards of Training Certification and Watch keeping
T	Tonnes
T-AIS	Terrestrial (received) Automatic Identification System
TEU	Twenty Foot Equivalent Unit, based on the volume of a twenty foot container
UNCLOS	United National Convention on the Law of the Sea
VHF	Very High Frequency (radio communication)
VMS	Vessel Monitoring System
VTS	Vessel Traffic Service
WC	Worst Credible
ZOC	Zone of Confidence

1 INTRODUCTION

This report documents a Hydrographic Risk Assessment for the sea area comprising the New Zealand Exclusive Economic Zone (EEZ), excluding the Sub-Antarctic islands (south of 48°S latitude) and the Kermadec Island shelf, and was carried out at the request of Land Information New Zealand (LINZ). It is important therefore to note that the views expressed in this publication do not necessarily reflect those of the New Zealand Government.

This Risk Assessment uses Geographic Information System (GIS) spatial analysis techniques to identify areas of hydrographic risk using data-based evidence. The data used is in layers (39) with a base layer of a 12 month traffic record, taken from AIS data. The study uses a risk comparative technique to assist LINZ to effectively prioritise future hydrographic surveys and charting improvements throughout the New Zealand EEZ.

This Hydrographic Risk Assessment identifies important areas of benefit for charting improvements, based on the needs of contemporary shipping for the provision of accurate and adequate nautical charts. From this analysis, LINZ can develop a survey and charting development programme that will span a number of years. The prioritisation and content of the work programme will be part of the LINZ decision-making process associated with planning of its resource deployment.

The report is in three separate components, together with a Synopsis report: the National Overview (this document), the North Island, 15NZ236-B and the South Island, 15NZ236-C. The Synopsis (15NZ236-D), is also separate. This Overview report (15NZ236-A) includes:

- The background information and methodology of the risk project;
- The analysis and results at a National Overview;
- Hydrographic Risk Assessment Discussion and Conclusions;
- The supporting Annexes.

1.1 BACKGROUND

The use of risk-based techniques to prioritise a hydrographic work programme provides added value to the selection of candidate areas for hydrographic survey. The LINZ Hydrographic methodology, differentiates between varieties of coastal areas, each with differing bathymetry and trading/growth characteristics. Risk is only one factor that the methodology takes into account. For example, the economic activity in an area dictates the ship types and sizes that serve the area, but information about the potential for economic growth has also been used, as realisation of that potential may result in an increase in vessel traffic volume, and possibly vessel type and size. Thus there are three key components: risk, ship types and sizes; and economic growth, that when combined, provide the evidence required to promote one area over another for hydrographic survey prioritisation.

A location with outstanding environmental status provided the fourth factor in prioritisation; an incident in any area sensitive to environmental damage provides increased consequence impact. Environmental damage in an area with economic activity linked to environmental utility provides further consequence impact. Grounding consequence in both environment and economics is related to the release of bunkers or cargo. Environmental status is therefore attached to risk, which is linked to vessel size and type.

The maritime trade around the New Zealand coast, in common with the rest of the world, has changed dramatically in recent decades. Larger, faster cargo vessels are calling at fewer hub ports, feeder services have increased and there has been a dramatic increase in cruise ship calls, with visits by large vessels to remote locations becoming increasingly common place. This trend of growth is projected to continue.

The risks associated with the use of out of date chart data have therefore increased significantly in recent years and there is a need to systematically re-survey many areas around the NZ coast. There is both a budgetary and a practical need, though, to prioritise. This report considers a methodology to enable prioritisation. It is risk based, but combines the economic drivers with the risk considerations. This process is a crucial base for survey planning, as comprehensive statistical data was available in few areas. It was also unknown if groundings have occurred that could be directly linked to out of date or inaccurate charts, therefore the risk work was mainly proactive.

The prioritisation process is not only risk based, but transparent against set criteria. It also needs to be clearly documented, systematic and recorded in a uniform manner. To achieve this, the methodology and required input data was uniformly applied across the candidate harbours, coastal and ocean areas.

The overall severity of impacts from a marine accident on a coastal zone is dependent on a large number of factors. Areas of economic success or environmental importance can be severely affected, but severity of impact is dependent on their distance from the casualty. Longer term impacts on trade, especially tourism, are also lessened the greater the distance from the event. Severity of consequence are thus geographically relevant and the best way to assess such impacts is to employ a Geographical Information System to evaluate the risk.

This risk based result will significantly benefit hydrographic decision-making and will identify the areas that are priority candidates for charting improvements.

1.2 PROJECT SCOPE

The geographical scope comprises the development of a Hydrography Risk Assessment for the New Zealand waters within the Economic Exclusion Zone, excluding the Sub-Antarctic islands (south of 48°S latitude) and the Kermadec Island shelf. The scope includes the development of a charting benefit model to identify where areas of heightened hydrographic risk can be improved through charting re-organisation or hydrographic survey upgrades.

In more detail, this comprises:-

- Decoding, cleaning and post-processing to prepare a fused AIS dataset, made up from raw Terrestrial and Satellite AIS data. AIS data is transmitted by all SOLAS ships in service over 350 gross tons and some NZ domestic registered vessels.
- Undertaking a programme of data gathering throughout New Zealand, categorised by the boundaries of each Regional Council region (stakeholders included Regional Councils, port & harbour companies). This included the development of a data catalogue, ordered by Regional Council jurisdiction.
- Provision of traffic analysis of all SOLAS vessel types and domestic vessels, including traffic frequency, density and type.
- Developing risk criteria appropriate to the NZ data volume and ship traffic types.
- Developing a hydrographic risk model using the developed risk criteria.
- Developing a hydrographic chart benefit model for New Zealand waters.
- Provision of a purpose-built database to catalogue and store all the data gathered.

1.3 OFFICIAL NAUTICAL CHARTS

Reliable up-to-date nautical chart information is vital for safe navigation. As the New Zealand Hydrographic Authority (NZHA), LINZ charts the country’s surrounding sea and environs, from the South West Pacific to the Antarctic, as mandated by the International Hydrographic Organization (IHO), to meet NZ’s treaty law obligations under SOLAS[1].

Nautical charts and nautical publications, such as sailing directions, light lists, notices to mariners, tide tables and other nautical publications necessary for the intended voyage, are required under SOLAS Regulations to be carried on board; to be adequate and to be up to date, for all SOLAS vessels.[2]

[1] **IMO SOLAS Chapter V, Regulation 9 Hydrographic Services**

[2] **IMO SOLAS Chapter V, Regulation 27 Nautical Charts and Nautical Publications**

Additionally, Maritime Rules Part 25 sets out the requirements for the carriage of charts and nautical publications on ships. It applies, with certain specified exceptions, to commercial vessels of 12 metres or more in length overall that operate within enclosed water limits and all commercial vessels operating outside the enclosed water limits.

The mariner must also use the largest scale chart available and suitable for the type of navigation it is being used for.

1.4 DATA USED IN THE PROJECT

1.4.1 AUTOMATIC IDENTIFICATION SYSTEM DATA (AIS)

A full 12 months record of shipping traffic using New Zealand waters has been used as a core input into the Hydrographic Risk Assessment. Traffic was broken down into ship types as transmitted by AIS transponders fitted to all internationally trading vessels ("SOLAS" vessels) and most domestic vessels carrying passengers for commercial gain (i.e. entered into SSM or MOSS). Covering a twelve month span, this is the most comprehensive record of ship traffic used on any New Zealand based safety assessment[3], which has been corrected against ship data held by the ITU.

The terrestrially recorded AIS traffic record was supplied by Marico Marine from their national recording database. Additional data was supplied by LINZ from the NZ Government system, which assisted in a QA of the data record and infill where the reception record could be improved. Both terrestrial datasets were used to provide a database with the best records of coverage.

For areas where no terrestrial coverage was available, Satellite recorded AIS (S-AIS) data was used. The primary S-AIS data was sourced from exactEarth, with infill provided by S-AIS recorded by Orbcom in the Government system. ExactEarth satellite data was used because of its frequency of data update as well as superior recording of time in relation to a vessel's position. This improved the link between terrestrial datasets (which are real time) and satellite, which suffers some delay until the data is downloaded to a ground station, at which time the time stamp is added to the received data[4].

As any S-AIS data is not recorded real time and is intermittent in nature: tracks will be linked together by a computer, not necessarily reproducing the exact track taken by a vessel. Where data showed

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[3] **The most recent coastal safety review used a three month record of AIS data.**

[4] **AIS data does have a time within it, but this is a time breakdown within a second to allow two AIS transponders in an area to synchronise transmission and reception (and thus avoid data collisions). AIS "time" does not include minutes (or hours), so remote reception needs to add those time elements when the data is received. Dependent on any delays from transmission to reception.**

tracks in obvious error (e.g. crossing land), these were manually corrected. Thus the final track database used for the project will contain some minor inaccuracies and should not be relied on as an exact record of any vessel.

1.4.2 ADDITIONAL DATA COLLECTED

A key component of the risk assessment was the gathering of location information and local data to support the identification of risk areas and provide local input to assist with prioritising future hydrographic surveys.

Harbour Masters, Councils' representatives, Port Company Operators and other key stakeholders were interviewed in each region during data gathering visits.

Statistics of vessel movements, vessel types and sizes were compiled from data supplied by stakeholders, augmented with data publically available from the internet.

Where GIS shapefiles of sensitive sites and other datasets were available from stakeholders, principally from Councils' Tier 2 Marine Oil Spill Plans, these were uploaded directly into the GIS risk model.

Shapefiles of Marine Reserves were supplied by the Department of Conservation (DOC); the Ministry for Primary Industries (MPI) supplied datasets of fishing vessel routes for the study year.

1.5 NEW ZEALAND CHARTING DEFINITIONS

Hydrographic charts have two functions: marine navigation and information sources. Most hydrographic offices have an obligation to provide adequate and accurate nautical chart cover of their national waters and any other waters under their jurisdiction, to such an extent and on such scales as to permit safe navigation for all classes of vessel from the smallest to the largest, throughout coastal waters including large ports to minor inlets of purely local interest.

1.5.1 CHART ADEQUACY

Charting scales, extents of coverage and quality of seafloor coverage all combine to denote chart adequacy. The adequacy of nautical charts is complex but the components overall that contribute to the LINZ measure of charting adequacy can be represented by the diagram below.

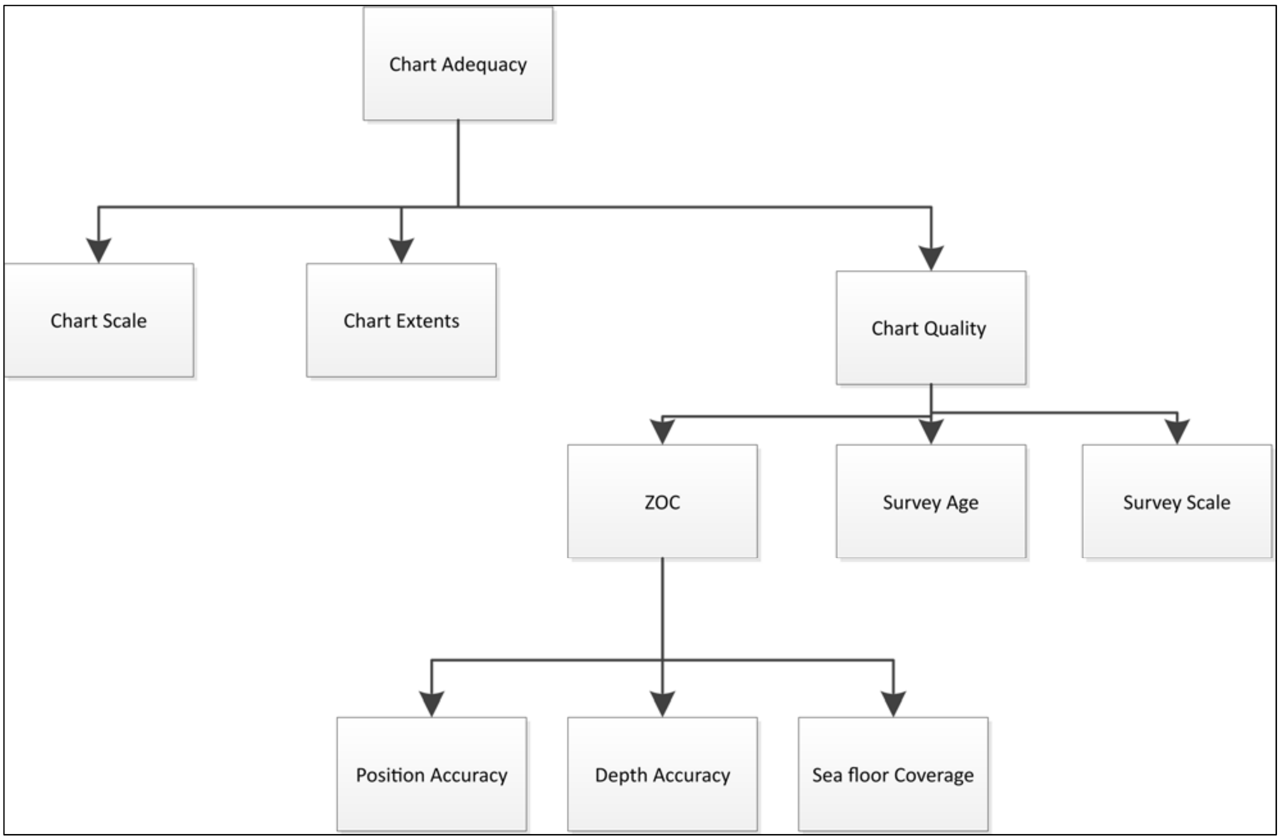


Figure 1 : Chart Adequacy

1.5.2 NZ Chart Scales

The LINZ chart series was developed many decades ago to meet the needs of shipping at that time. Shipping traffic, vessel types and sizes have changed considerably since many of the NZ charts were schemed, and may not be suitable or adequate for today's or future needs.

National nautical chart series usually encompass the largest scale publications available, showing the detailed configuration of the seabed offshore. Information about the shape of the seabed is used by a variety of users other than navigators: dredging contractors, construction engineers, defence departments and so on.

The combined effect of the requirements of marine navigation and providing an information source has caused the national chart series to cover national waters in varying detail, reflected by the large scales used for port plans, and usually the existence of at least two continuous coastal series, one on a relatively large scale, the other slightly smaller.

With the advent of ECDIS (Electronic Chart Display Information System), the IHO members have agreed recommended scale ranges for:

- Offshore charting

- Coastal charting
- Harbour Approach charting
- Berthing charting

The New Zealand charting area under consideration includes coastal, approach and harbour charts of scales from 1:75,000-1:4,000,000 for medium scale coastal charts, to 1:2,500-1:75,000 for large scale or harbour charts. These charts are all published on the WGS 84 geodetic datum. All New Zealand Charts for the area inside the EEZ now have depths and heights in metres. Previous versions with depths in fathoms and heights in feet have all been withdrawn.

A range of different scales are recommended for the stated type of navigational use, which sets the scales for printed charts. By policy, LINZ use the following guidance for the scales of their NZ chart portfolio. This LINZ policy is in accordance with the IHO recommendations for navigation type.

LINZ Navigational Purpose Scale Ranges (Paper Charts)			
Subfield	**Navigation**	**Purpose**	**Available Compilation Scales for ENC charts**
1	Overview	>=3,000,001	1:3,000,000
2	General	800,001 – 3M	1:3,000,000 1:1,500,000 1:700,000
3	Coastal	80,001 – 800K	1:700,000 1:350,000 1:180,000 1:90,000
4	Approach	25,001 – 80K	1:90,000 1:45,000 1:22,000
5	Harbour	8,001 –25K	1:22,000 1:12,000 1:8,000
6	Berthing	>=8K	1:8,000 1:4,000

Table 1 : LINZ Paper Chart Compilation Scale

A ship's ECDIS will comply with the standard scale table (**Table 2**) when a charting range is selected on the ECDIS system. Setting the range on an ECDIS will select the chart data scale nearest to the chosen setting. For harbour approaches, the system should automatically change scale to the charting scale as recommended. This provides the mariner with a paper chart scale to ENC scale conversion. The paper chart compilation scale is rounded down to the nearest ENC Compilation Scale (e.g. Paper Chart 20,000 = ENC 12,000).

One of the key tests in the charting benefit model is to determine if chart data is available at the right scale (as recommended by IHO) for the navigational purpose of the area in which a vessel was navigating.

Radar Range / Standard Scale Table (ENC)	
Selectable Range (in nautical miles)	**Standard Radar Scale (rounded)**
200	1:3,000,000
96	1:1,500,000
48	1:700,000
24	1:350,000
12	1:180,000
6	1:90,000
3	1:45,000
1.5	1:22,000
0.75	1:12,000
0.5	1:8,000
0.25	1:4,000

Table 2 : IHO ENC Compilation Scale

1.5.3 CHART EXTENTS COVERED BY THIS WORK

LINZ produces official nautical charts to enable safe navigation in New Zealand waters and is in addition the Charting Authority for the sea areas south of New Zealand to Antarctica as well as a significant area of the South-West Pacific. The charts produced by LINZ encompass AtoNs and other navigational aids to assist the Mariner to navigate safely.

This hydrographic risk assessment covers from the NZ coast to the NZ Economic Exclusion Zone, excluding the Sub-Antarctic islands (south of 48°S latitude) and the Kermadec Island shelf.

1.5.4 CHART QUALITY

Chart quality may be said to comprise of three factors: Zone of Confidence (ZOC); survey age and survey scale. LINZ has policy to add the MQUAL Charting Quality CATZOC rating to its charts and has done this to almost all of its coastal charting series[5]. The CATZOC rating is of help to the navigator as well as a Hydrographic Risk Assessment and presently the rollout programme extends to the Coastal Chart portfolio.

To date, New Zealand has provided quality indicators on all of its hydrographic charts by way of Source Data Diagrams and Diagrams of Sounding Line Density.

1.5.4.1 ZONE OF CONFIDENCE

The IHO Data Quality Working Group (DQWG) developed the concept of the Zone of Confidence (ZOC) as a solution for the assessment and display of hydrographic data quality, supporting safe and efficient navigation. Areas covered by hydrographic surveys are classified by identifying various levels of confidence with respect to depth accuracy, position accuracy, thoroughness of seafloor search, and the characteristics of the survey. Six ZOC have been developed - A1, A2, B, C, D and U.

To decide on a ZOC Category, all conditions outlined in columns 2 to 4 of the table must be met.

[5] Not all Hydrographic offices have this policy, which makes LINZ a leader in this area; others are following. As Hydrographic Risk is much better informed by the ZOC rating of a chart, this LINZ policy is important.

1	2	3	4	5
ZOC[1]	Position Accurancy[2]	Depth Accurancy[3]	Seafloor Coverage	Typical Survey Characteristics[5]
A1	± 5 m + 5% depth	= 0.50 + 1%d Depth (m) / Accuracy (m) 10 / ± 0.6 30 / ± 0.8 100 / ± 1.5 1000 / ± 10.5	Full area search undertaken. Significant seafloor features detected[4] and depths measured.	Controlled, systematic survey[6] high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.
A2	± 20 m	= 1.00 + 2%d Depth (m) / Accuracy (m) 10 / ± 1.2 30 / ± 1.6 100 / ± 3.0 1000 / ± 21.0	Full area search undertaken. Significant seafloor features detected[4] and depths measured.	Controlled, systematic survey[6] achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder[7] and a sonar or mechanical sweep system
B	± 50 m	= 1.00 + 2%d Depth (m) / Accuracy (m) 10 / ± 1.2 30 / ± 1.6 100 / ± 3.0 1000 / ± 21.0	Full seafloor coverage not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth. But lesser position accuracies than ZOCA2, using a modern survey echosounder[5], but no sonar or mechanical sweep system.
C	± 500 m	= 2.00 + 5%d Depth (m) / Accuracy (m) 10 / ± 2.5 30 / ± 3.5 100 / ± 7.0 1000 / ± 52.0	Full seafloor coverage not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.
D	worse than ZOC C	worse than ZOC C	Full seafloor coverage not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.
U	Unassessed – The quality of the bathymetric data has yet to be assessed			

Table 3 : CATZOC Categories

Figure 2, below shows the ZOC ratings for the LINZ portfolio for New Zealand offshore waters.

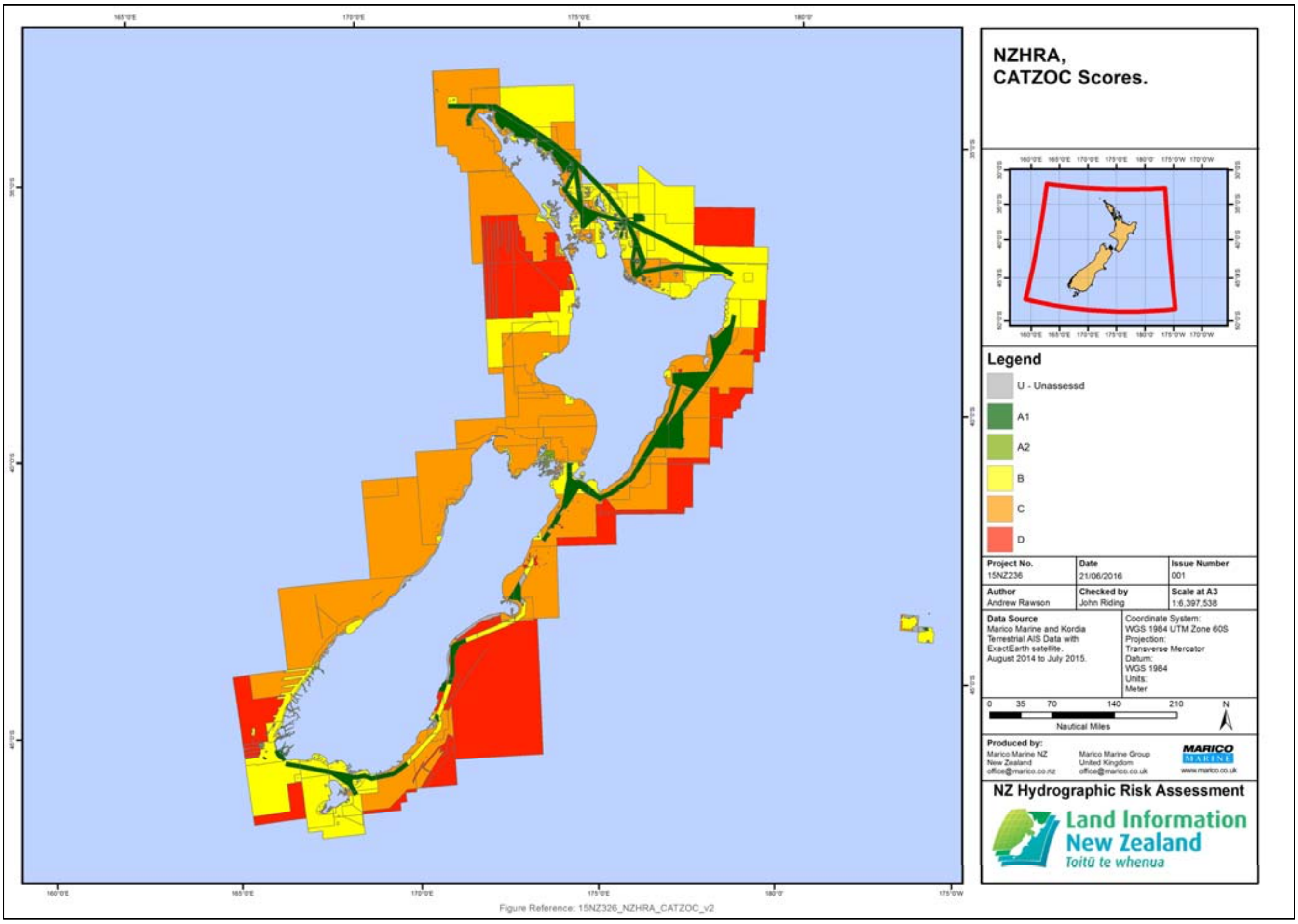


Figure 2 : Zone of Confidence for NZ Chart Portfolio

1.5.4.2 SURVEY AGE

Whilst in general, the main New Zealand ports may have been surveyed within the last 20 years, significant parts of the main harbour published charts use chart data from surveys conducted some 60 years ago. For example, Marlborough Sounds chart NZ 6153 has large areas of survey data dating from 1942-43, including sections of Tory Channel and Queen Charlotte Sound (northern approach to Picton). These routes incorporate the Cook Strait ferry services, with over 1.2 million passenger transits each year, see **Figure 3,** below.

Anecdotal reports from Port operators and Harbour Masters indicate that these areas may have in fact been regularly sounded, for example by port or Harbour Master workboats, but the data has either not been passed on to LINZ for updating the charts; has been surveyed at a standard less than acceptable for LINZ use, or has been passed on to LINZ but not fully incorporated into the charts. This predominantly relates to channels that are dredged to a maintained depth by Port Companies. There remains concern with the underlying problem of liability associated with not updating charts.

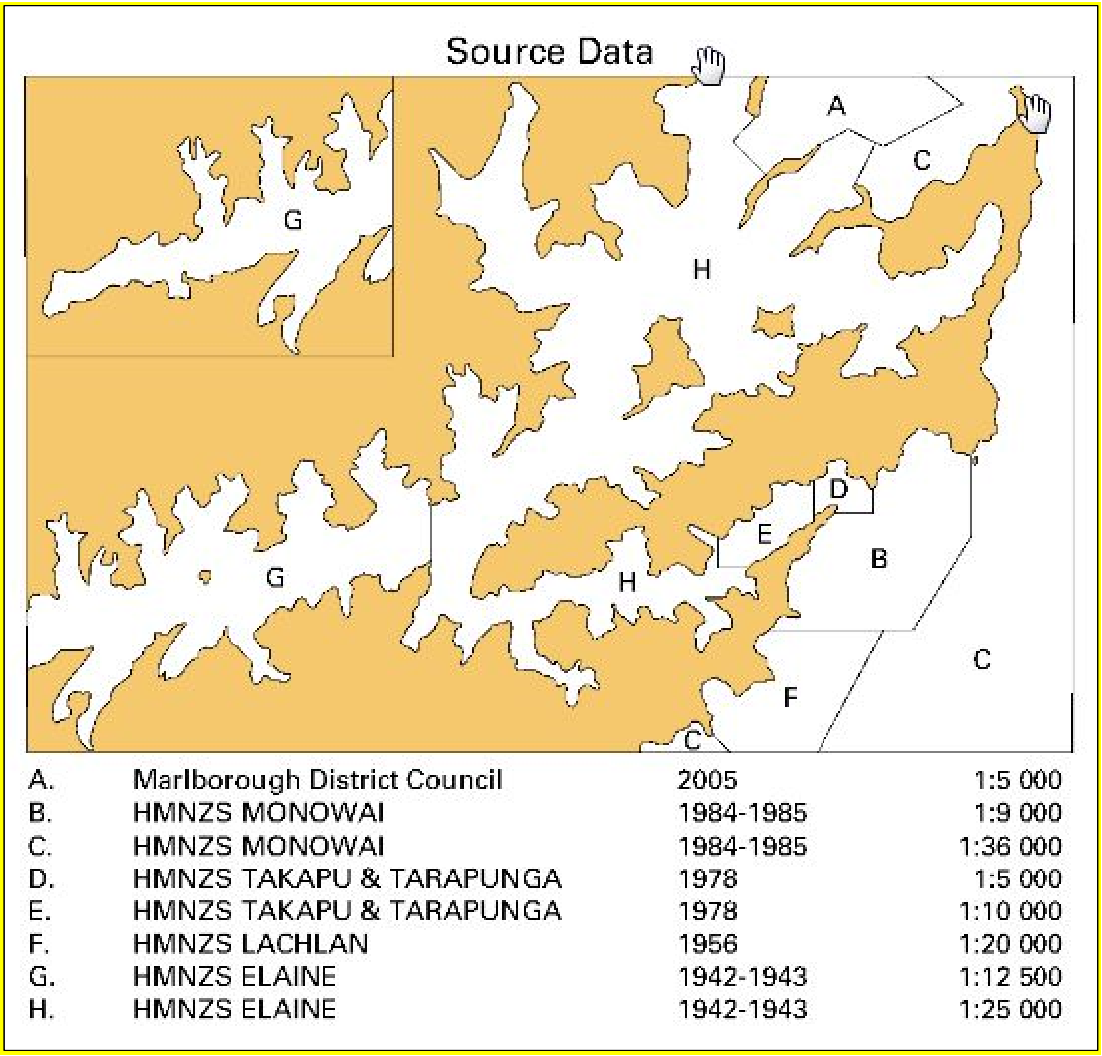
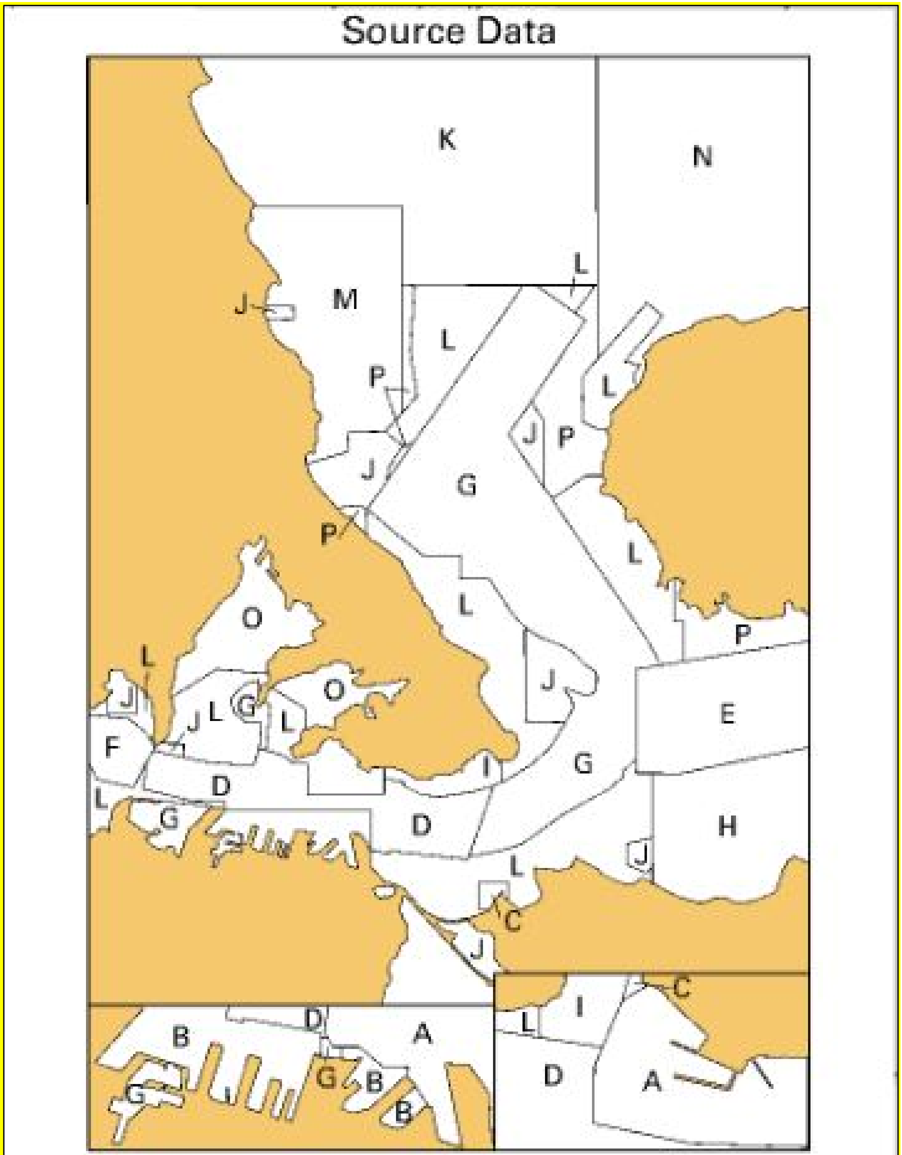


Figure 3 : Chart NZ 6153 Marlborough Sounds – 1942 Source Data

Auckland Harbour East chart NZ 5322, which includes the main approach channel to the Port of Auckland (with over 1,500 ship calls in 2014) shows areas adjacent to the main shipping channel, that were last surveyed in 1955. (Refer **Figure 4)**



A. Ports of Auckland	2007	1:1000-2000
B. Ports of Auckland	2007	1:2750
C. Ports of Auckland	2006	1:1000
D. Ports of Auckland	2006	1:4000
E. Ports of Auckland	2004	1:10 000
F. Ports of Auckland	2003	1:4000
G. Ports of Auckland	1996 - 2007	1:7500 & larger
H. RNZN	1993	1:10 000
I. RNZN Hydrographic Office	1981 - 1983	1:1000 & larger
J. Auckland Harbour Board	1974 - 1988	1:2000 & larger
K. RNZN	1975 - 1976	1:24 000
L. Auckland Harbour Board	1967 - 1987	1:4800 & smaller
M.HMNZS Takapu	1958 - 1977	1:12 000
N. HMNZS Takapu & Tarapunga	1968 - 1969	1:18 000
O. HMNZS Lachlan	1961	1:9000
P. HMNZS Lachlan	1955 & 1956	1:10 000

Figure 4 : Chart NZ 5322 Auckland Harbour East - 1955 Source Data

The size of vessels and the accuracy of navigation now possible using satellite derived positioning are significantly different from the original intended purposes for which many existing charts were derived. The mariner is advised accordingly, both during training and by remarks on the charts and source data advice. This mitigates liability risk by providing clarity of chart limitations.

Despite this, there remains a reasonable concern that inadequate and inaccurate nautical charting could adversely affect safety of life at sea and the protection of the marine environment. It may also inhibit maritime trade, thereby adversely affecting the economy of some regions. There remains a potential for liability associated with not providing fit for purpose charts.

1.5.5 NZ Chart Portfolio

The New Zealand official chart Portfolio comprises some 242 charts, including plans and insets, which fall within the IHO recommended range for navigational purpose as follows:-

Navigational Purpose Scale Range	No. of Charts
General	10
Coastal	47
Approach	70
Harbour	82
Berthing	33
Total	**242**

Table 4 : NZ Chart Portfolio

2 METHODOLOGY OVERVIEW

2.1 INTRODUCTION

This section is designed to provide an overview of the processes and data used to derive the risk assessment. There is a full methodology document at **Annex A**, which describes the process.

2.2 GEOGRAPHIC INFORMATION SYSTEM (GIS)

The design of the Hydrographic Risk Assessment methodology involves many layers of information, each of which is scored by the risk criteria. In the NZ assessment, there are 39 data layers. The individual risk calculations within each layer are simple, but as each calculation needs to be attached to a geographic cell, the number of calculations in any layer is significant. As each layer is linked overall by the risk criteria, using a Weighted Overlay Analysis methodology, the assessment as a whole becomes complex.

Geographic Information System software is a logical tool for the large number of calculations that interact geographically. Although programming of the GIS is needed, the technology provides the interactive display essential to relate the developed risks geographically (by colour) with the candidate areas being considered. The use of GIS technology to display risk pictorially over any charted area provides an easily interpreted output for this type of risk assessment.

The GIS package combines risk criteria with marine traffic levels in areas of harbour, coastal or offshore significance. It further links the quality of charting in such areas (as just one example of risk criteria) and outputs an overlay of risk mapping onto the charted area.

The GIS based risk model with its underlying risk matrix was populated with the relevant Likelihood and Consequence datasets (likelihood being calculated from the traffic, consequence being calculated from event tree outputs, setting the consequence scales of the risk criteria.

The risk model factors specific to the study area were informed, as were the relative weightings/importance of risk model factors, by the data gathering process. The GIS model was run to calculate the risk assessment results, with consequent iterations as required to run the charting benefit model.

2.3 RISK MODEL

2.3.1 OVERVIEW

This Hydrographic Risk Methodology is based on the concept of the International Maritime Organisation (IMO) Formal Safety Assessment (FSA) process and the Most Likely/Worst Credible risk methodology. FSA is a tool for proactively assessing risk and regulatory cost benefit for international use. It was originally developed by the United Kingdom Maritime and Coastguard Agency as a method of deriving risk-based regulatory requirements. The Hydrographic Methodology was developed for the IMO United Nations' sister, the International Hydrographic Association (IHO), by Marico Marine Ltd. under contract to LINZ, using a Step by Step system that is linked to the FSA process. The Hydrographic Risk methodology has formally been endorsed by IHO and a Risk Assessment is now a key component of the IHO's capacity building strategy.

2.3.2 KEY RISK DEFINITIONS

There are two different types of risk that need to be considered when reading this report, Inherent Risk and Hydrographic Risk.

Inherent Risk is easy to understand, in that a harbour may present a difficult entrance (e.g. narrow, shallow, cross currents and poor aids to navigation). This provides an inherent heightened risk for a vessel wishing to transit the entrance. Hydrographic Risk, on the other hand measures traffic by volume, type and size, as well as a range of other factors assessing consequence impacts.

Thus the inherent risk of a single transit into a harbour can be high for a vessel individually, but a hydrographic risk result may be lower, simply because the numbers of transits per annum are low and/or the vessels involved are small.

This hydrographic risk model describes three factors needed to measure risk: the exposure of vessel traffic, the likelihood of those vessels having an incident and the consequences of those incidents. The consequences of an incident are identified as loss of life; potential for pollution; salvage costs; damage to vessels and the economic impact to the wider economy.

2.3.3 EVENT TREE ANALYSIS

Event Tree analysis was used to establish the range of possible consequences of an initiating event. This was done for a most likely outcome and a worst credible outcome. It is easy for anyone (with or without marine expertise) to identify "armageddon" out of many marine scenarios. However this type of outcome rarely follows the reality of the marine casualty record. What is needed for risk assessment is the "most likely" outcome, balanced by a "worst credible" outcome, which is also not the "worst possible" outcome. The difference between "most likely" and "worst credible" is the range of outcomes useful to the hydrographic risk assessment. These outcomes will vary with the vessel type.

Event trees were thus developed to describe, using marine expertise, the type of accident scenarios arising from any grounding or loss of hull integrity in the areas and vessel types using the waters. The grounding outcomes (consequence criteria) are related to vessel types trading in the area of interest, as well as vessel size. This information was derived from T-AIS and S-AIS data and site visits. Event tree analysis was then used to scope the Most Likely and Worst Credible outcomes of a vessel incident, and these values were input into the risk calculations. These are attached at **Annex B.**

2.3.4 VARIABLE CELL SIZES

The waters out to the EEZ were divided into grid cells of varying resolution depending on location: 3 km square cells for areas between the 12nm limit and the EEZ's outer boundary; 1km squares for the Territorial Sea inside 12 nm, and 500m squares for harbour administrative areas, typically (but not exclusively) gazetted pilotage limits. This provided a higher resolution of risk result inshore and within harbour areas, such that berthing charting could be assessed equally to the much reduced scale of offshore charts.

Each grid cell has an attribute for each marine traffic record. Marine traffic has causation and consequence factors within the cell that are relevant to grounding of the vessel type. Causation and consequence factors are related to the proximity of the vessel track to a feature of interest to the risk assessment. The possibility of a traffic record crossing a cell is more likely the larger the cell size, which could affect the risk calculation between larger and smaller cell sizes. To ensure consistency, a measure of traffic density has been used - traffic per unit area. Therefore, if one cell size is twice as large as another, twice the number of vessel movements are required to cross the cell to trigger a result having same traffic density as in a cell half the size. This ensures the risk calculations are unaffected by the change from coarse to fine grid cell sizes as the coastline and harbour waters are approached.

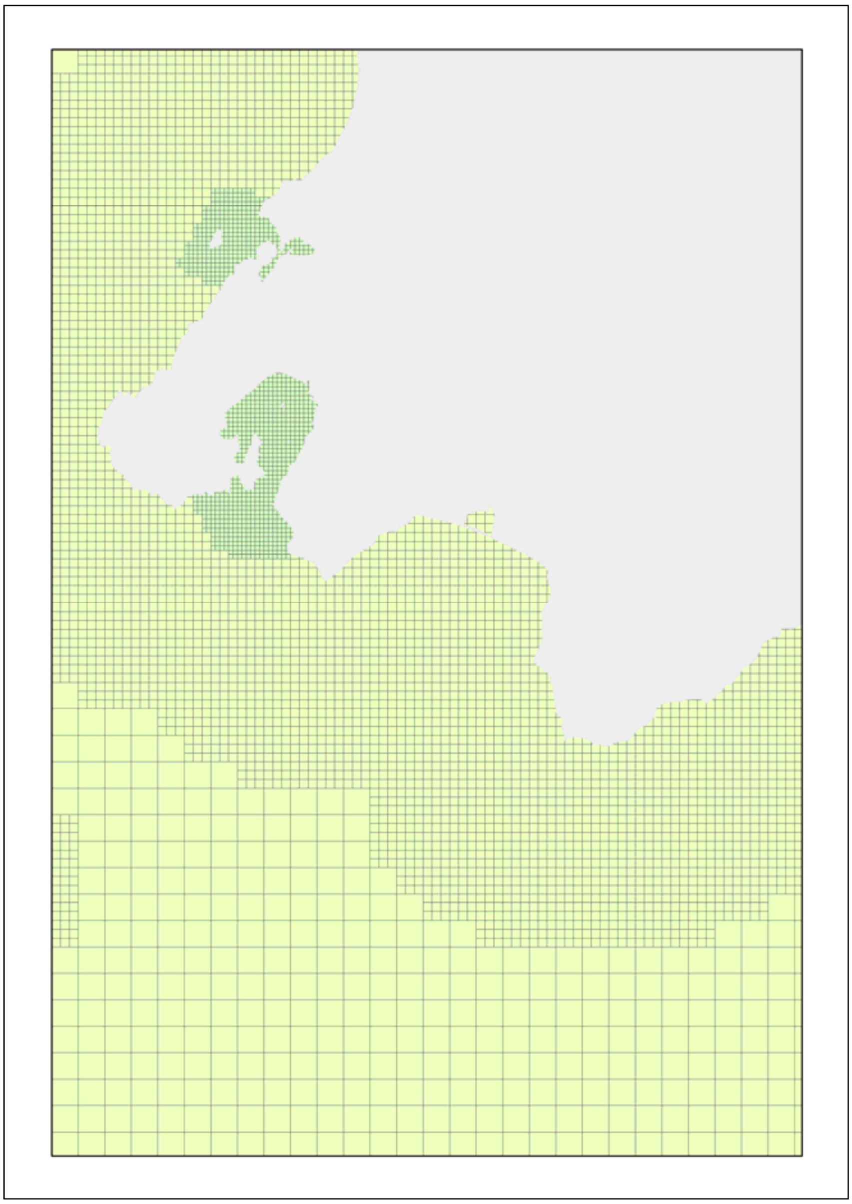


Figure 5 : Example of Variable Cell Sizes – Wellington Area

2.3.5 PROXIMITY TO RISK FACTORS

Many of the causation and consequence risk factors were judged in terms of proximity. The closer vessel traffic goes to the feature or hazard, the more likely an incident is, or the more significant its consequence. The vessel tracks were thus analysed for proximity to navigational hazards. Each feature when mapped was buffered at multiple distances as defined by the risk matrix and the greatest risk score in each cell recorded as that cell's attribute.

2.3.6 WEIGHTING

In this weighted modelling approach, a number of criteria are combined with each factor scored on its contribution to the total model, normally expressed as a percentage. The technique of weighted overlay analysis is widely employed for multi-criteria problems such as optimal site selection and suitability modelling. Each risk factor was therefore assigned a weighting which enabled calculation of the relative significance of each factor to another.

Given the variable cell sizes and the traffic therefore represented as a density, the final result is a risk map with each cell showing a hydrographic risk score and each cell directly comparable with others.

2.3.7 RISK SCORING

The Likelihood and Consequence were then combined to produce a Risk Score for each grid cell. For there to be hydrographic risk there must be a combination of traffic, likelihood criteria and consequence criteria. The traffic type, size and volume thus influenced the risk levels in each cell associated with each of the criteria.

Each risk criteria factor was scored on a scale of 0 to 5 given the risk matrix presented in this report. All grid cells used in the analysis therefore have a score for each of the risk factors.

2.3.8 RISK CRITERIA

Hydrographic risk is dependent on traffic, with inherent potential loss of life and pollution potential (related to vessel volume, type and size). The traffic risk may be increased by Likelihood Criteria such as ocean conditions; navigational complexity; Aids to Navigation (AtoNs) and navigational hazards. The risk may be further multiplied by Consequence Criteria such as environmental impact, cultural importance, and economic importance. Risk Criteria were therefore divided into Traffic, Causation and Consequence.

This hydrographic risk model has been developed a GIS using Risk Terrain Modelling. In order to compare risk levels, 39 different criteria datasets or 'layers' were used. **Annex C** presents the full "Risk Matrix" criteria and the developed weighting and rating input data.

2.3.9 VESSEL TRAFFIC

Vessel traffic is a significant input factor into any assessment of marine risk. Clearly if no vessels navigate through a waterway, the likelihood of a vessel having an incident related to a charting problem is nil. Each vessel has an inherent potential for loss of life or pollution that could occur once an incident has taken place. This potential is, to an approximation, a function of the size and type of vessel, which indicates both the number of passengers or fuel it could normally carry (for example, a large tanker would carry more product than a smaller one and a passenger vessel would carry more persons than a cargo ship). A model of traffic risk was built by multiplying the gross tonnage of each vessel type, by a respective vessel type risk factor.

Risk Criteria considered under Traffic therefore included the following categories:

1) Potential for loss of life
2) Potential for oil outflow or other adverse effect on the environment
3) Vessel damage and salvage costs
4) Economic costs of a vessel incident

In the methodology, vessel traffic is assigned 25% overall weighting.

2.3.10 Causation Factors

Causation factors considered included charting quality and adequacy; route characteristics such as navigational complexity and depths of water; the presence of navigational hazards; bathymetric and prevailing MetOcean conditions; and what mitigations were already in place, such as pilotage and tugs.

In the methodology, causation criteria are assigned a 25% overall weighting.

The causation factors developed for the New Zealand Risk Assessment risk matrix (see **Annex C**) are:-

1) Chart Quality
2) Survey Age
3) Chart Scale and Extents
4) Navigational Complexity
5) Depth of Water 15m Contour
6) Traffic Density
7) Prevailing Wave/Wind
8) Tides/Current
9) Longwave/Surge
10) Poor Visibility
11) Sea Mounts
12) Isolated Dangers - Rocks/Wrecks/etc.
13) Charted Tidal Hazards
14) Breaking Reefs

15) Harbour Risk Mitigation Resources
16) Pilotage
17) Dynamic Seabed - Estuarial
18) Seismic/Volcanic Factors

2.3.11 Consequence Factors

The hydrographic risk model identifies Likelihood and Consequence risk factors, with Consequence criteria including damage to vessel, contents and life; damage to the environment; and indirect damage including damage to tourism and the local economy.

In the methodology, consequence criteria were assigned a 50% overall weighting.

The consequence categories developed for the New Zealand Risk Assessment risk matrix (see **Annex C**) are listed below, not in order of their importance (only the risk matrix ratings and weightings can provide that):-

1) Response Complexity
2) Salvage Complexity
3) Formal Reserves - World Heritage Sites
4) Marine Reserves
5) Coastal (Sensitive Resources)
6) Wetland Resources
7) Aquaculture/Fishing Grounds/Shellfish Harvest Sites
8) Tourism
9) Cultural (Iwi)/Treaty History Sites
10) Recreational/Social Amenity
11) Port Access Channels
12) Critical Infrastructure (Berths) - Economic Contribution
13) Proximity to Sites of High Economic Contribution
14) Proximity to Sites of Moderate Economic Contribution
15) Proximity to Sites of Low Economic Contribution
16) Cruise Ship Stops
17) Pipelines/Cables

The risk assessment takes account of potential damage to pristine environments from a vessel incident, as well as resulting salvage costs. Economic and cultural inputs that are spatially relevant were included.

2.4 LIMITATIONS OF THE RISK MODEL ANALYSIS

The importance of accurate data to a multifaceted risk assessment is critical. Not only does the traffic record have to be comprehensive, but the locational accuracy of marine reserves/sites of important coastal wetlands and culturally important areas is critical to the success of the hydrographic risk accuracy. A large number of comprehensive spatial datasets are available in New Zealand, for example marina locations with attached economic contribution and capacity and the Freight Information Gathering System (FIGS) dataset for port cargo volumes. The rich data directly supports layered risk analysis, improving the result, and enhances the information that can be obtained during the data gathering phase. However, they contribute to the volume of data that the hydrographic risk model has to process. These datasets also have to be taken as accurate, which they probably are; but have not been validated for the purposes of this project.

The learning from undertaking this project is the need to first have the traffic profile correct and the analysis audited, especially for the vessel types that have a significant impact on the hydrographic risk result. The key vessel types are those which carry passengers (hence carry quite significant potential loss of life (PLL)) and tankers (which carry the potential for significant environmental impact). As the presence of traffic is a fundamental driver of hydrographic risk, ensuring this is correct has been proven to be key. As the hydrographic risk model runs first, with that output being the input for the charting benefit model, then any correction of the traffic record of relevance to the assessment has to result in a rerun of both the risk and benefit models.

In the event, the audit of the dataset did identify some problems in the AIS data underpinning the risk assessment, thus subsequently affecting the charting benefit. In the recording of data from a satellite service, incomplete MMSI data had been transposed in a storage database, causing some cruise vessels to be identified as bulk carriers (including a name change to that of a valid bulk carrier) and in one case a fishing vessel to identify itself as a tanker. Such problems were identified by review of traffic analysis plots and using knowledge taken from data gathering to question the location of an apparently incorrect ship type. Once problems with AIS track records of cruise vessels and tankers were unearthed, each location where such vessels should be expected was audited. In the case of cruise vessels, these were identified also from port visit records to confirm their presence.

Satellite AIS data is only beginning to come of age and its limitations are referenced further in **Section 3.2.1**. Of key relevance is the fact that vessel tracks offshore that are received by Satellite AIS may not have been in the exact location as depicted in the GIS output. This may be because of the inherent lapse in reception between passing satellites, or the fact that the data timestamp is only completed once the satellite downloads the data to a ground station.

2.5 CHARTING BENEFIT MODEL

The Charting Benefit is a separate model, run after the risk assessment output has completed. The benefit module complements the hydrographic risk module in that it measures the ability of the hydrographic system to reduce risk by a charting upgrade (either a charting reorganisation or improved seafloor coverage or a survey update). The purpose of the charting benefit model is the identification of positive benefit areas that require charting improvements. The charting benefit is not driven by cost, it is driven by the available scope of achievable charting upgrade in relation to the charting risk present in any given area.

The benefit model inputs include ZOC for a given depth of water; charting scale for harbour areas, harbour approach and coastal zones as well as the coverage provided by charting extents. The charting benefits are based on hydrographic survey data supplied by LINZ, which was taken up to date to the end of the 2015-16 LINZ financial year.

In order to identify positive benefit areas, the charting model incorporates the charting adequacy inputs of Chart Scale and Extents, Chart Quality and Survey Age. The output scale ranges are classified by the Natural Breaks (Jenks) system, which is inbuilt into the ESRI Arc-GIS package. The scale ranges are classified from negative to positive, in scale ranges, as follows:

- Negative Benefit
- Marginal Benefit
- Moderate Benefit (ALARP)
- Positive Benefit

Each scale range has a colour designation, dark blue represents high benefit availability, green represents no benefit availability.

The model is designed for a given set of improvement parameters (see **Table 5**) based on hydrographic survey data supplied by LINZ, updated to the end of the 2015-16 financial year.

Depth in meters / Parameter	Measure of Available Quality Improvement (CATZOC)	Survey Age (in years)
0m -40m	A1 or A2	=<10 years
40m – 500m	B	=<10 years
>500m	C and D	=<20 years

Table 5 : Chart Benefit Model Input Criteria

The above specifications include the highest charting adequacy standards, in consultation with LINZ, given a range of depth survey data across New Zealand. The charted depth data points are used for the charting benefit model, as opposed to depth contour data.

2.6 CHARTING BENEFIT MODEL OUTPUT LIMITATIONS

The accuracy of the model depends on the availability of the chart adequacy datasets, as well as the chart data itself. Where electronic data are accessible from nautical charts, the model provides accurate output. Conversely, in areas where channel sounding depths are not published, for example, where channel depths are maintained to an advertised depth by a port company or regional council, the benefit module cannot work. In this case, it will erroneously show a maximum benefit for LINZ to review. An example of this are the Otago harbour channels, which are maintained to an advertised depth by Port Otago and surveyed annually. It is uneconomic to update the official nautical charts annually for this area, so the chart is marked with the maintained depth. The Chart Benefit model will show a high benefit on the basis of it being a harbour channel with no point-sounding data and the dataset may be old in relation to the surrounding data. This is an erroneous result. However, the point of the model is to identify areas with the potential for benefit through a planned LINZ workstream. This is then reviewed by a hydrographer and cartographer. Once the reason for the high benefit score is understood, any charting update need can be established.

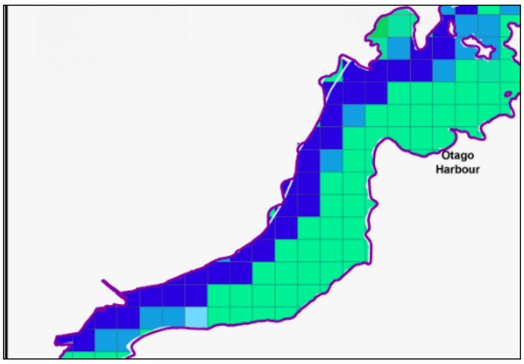


Figure 6 : An Area of Maintained Depth Channel May Show a False Positive Benefit

As the charting benefit model was developed for the New Zealand assessment, the project had a research and development aspect. In essence the chart benefit model establishes an importance on the availability of (or potential for) charting quality upgrade in any one cell of the GIS.

3 DATA GATHERING

3.1 DATA COLLECTION - INTRODUCTION

Site visits were made to every Regional Council/Unitary Authority region of New Zealand. Each commercial Port operation was visited and the Regional Harbour Master (where appointed) in the North and South Islands. Additionally, a number of small, mainly recreational or minor fishing harbours around the NZ coast were visited where time and access permitted, and data was collected from interviews and any locally available statistics.

Data for offshore islands, such as Stewart and Chatham Islands was obtained from the relevant authorities or Harbour Master. For example, in the case of Stewart Island, the Environment Southland Harbour Master was able to supply relevant information, and for the Chatham Islands Environment Canterbury's Regional Harbour Master provided relevant material. Great Barrier Island ferry passenger numbers were kindly calculated for the project by Great Barrier Radio and Port Fitzroy Store operators.

Cargo tonnages per wharf and berth utilisation figures were amongst the data records collected wherever possible, from Port Companies, Harbour Masters, fishing companies, ferry operators and local cruise operators.

Statistics on non-SOLAS commercial and recreational vessels were requested from marina operators, yacht clubs, Councils/Harbour Masters, swing mooring records and fishing companies.

The study period chosen was July 2014 – June 2015, the full year ensuring that seasonal variations were adequately represented. Seasonal variations in traffic patterns were particularly significant for fishing, passenger and recreational vessel types.

Port Company Annual Reports, Port and company websites and Statistics NZ figures were used wherever possible to cross-reference and verify data verbally supplied by interviewees.

3.2 AUTOMATIC IDENTIFICATION SYSTEMS (AIS) DATA

Actual vessel tracks were sourced from AIS, both satellite derived and terrestrial, to show traffic profiles and density. Terrestrial AIS (T-AIS) data was used in preference, however for areas where this was not available, S-AIS data was used. S-AIS data is recorded at intervals only whenever the satellite passes over the study area and is thus not as accurate as T-AIS data. The time period for the S-AIS updates around the NZ coast was around 2-4 hours, resulting in intermittent data records outside the range of terrestrial reception. Where T-AIS reception was available, this data was prioritised over S-AIS.

To overcome this limitation and provide greater accuracy, processing was undertaken by Marico to decode, clean and post-process the raw AIS data. Post-processed vessel tracks were enhanced with port visit records taken from regional data gathering.

An entire year's worth of vessel tracks was detailed using AIS for the year July 2014 – June 2015, thus being representative of the more recent economic activity of the NZ economy, as well as covering seasonal variations. Typical AIS data includes vessel name, details, location, speed and heading. Each vessel was modelled in the risk assessment by its type, size, passenger carriage and fuel carriage.

AIS vessel tracks do not represent all of the non-SOLAS vessels which are not required under legislation to carry AIS. Typically these comprise of smaller coastal vessels; smaller fishing vessels; tugs, barges and other workboats; and recreational vessels, although a number of these are fitted with AIS, either voluntarily or due to company or other requirements. Domestic vessel trades that were not accounted for using AIS data (i.e. vessels that are not required to carry AIS) were incorporated into the risk model with their routes and traffic density plotted manually.

3.2.1 LIMITATIONS OF AIS DATA

The AIS information transmitted by a ship is of three different types:

- Fixed, or static information, which is entered into the AIS on installation and need only be changed if the ship changes its name or undergoes a major conversion from one ship type to another;
- Dynamic information, which, apart from 'Navigational status' information, is automatically updated from the ship sensors connected to AIS; and
- Voyage-related information, which might need to be manually entered and updated during the voyage.

Examples of manually input data, entered at start of the voyage and whenever changes occur, are:

- Ship's draught;
- hazardous cargo;
- destination and ETA;
- route plan (way-points);
- the correct navigational status; and
- safety related short messages

Integrity of data that must be input by the vessel's operator is consequently not assured. The limitation of this part of the AIS data is thus related to the correctness of the manually input figures.

Automatic inputs, for example gyro heading input, may also be subject to errors or limitations. Poorly configured or calibrated ship sensors (position, speed and heading sensors) may lead to incorrect AIS information being transmitted.

In addition, a number of specific vessel types (e.g. warships, naval auxiliaries and ships owned/operated by governments) are not required to be fitted with AIS.

Other inherent limitations of AIS data include the fact that some classes of vessels, in particular leisure craft and fishing boats, are not required to be fitted with AIS. Even if some of these exempt vessels choose to carry AIS, accurate transmission of data may still be limited by the availability and suitability of vessel instrumentation.

Furthermore, some vessels, fitted with AIS as a mandatory carriage requirement, may switch off or disable AIS under certain circumstances by professional judgement of the master. This commonly occurs for example with fishing vessels who are reluctant for other fishers to know where they are fishing at any given time.

Additional errors may be induced by the incompatibility or lack of integration with other electronic systems. Transmission errors may also occur if the transponder coverage is incomplete. Shipboard AIS transponders have a horizontal range that is highly variable but typically only about 74 km. They reach much further vertically, up to the 400 km orbit of the International Space Station (ISS).

A common limitation of AIS currently observed around the NZ coast is the incorrect identification of AIS “pseudo” AtoNs, transmitting as if they were ships.

Examples of raw AIS data that required post processing by Marico included:

- Missing or incorrect data - blank/unknown
- Wrong vessel name
- Wrong vessel type
- Inaccurate AIS time stamps
- Missing records

3.3 DATA CATALOGUE – INTRODUCTION

A purpose-built database was developed by Marico to catalogue and store all the data gathered, to ensure provenance and maintain data sensitivity classification. The database that was developed for this project is enabled with a ’Confidential’ function so that stored passenger numbers and other information that is commercially sensitive, may be kept entirely private.

3.3.1 Use of the Data Catalogue Datasets

The datasets collected were used to populate the risk criteria, which supplied the base data for the risk calculations within each cell of the GIS. As much of the risk assessment is undertaken in a GIS using a programmed model, with many layers of information, there is much that can only be reviewed from the GIS itself. The risk criteria within the GIS risk matrix provide the parameters for each of the risk layer calculations occurring within each cell. The data catalogue allows the setup of the risk criteria to be audited back to the source data used in the risk assessment.

3.4 OTHER SOURCES OF DATA

3.4.1 Interviews

Harbour Masters, Regional Councils or Territorial Authorities, Port Company Operators, local vessel operators and other key stakeholders were interviewed in each region during data gathering visits. From interviews, traffic analysis was updated for all vessels, including traffic frequency, density, type and size. Interviewees were also given a questionnaire to fill in, requesting the following information:

Shipping Data and Port Systems

- Types of vessels and characteristics (including LOA and GRT)
- Harbour characteristics, Infrastructure, AtoNs
- Harbour Ferry and Coastal Ferry Routes, Movements and Passenger Volumes
- Coastal Shipping Routes, Cargo Types and Volumes
- Passenger Volumes (port throughput) and Local Operators (numbers or estimate)
- Vessel Incidents and Statistics
- Oil Spill Incidents and Volumes/Statistics
- Berths Key to the Port Operations
- Berths with high passenger volume
- Berths with high freight volume.
- DG Berths
- Specialised berths

Environment

The availability of Geospatial data layers which would include:

- Marine reserves (DOC or Regional Council)

- Coastal Reserves of importance or other Protected Sites
- Identified Breeding Grounds (Coastal & Harbour)
- Reef, Mangroves or other type of Wetlands (Coastal & Harbour)
- Coastal & Harbour Recreational areas
- Culturally sensitive areas (regional, local)

Tourism

- Tourism focus areas including number of visitors or data
- The Regional Value Estimate of the Coastal Tourism market
- Local tourist vessels destinations (current or proposed)
- Cruise Ship Stops or Destinations (current or proposed)
- Past and Future Cruise Schedules
- Local Vessel routes and passenger volumes
- Known Tourist Dive Sites

Local Economic Information

- Coastal centres of highest economic contribution in the Region
- Coastal locations with businesses sensitive to shipping incident involving pollution.
- Berths or terminals which stand out as high economic value in relation to others in a port
- Regional GDP data
- Regional Tourism data
- Marina size and location

Local Contacts

- Fishing Operators or Processors (representative organisations)
- Recreational Clubs (representation)
- Local Iwi consultation links
- Local Commercial Operators (passenger/Charter - Sea)
- Tourism Offices – Statistics
- Organisations with Coastal Interest of relevance to Charting

Each interviewee was asked to provide any available datasets including GIS shapefiles of areas such as marine reserves, protected areas and areas of environmental or cultural significance.

A full list of stakeholder consultees is provided in **Annex D**.

3.4.2 Vessel Statistics

Port statistics of vessel movements, vessel types and sizes were compiled for each of the main NZ ports. Further information was obtained from cruise vessel operators and agents about cruise calls, including future aspirations for potential cruise ship routes around the NZ coast. The trend is for larger and more manoeuvrable cruise ships to visit NZ waters and to provide new experiences for their passengers by calling at locations not previously visited.

Details of the fleet of coastal domestic vessels and schedules, where vessels were scheduled, were obtained from local vessel operators or skippers, and on-line information. Wherever possible, locally sourced data was used to validate internet sourced data and vice versa.

In 2014, MNZ research estimated that there were around 960,000 recreational boats in NZ. Around 24% of these vessels were located in the Auckland region. A regional estimation of numbers of recreational vessels elsewhere was made by using marina capacity and utilisation, augmented by numbers of recreational boats kept on swing or other moorings plus boat ramp counts by Harbour Masters or Councils to estimate the numbers of small trailered boats.

This data enabled an estimate of small or non-commercial vessel traffic density and an assessment of the economic value of these amenities to the regions' economies.

Some vessel types, for example commercial fishing vessels, do not follow scheduled routes however Vessel Monitoring System (VMS) data was supplied by the Ministry for Primary Industries (MPI) showing cumulative fishing vessel tracking data for the study period enabling a comparison of fishing traffic densities.

For fishing vessels, the total tonnage landed at each port for the study year was used to assess wharf capacities to enable ranking of importance of fishing vessel wharves.

3.4.3 Domestic Passenger Data – Scheduled Services

Where possible, domestic passenger service providers were contacted and data on annual passenger numbers requested. A minority of passenger service operators provided indicative data only. In these instances, the number of scheduled trips was available online, from which, when combined with vessel size and route taken, along with average seasonally-adjusted capacity utilisation, were calculated total passenger numbers. These calculations were cross-referenced wherever possible, with published passenger numbers, for example in newspaper articles; Annual Reports; minutes of Council meetings, etc.

3.4.4 Domestic Passenger Data – Unscheduled Services

In some cases, for instance for unscheduled water taxi services, figures were not available, so an estimate of passenger numbers was calculated using vessel passenger capacity and average utilisation, combined with an estimation of numbers of trips and possible destinations, using local information and local data wherever available. Where data was not readily available from local sources, web-based research and Marico's first-hand knowledge was used to supplement any obtainable statistics.

Details of domestic passenger vessels and schedules, where vessels were scheduled, were obtained from local vessel operators or skippers, and on-line timetable information. Wherever possible, locally sourced data was used to validate internet sourced data and vice versa. All domestic passenger data was calculated over the full project year including seasonal variations in timetabling and passenger numbers.

3.4.5 Economic Data

Regional economic information was used to inform the risk assessment about current levels and types of trade and GDP, potential for growth, as well as potential effects on trade and tourism. The assessment included a prognosis of growth and development to be reasonably expected, with information about the sensitivity of trade and tourism to the consequences of a marine disaster.

Almost 99% of all New Zealand's exports and imports by volume are transported by sea, making New Zealand's 13 major commercial ports and connecting shipping routes vital to economic success. In 2002 the marine economy contributed $3.3b (3% of total GDP) to the total economy ($115b), an increase of 28% from 5 years previous. Of New Zealand's total marine economy, the shipping and fisheries and aquaculture categories were the largest contributing categories, at 27% and 26%, respectively.[6]

[6] **Statistics NZ - New Zealand's Marine Economy 1997–2002**

3.4.6 ENVIRONMENTAL IMPACT DATA

GIS shapefiles were provided by Regional Councils from their Tier 2 Marine Oil Spill Response Plans Annex 4, which supplied location data of environmentally Sensitive Sites. This included bird breeding grounds, wetlands, culturally sensitive sites and other regionally sensitive areas, enabling a representation of the environmental impact, or loss of public utility in the event of a vessel incident. These GIS datasets from Councils' Tier 2 Plans were used whenever obtainable, to map and identify sensitive sites. Where datasets were not available in GIS format, this data was captured into the GIS manually.

Shapefiles of Marine Reserves were similarly supplied by DOC.

3.4.7 CULTURAL DATA

Sites of importance to iwi were sought during the data gathering phase. These were then added into the GIS database as a shape file associated with the location. Much of this data was available from Regional Council/Unitary Authority pollution response plans.

4 NATIONAL OVERVIEW RESULTS

4.1 INTRODUCTION

This section provides plots of all recorded traffic within the NZ study area, followed by plots of the resulting hydrographic risk, then plots of the same area showing where charting improvements show a positive benefit.

Traffic recorded is for the period July 2014 to June 2015, which in the case of fishing vessels includes VMS data recorded by MPI. As traffic data is extracted along the lines of the Earth's longitude, there are limits of coverage as lines of longitude curve in towards the South Pole.

4.2 MARINE TRAFFIC ANALYSIS

4.2.1 ALL TRAFFIC

The figure below presents all of the NZ traffic with AIS transponders installed, as recorded between July 2014 and June 2015. This plot does not include Fishing Vessel records from VMS data, which are presented in a later image in this section.

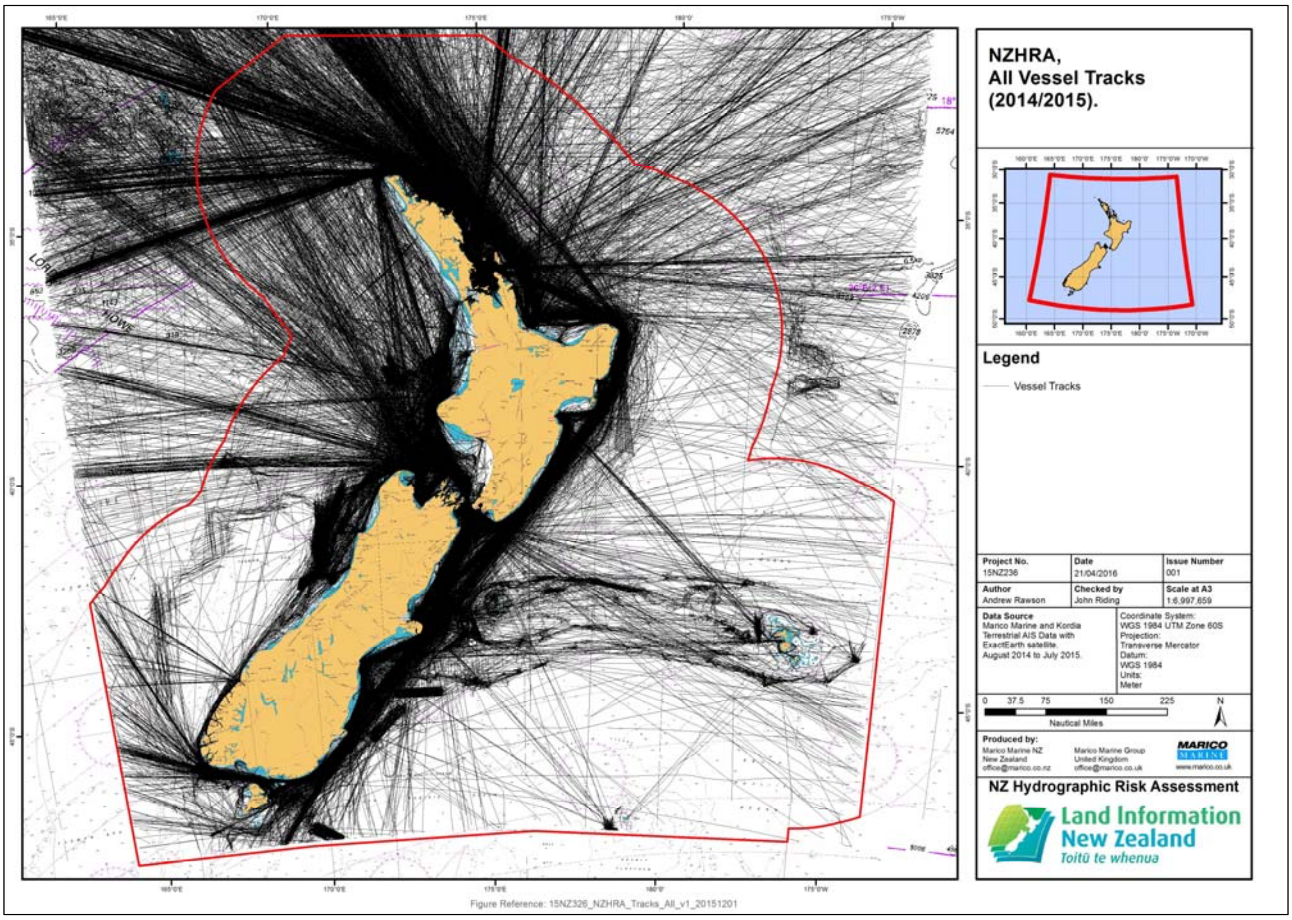


Figure 7 : Plot of all Vessels providing an AIS Transmission in the NZ Study Area

4.2.2 TRAFFIC DENSITY - NATIONAL

Figure 8 presents a density plot of the NZ marine traffic profile, shown in landscape over the page. A density plot highlights traffic routes around the NZ coastline, as well as establishing the areas of high traffic density in relation to other areas. Density is calculated by the sea miles transited in a cell, but this record is solely based on AIS transmissions. It is not limited by vessel type, just water usage.

This is on the basis that:-

- LINZ needs to identify busy coastline or port areas irrespective of the ship type in any development of a programme of work for nautical chart improvements.
- Vessel type (including size/draught) are used in the risk model, such that a higher proportion of deep draught vessels (or vessels whose loss would create large consequences) cause hydrographic risk to rise.

This shows the higher density of traffic experienced along the East Coast of the North Island as well as the South Island where traffic records are concentrated in the sea area down to Akaroa. Traffic density is important to the hydrographic risk profile, especially in relation to the location and relevance of the assumed traffic "routes" where LINZ has historically provided an improvement in seafloor coverage for charting purposes. The density plot is in nautical miles per year steamed, but it should be reiterated that high traffic density does not necessarily translate into high levels of hydrographic risk.

Traffic in the Hauraki Gulf and the approaches to Auckland (Waitemata Harbour) showed high relative density in the year of the traffic data record. This is mostly related to the high volume of domestic passenger services, which are small in relation to other vessels but transit at high speed. This high density level is also reached in Wellington Harbour and its approaches, with the larger Cook Strait passenger ferry services. A medium level of traffic density extends along the trade routes connecting Auckland's port to the ports further south. The approaches to Tauranga as well as the coastline of East Cape (where traffic transits come together due to topography) also show a medium level of traffic density.

In the South Island, Marlborough Sounds and the Stewart Island link across Foveaux Strait show the same level of traffic density (medium). The traffic density plot is useful as it clearly lays out:

- The routes that marine traffic takes around the NZ coastline;
- Highlights the dramatically different traffic volume on the east coast of NZ, compared with that on the west;
- Highlights that although Auckland has the most significant levels of annual traffic volume, it is not the only area of the NZ coastline that experiences significant traffic volumes;
- Identifies where ship traffic transiting the NZ coastline converges (over the timescale of a year), such as East Cape, Cape Palliser and Akaroa;
- Identifies international transit "arrival" and "departure" areas on the NZ coastline.

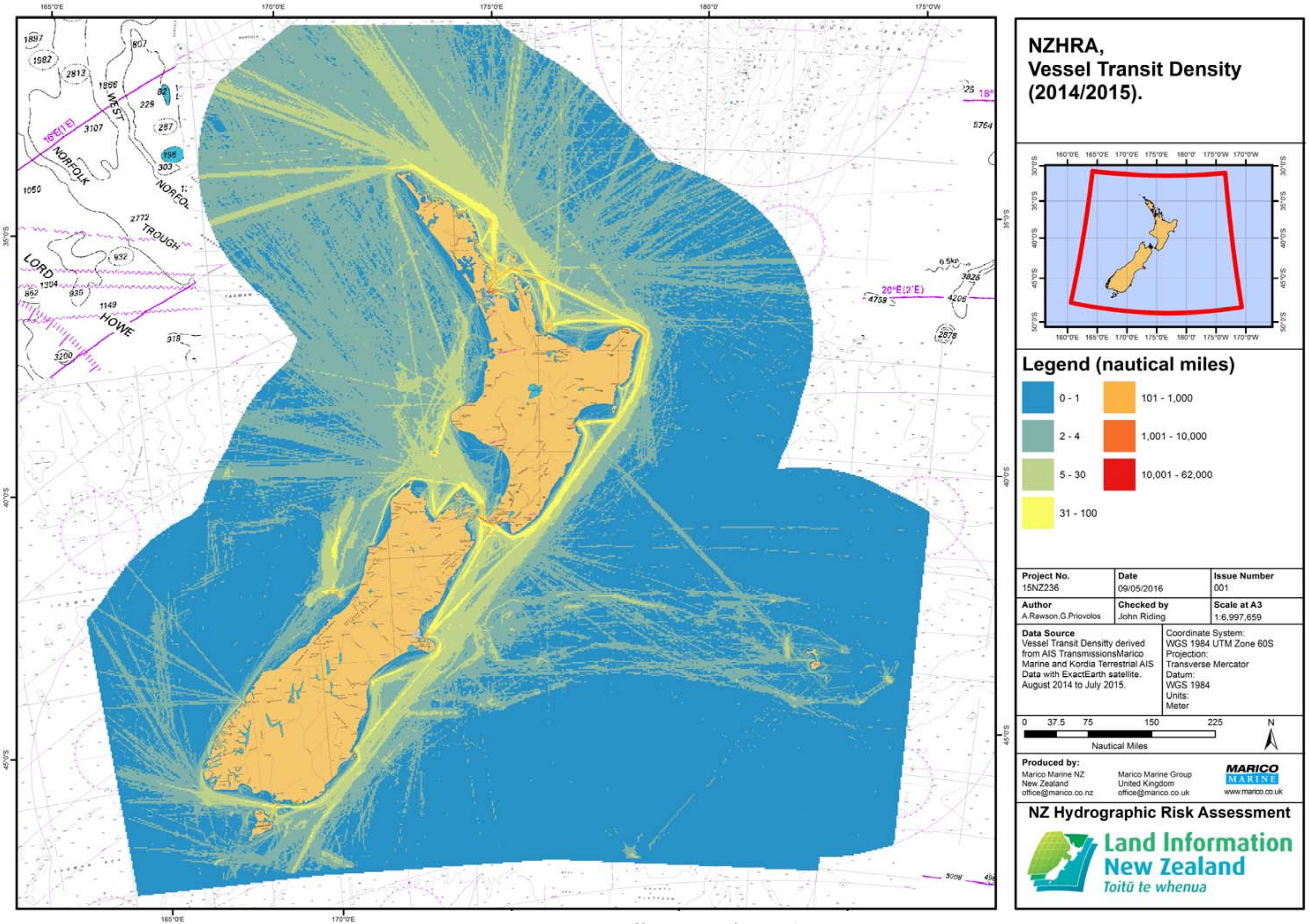


Figure 8 : Marine Traffic Density for Study Area

4.2.3 CRUISE VESSEL TRAFFIC OVERVIEW

The NZ cruise market has expanded significantly in recent years. This is set to continue. However this is not only an increase in the number of vessels using NZ waters, it is also a dramatic increase in vessel size. Both traffic volume and size are taken account of in the hydrographic risk assessment.

Along the Fiordland coast, cruise vessel routes directly to or from Australia can be observed.

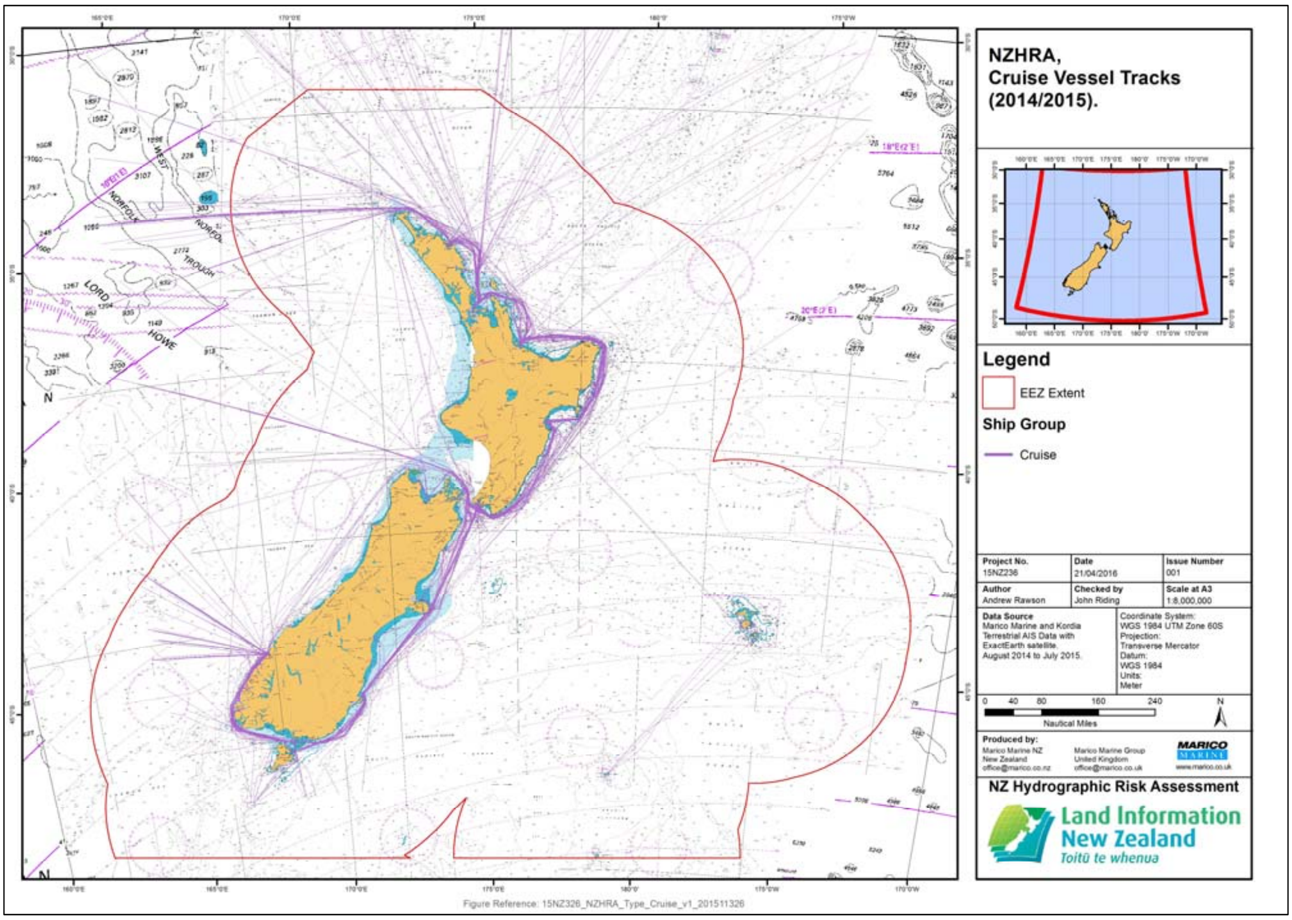


Figure 9 : Plot of Cruise Vessels using NZ Waters

4.2.3.1 CRUISE VESSEL STOPS

Figure 10, below, shows the locations around the NZ coast where Cruise Vessels stop. This may be either alongside a wharf, anchored or drifting offshore working their tenders in locations where anchoring is not feasible or safe. The risk criteria take cruise stops into account in the development of both the hydrographic risk profile and charting benefit output. This is because there may be a need to review the density of hydrographic survey seafloor coverage if cruise vessels regularly anchor and work tenders to ferry passengers to an attraction. Note that both the track and the cruise vessel stop plots show the increasing importance of Fiordland as a cruise destination and Milford Sound as an international arrival or departure port.

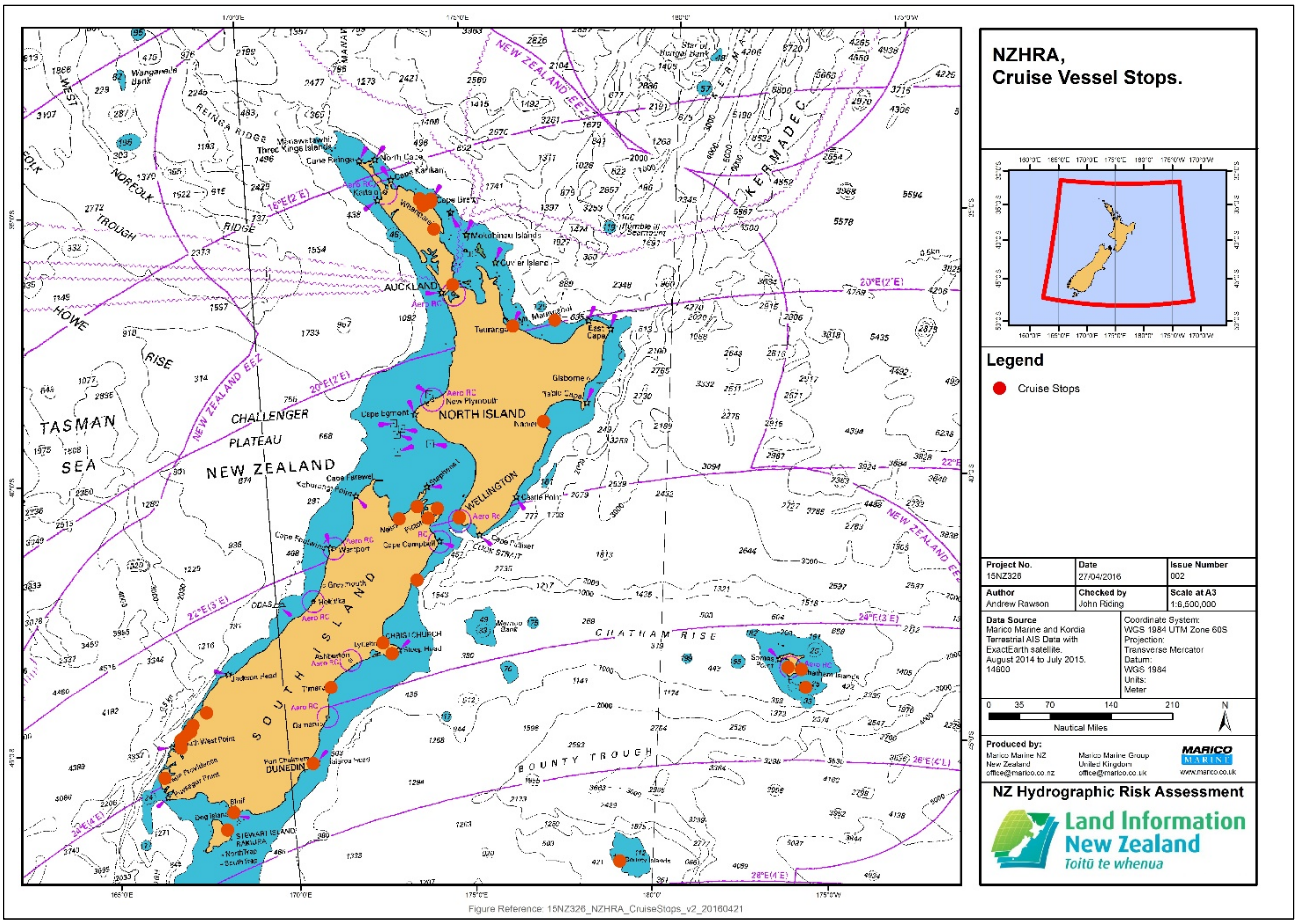


Figure 10 : Plot of Locations in which Cruise Vessels Stop

4.2.4 DOMESTIC PASSENGER TRAFFIC

The level of domestic traffic is key to the hydrographic risk assessment, especially those in passenger services. In some of its population centres, NZ is developing mature passenger traffic routes, with significant passenger volumes. Most of these are high speed craft designs, or, as in the case of the Cook Strait, traditional passenger and freight RoRo ferries.

Figure 11 presents the relative national density of domestic passenger use by location. This is taken from data gathering, where records of the volume of passengers on each route in NZ was collected, in some cases by individual companies. In some areas, e.g. within Auckland city jurisdictions, these records are available to the general public due to the licencing system employed (Auckland Council has bylaw requirements for all vessels carrying passengers to be fitted with AIS transponders). In other areas, passenger operators view the volume of passengers on their route (or by company) as confidential. The project data gathering was able to obtain passenger figures per route for all such routes in NZ.

Figure 11 also shows the relative importance of the passenger trades in relation to the other regions of NZ. Domestic passenger volumes are growing strongly in some areas, especially where international tourism is increasing. Fiordland is a good example, where growth in the order of 20% in a year has reportedly occurred. This may well be a transient record, given the nature of the international tourist trade, although some of the volumes do provide surprise. In 2014-15, the NZ $ declined and a visiting tourist boom was apparent.

In terms of orders of magnitude, Auckland passenger volumes dominate the record. The volume of passengers experiencing a Milford Sound cruise per annum is (using the same order of magnitude yardstick) lower than that of the Cook Strait ferry service, but it is in that same data category. Although the actual volumes have not been published in this project, it is very useful information for those managing the vehicular access to and from Fiordland.

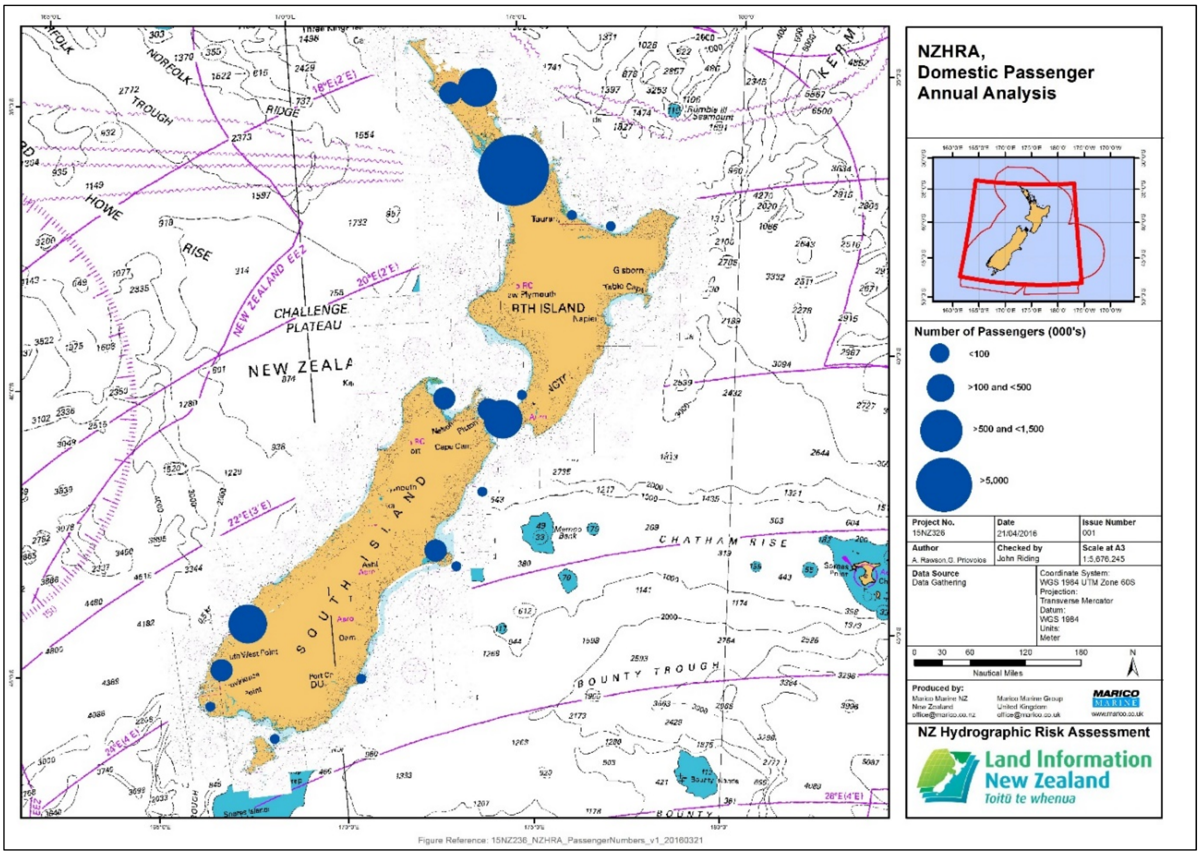


Figure 11 : Relative Importance of Domestic Passenger Trade (Passenger Numbers)

4.2.5 TANKER TRAFFIC

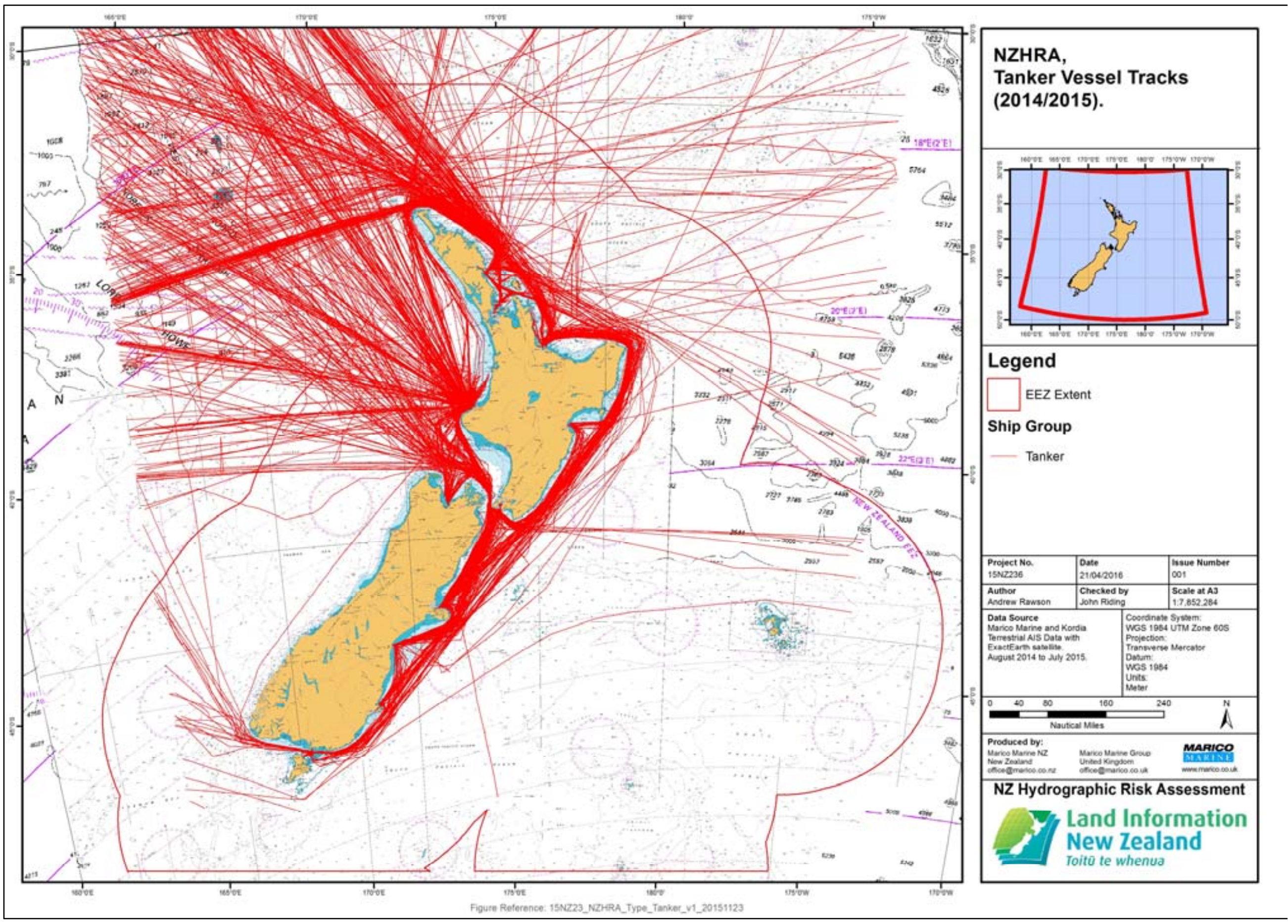


Figure 12 : Tanker Traffic through the NZ EEZ

Figure 12 shows the level of tanker usage in NZ waters for 12 months. Overall, tanker traffic is a significant sector of the annual NZ vessel statistics. Apart from the west coast of the South Island, there are records of tanker transits throughout NZ waters. Much of this trade is also international, with transits passing to the south of NZ also visiting the Victorian, NSW and Tasmanian ports of Australia. There is also evidence of Tankers passing through NZ waters as a waypoint to other destinations, exercising their UNCLOS *right of innocent passage* including traversing through Cook Strait and Foveaux Strait.

There is a voluntary routeing guidance for Tankers around the New Zealand coast, provided by MNZ and promulgated by LINZ[7]. The evidence from this record is that the majority of Tankers do follow the voluntary routeing guidance. However, there are a recordable number that do not. In addition, some Tankers follow the coastline in relatively close proximity to the land in some areas, such as East

[7] **NZ Nautical Almanac Annual Notice to Mariners, ANTM10**

Cape. Although transiting in deep water, a vessel needs to take account of the need for sufficient drifting time to conduct repairs in the event of propulsion failure. This is especially true in locations of coastal tidal flow.

4.2.6 GENERAL CARGO TRAFFIC

The General Cargo traffic record for 2014-15 is presented in **Figure 13**. This category includes container vessels, various types of dry bulk carriers, refrigerated vessels and traditional general cargo ships ('tween-deckers'). As vessel type groupings are set by the AIS transmission protocols, it is not possible to break this group down further, except on a vessel by vessel basis[8].

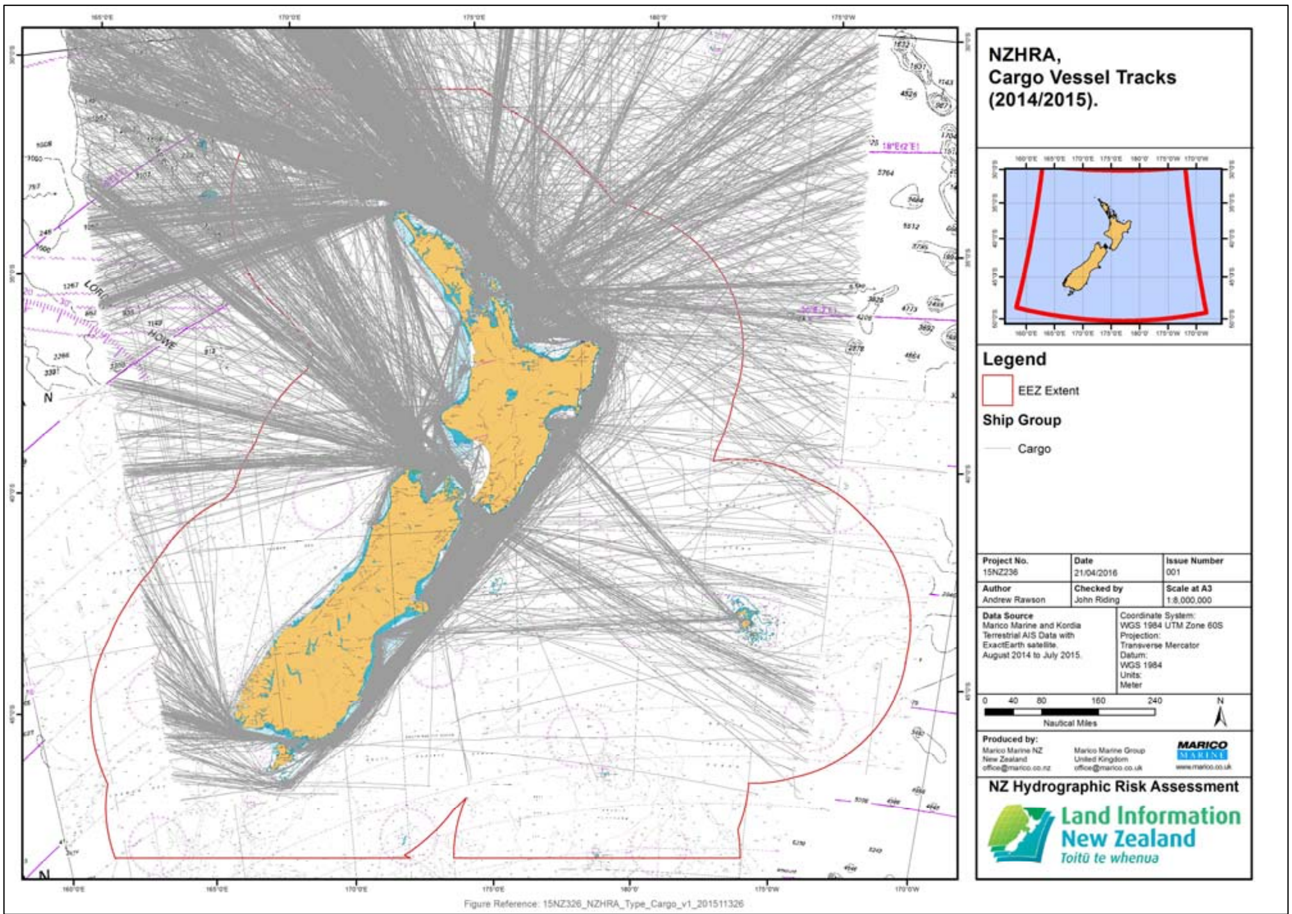


Figure 13 : 12 Month Record of General Cargo Vessels in NZ Waters

General cargo vessels are found throughout NZ waters and represent the majority of transiting traffic. They can range significantly in size (both length and Gross Registered Tons).

International vessels exercising their navigational right of passage occur with traverses through the Cook Strait as well as through Foveaux Strait.

[8] **As vessels are uniquely identifiable by their radio licence (MMSI number), the vessel type can be determined individually.**

4.2.7 FISHING VESSELS

There is considerable fishing activity in NZ waters, which differs by location dependent on the fishery in season. This plot amalgamates all of the activity together, which is sufficient for hydrographic purposes. The record is taken from both AIS transmissions as well as VMS data. There are some vessels engaged in offshore survey evident in the fishing vessel plot. Fishing vessels can sometimes be engaged in survey or research work, especially larger vessels. This vessel type is included in the hydrographic risk assessment although they have a lesser influence on the risk score, partly due to shallow draught, in comparison to other vessel types.

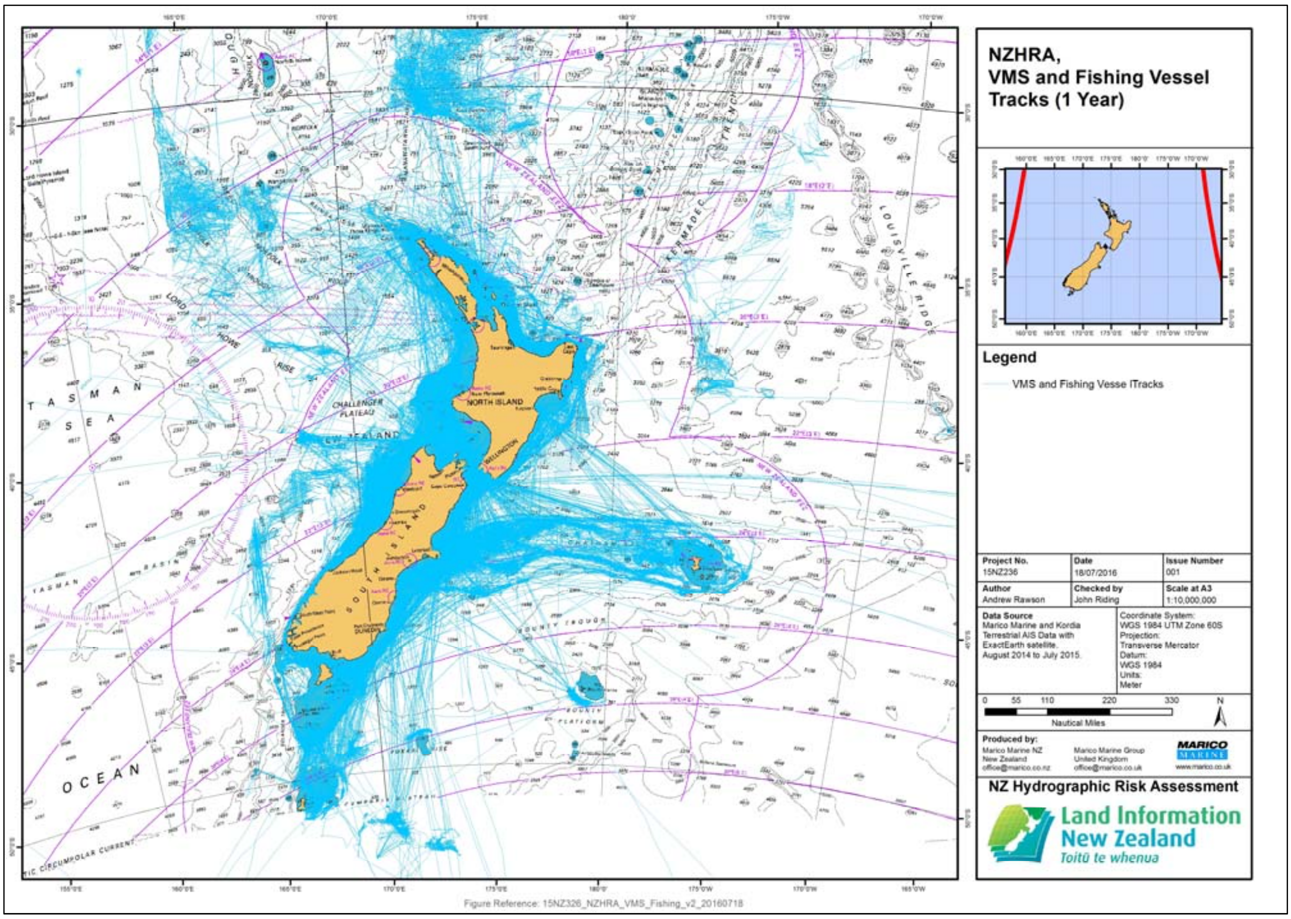


Figure 14 : Fishing Vessel Track Records in NZ Waters (VMS and AIS Data, 2014-2015)

4.2.8 RECREATIONAL CRAFT

Recreational craft use in NZ is significant, with the country being recorded as having one of the highest boat ownership rates per head of population in the world. The record presented in the figure below is for larger recreational craft as well as some so called "mega yachts", all of which are carrying AIS transponders. The craft represented show recreational craft usage extends throughout NZ coastal waters. There are also a significant number of international voyages undertaken by recreational craft. On a national basis, the highest concentration of recreational craft use is along the north-eastern coast of NZ.

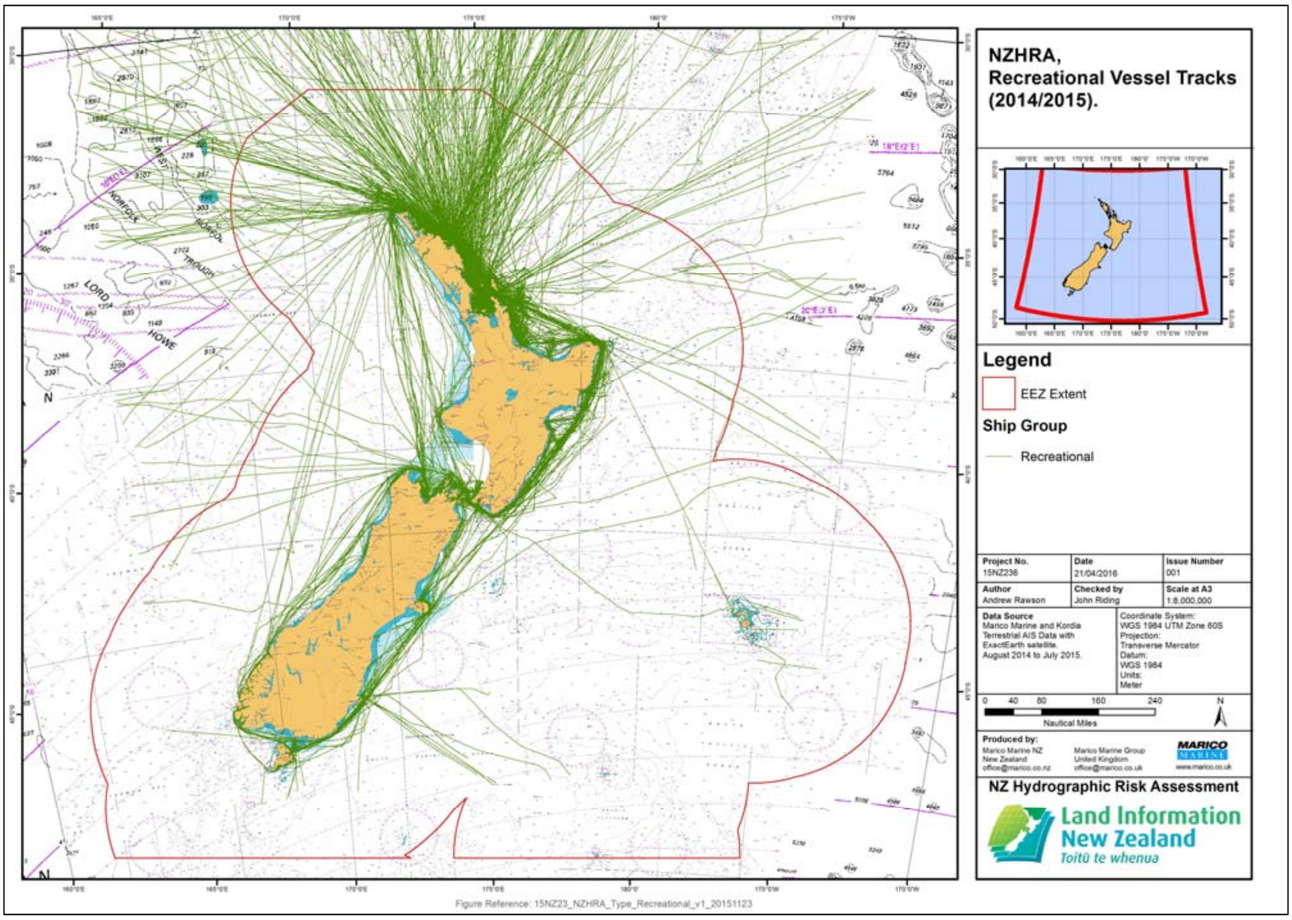


Figure 15 : Plot of Recreational Craft (with AIS) in NZ Waters

4.3 NEW ZEALAND ANCHORAGE LOCATIONS

NZ anchorage locations for the 2014-15 period have been detected from the AIS data record, where vessels have become stationary for a set test period, as well as having declared (via AIS) of an anchoring event. This does not include areas where vessels may have been drifting, as a number of tests are run to establish that a vessel is stationary and (sometimes) swinging with tidal change. The reason for this analysis is to allow a comparison within the risk assessment to establish locations where vessels are anchoring in relation to those anchorage areas designated by the charting. LINZ would normally improve the seafloor coverage or even record information provided about seafloor type (holding) for an anchorage area.

Areas that appear to be important for vessel anchoring outside of designated anchorages are Taranaki; Tauranga approaches (where anchorages were recently reconfigured), the outer Queen Charlotte Sound, Marlborough, Lyttelton approaches, Bluff Approaches and parts of Fiordland.

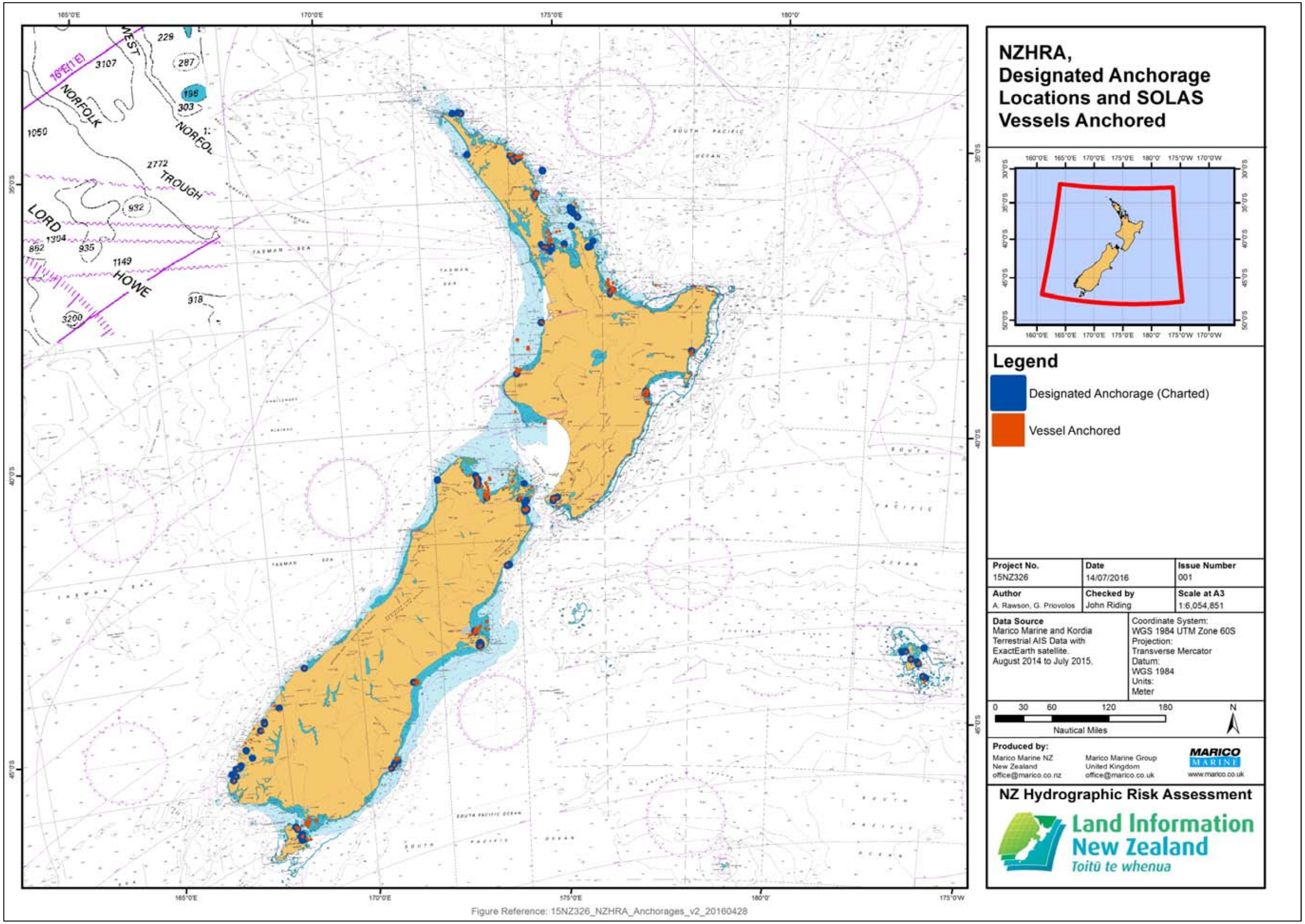


Figure 16 : Anchorages in NZ Waters – AIS data

4.4 HYDROGRAPHIC RISK

4.4.1 INTRODUCTION

The New Zealand Hydrographic Risk Assessment was analysed regionally, taking account of Regional Council boundaries. Where a Unitary Authority has the responsibility of a Regional Council, the Unitary Authorities' boundaries were used for the regional analysis. There are a number of locations where the hydrographic risk profile is heightened. This may be due to a high level of traffic overall (or vessel types with greater loss of life or polluting potential), or due to a location where either environmentally or culturally important sites are present (close to transiting traffic). However, heightened risk in the hydrographic sense does not necessarily mean there is a need for charting upgrades, it may just be heightened risk. If charting is at its most appropriate standard for the heightened risk area and seafloor coverage is complete, then only a low charting benefit will be available. In other words, heightened risk will be present in areas for a number of reasons, but if charting is already to a good and modern standard, then charting makes the lowest contribution possible to the risk profile.

An assessment of the benefits available from charting upgrades is needed for the development of the LINZ work programme.

4.4.2 OVERVIEW OF HYDROGRAPHIC RISK

It is only to be expected that hydrographic risk will be the highest where the water depth is reducing. The result, **Figure 17**, shows a national overview of hydrographic risk.

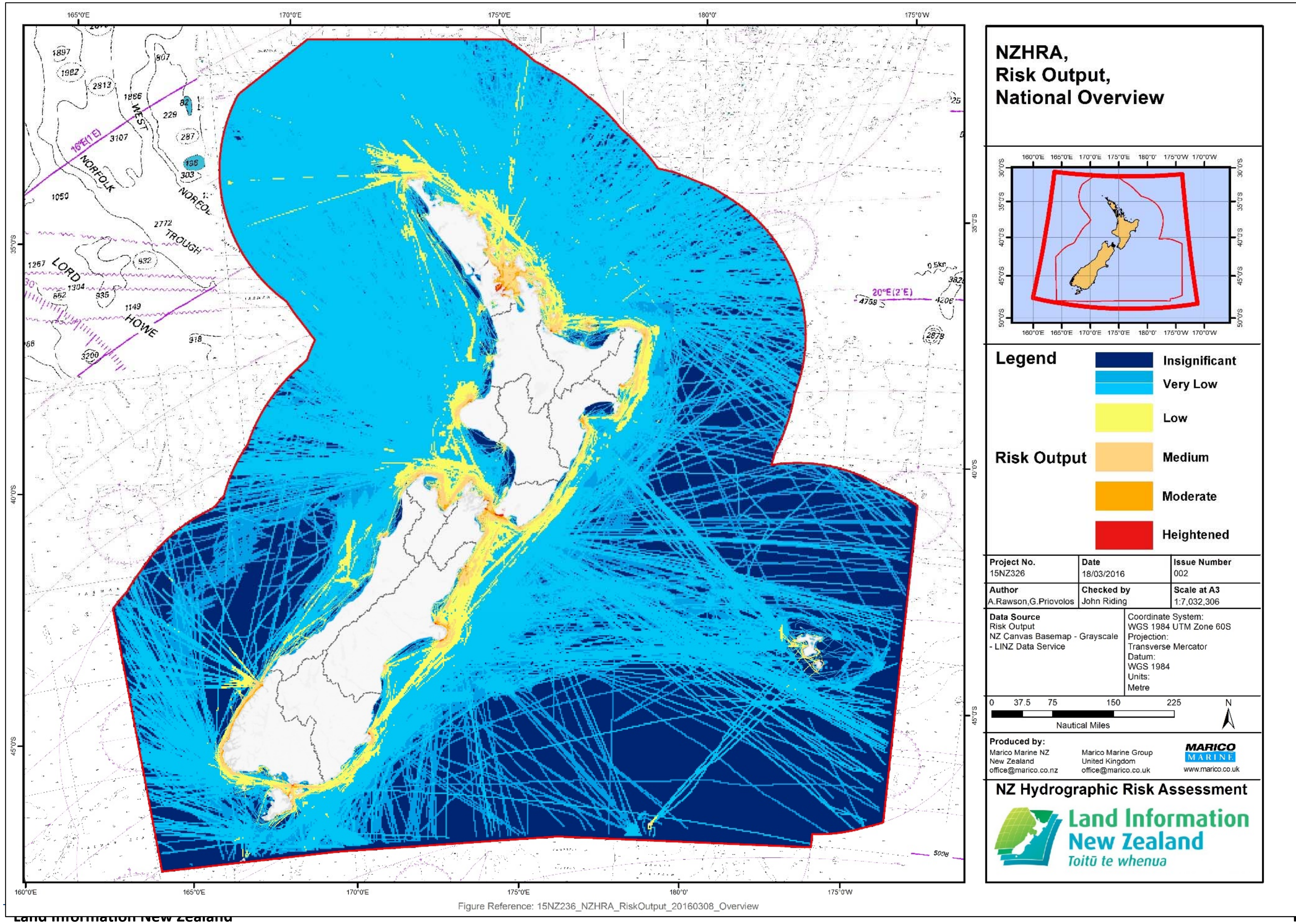


Figure 17 : National Overview of New Zealand Hydrographic Risk

4.4.3 Hydrographic Risk Results – New Zealand

The following tables identify, in geographic order from north to south, areas where the comparative charting benefit is positive with an associated elevated risk level, indicating where charting improvements may be beneficial.

Twenty-nine areas of heightened hydrographic risk combined with a positive charting benefit are identified. Three additional areas show a moderate hydrographic risk combined with a positive charting benefit.

These 32 areas are summarised in **Table 6** and **Table 7**. This is a high level risk summary, which must be interpreted with care.

NEW ZEALAND NORTH ISLAND Important Areas for Charting Improvements				
Region		Area	Comparative Benefit Level	Comparative Risk Level
1	**Northland**	Whangarei Harbour	Positive	Moderate
2	**Auckland**	Kawau Bay	Positive	Heightened
3	**Auckland**	Auckland - Inner Hauraki Gulf	Positive	Heightened
4	**Auckland**	Auckland - West Harbour	Positive	Heightened
5	**Auckland**	Auckland – Tamaki Strait	Positive	Heightened
6	**Bay of Plenty**	Tauranga Approaches & Centre Harbour	Positive	Heightened
7	**Bay of Plenty**	White Island	Positive	Moderate
8	**Gisborne**	Gisborne Approaches	Positive	Heightened
9	**Hawke's Bay**	Napier Approaches	Positive	Heightened
10	**Wellington**	Wellington Harbour & Approaches	Positive	Heightened
11	**Taranaki**	Taranaki Harbour & Approaches	Positive	Heightened

Table 6 : Summary of Important Areas – North Island

NEW ZEALAND SOUTH ISLAND Important Areas for Charting Improvements				
Region		Area	Comparative Benefit Level	Comparative Risk Level
12	Tasman Bay	Rabbit Island	Positive	Moderate
13	Nelson	Nelson Approaches	Positive	Heightened
14	Marlborough	D'Urville Island	Positive	Moderate
15	Marlborough	Marlborough Sounds	Positive	Heightened
16	Canterbury	Kaikoura	Positive	Heightened
17	Canterbury	Lyttelton Harbour	Positive	Heightened
18	Canterbury	Banks Peninsula	Positive	Moderate
19	Canterbury	Akaroa Approaches	Positive	Heightened
20	Canterbury	Timaru Harbour & Approaches	Positive	Heightened
21	Otago	Otago Harbour & Approaches	Positive	Heightened
22	Southland	Bluff Harbour Approaches	Positive	Heightened
23	Southland	Stewart Island – East Coast	Positive	Heightened
24	Southland	Dusky Sound	Positive	Heightened
25	Southland	Doubtful Sound	Positive	Heightened
26	Southland	Caswell, Charles and Nancy Sounds	Positive	Heightened
27	Southland	George Sound	Positive	Heightened
28	Southland	Bligh Sound	Positive	Heightened
29	Southland	Poison Bay	Positive	Heightened
30	Southland	Milford Sound – Fresh Water Basin/ Sandfly Point	Positive	Heightened
31	Southland	Milford Sound Approaches	Positive	Heightened
32	West Coast	Westport Approaches	Positive	Heightened

Table 7 : Summary of Important Areas – South Island

4.5 Hydrographic Risk and Benefit Results – By Region

No.	Area	Benefit	Risk	Region
1	Whangarei Harbour	Positive	Moderate	Northland Region
2	Kawau Bay	Positive	Heightened	Auckland Region
3	Auckland Harbour - Inner Hauraki Gulf	Positive	Heightened	Auckland Region
4	Auckland Harbour – West Harbour	Positive	Heightened	Auckland Region
5	Auckland Harbour – Tamaki Strait	Positive	Heightened	Auckland Region
6	Tauranga Approaches & Harbour	Positive	Heightened	Waikato Region
7	White Island	Positive	Moderate	Bay of Plenty Region
8	Gisborne Approaches	Positive	Heightened	Gisborne Region
9	Napier Approaches	Positive	Heightened	Hawke's Bay Region
10	Wellington Harbour & Approaches	Positive	Heightened	Wellington Region
11	Taranaki Approaches	Positive	Heightened	Taranaki Region
12	Tasman – Rabbit Island	Positive	Heightened	Tasman Region
13	Nelson Approaches	Positive	Heightened	Tasman Region
14	D'Urville Island	Positive	Moderate	Marlborough Region
15	Marlborough Sounds	Positive	Heightened	Marlborough Region
16	Kaikoura	Positive	Heightened	Canterbury Region
17	Lyttelton Harbour	Positive	Heightened	Canterbury Region
18	Banks Peninsula	Positive	Moderate	Canterbury Region
19	Akaroa Approaches	Positive	Heightened	Canterbury Region
20	Timaru Harbour & Approaches	Positive	Heightened	Canterbury Region
21	Otago Harbour & Approaches	Positive	Heightened	Otago Region
22	Bluff Approaches	Positive	Heightened	Southland Region
23	Stewart Island – East Coast	Positive	Heightened	Southland Region
24	Dusky Sound	Positive	Heightened	Southland Region
25	Doubtful Sound	Positive	Heightened	Southland Region
26	Caswell, Charles and Nancy Sounds	Positive	Heightened	Southland Region
27	George Sound	Positive	Heightened	Southland Region
28	Bligh Sound	Positive	Heightened	Southland Region
29	Poison Bay	Positive	Heightened	Southland Region
30	Milford Sound - Fresh Water Basin/Sandfly Point	Positive	Heightened	Southland Region
31	Milford Sound Approaches	Positive	Heightened	Southland Region
32	Westport Approaches	Positive	Heightened	West Coast Region

Table 8 : Hydrographic Risk Results – Identified Areas

4.6 CHARTING BENEFIT – NEW ZEALAND OVERVIEW

Charting benefit is shown as a combination of three factors: chart accuracy, chart quality and charting extent. Charting Benefit is a separate model, run after the risk assessment output has completed. Risk model inputs for charting benefit included ZOC for a given depth of water; charting scale for harbour, approach and ocean; and chart extent. In the chart benefit model, the charted individual sounding data points were used to give an indication of the ideal ZOC, and not depth contours. This improves the ability to assess the margin of charting improvement availability on a cell by cell basis.

Charting benefits are based on hydrographic survey information supplied by LINZ, which was up to date to the end of the 2015-16 financial year. Programmed work was added to the existing portfolio if it was known to complete by July 2016.

Over recent years LINZ have prioritised updating of NZ charts for what were assumed routes most frequently taken by ships. Remaining risk relates to the scale of charts in areas previously considered remote, but which may impact for example on boutique-style cruise ships undertaking expedition cruises to new places not previously visited by cruise vessels.

The NZ result is shown in **Figure 18**, over the page. The darker blue shows areas of positive benefit, the green areas where investment in charting improvements shows no benefit. This plot is at an overview level and benefit results are discussed in other sections of the report on a regional basis.

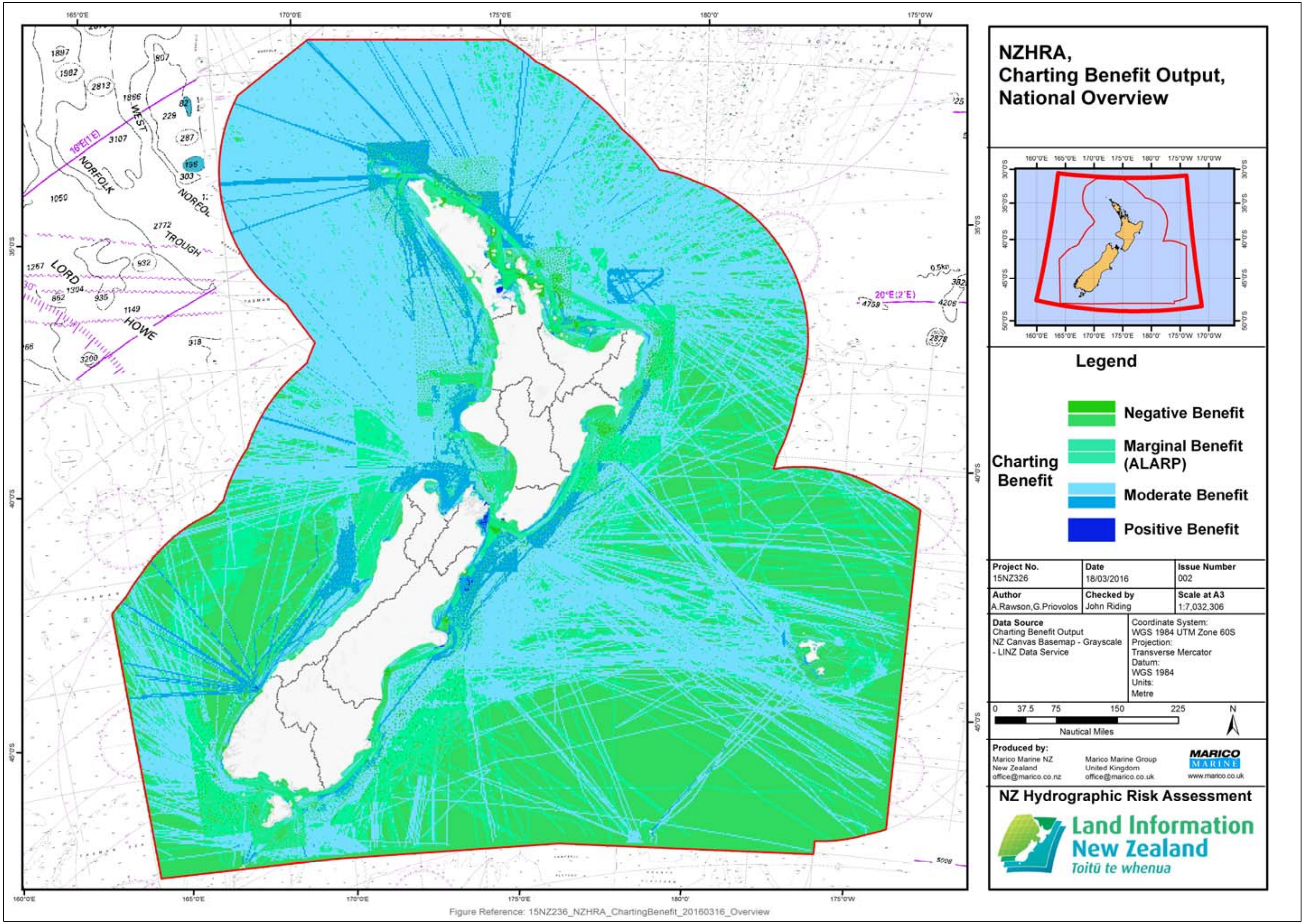


Figure 18 : Charting Benefit Plot for New Zealand Waters

5 DISCUSSIONS AND CONCLUSIONS

1) Although the project has provided some challenges to deliver a Hydrographic Risk Analysis for the study area within the NZ EEZ, a charting benefit assessment of the navigable waters by hydrographic risk has been achieved. A charting benefit model, based on the combination of the risk result per GIS cell and the available margin of charting improvements possible in that GIS cell, had to be developed. The resulting output clearly identifies areas of charting benefit that allows a survey and charting updating plan to be developed.
2) Analysis of Charting Benefit Results show a number of Harbour Approach areas of note. This is due in most cases to the scale or extent of the existing Approach charts. These are often at a scale more suitable for Coastal than Approach charting. A review of these areas by LINZ would be beneficial.
3) LINZ has policy to add the M-QUAL Charting Quality CATZOC rating to its charts and has done this to almost all of its coastal charting series (it is not needed on route planning charts). The CATZOC rating is of help to the navigator using ECDIS and it is also a key input into a Hydrographic Risk assessment. The rollout of CATZOC has to date extended into the Coastal Chart portfolio, but not into the route planning series of charts. Therefore, it is worthwhile LINZ considering extension into all of the LINZ portfolio within the NZ EEZ, so that the LINZ macro scale international charts are given a rating reflecting their seafloor coverage and quality overall. This will assist in a future review of the GIS based risk model. As this is offshore deep water, there is little or no reputational risk posed to LINZ by adding MQUAL CATZOC to all of its official nautical charting portfolio.
4) It is practically impossible to update all of the source data used in a chart at one time. This produces some scattering of charting benefit result in the plots. In the LINZ portfolio, there is chart source data in parts of some charts dating back to 1939. These areas will provide limited seafloor coverage information. Where charting benefit results are also positive it makes sense to have policy to prioritise these areas over others.
5) A few ZOC-U (unassessed) areas remain around the coast, as do some close inshore un-charted areas. The risk result highlights those areas were vessel traffic of note is apparent.
6) The updating of charts in the areas of maintained channels within harbour areas was a subject of feedback during data gathering. In some cases source data for maintained channels may not be updated for 10-15 years, e.g. Port of Tauranga which is charted as last dredged to various depths in 1996, although in practice maintenance dredging occurs annually. Whilst piloted vessels do not necessarily need to rely on official nautical charts

(Pilots have access to local survey results), those navigating pilot exempt (PEC) vessels do not always have similar access to the latest survey data, but rely on official nautical chart data. Most New Zealand ports are deepening channels to facilitate access to berths by larger vessels. Entrance channels are often deeper or different to charted, because of annual maintenance or capital dredging by ports or harbour masters. As the risk assessment methodology also shows these areas as providing benefit from Charting Upgrade, it may be of use to consider policy for charting update periods in such areas.

7) There are some informal anchorages in use around the NZ Coast, for example in the approaches to Gisborne and Taranaki. Full seafloor coverage and characteristics may not be available in these locations, and hydrographic survey seafloor coverage may not always meet the S-44; these may need to be brought to the attention of Mariners. However, it may be useful to consider seafloor conditions in such areas, in conjunction with the local navigational safety authority. Taranaki has a large number of tankers anchoring offshore and outside of designated anchorages. The chart does advise extreme caution when anchoring due to the poor nature of the holding ground throughout the area. There has been a case of a tanker dragging anchor and additional information about the sea floor may influence improvements.

8) Changes to Harbour responsibility in New Zealand Harbour Waters occurred following the Port Companies Act 1988. This has resulted in navigational responsibilities being delivered through Regional Council systems, who have jurisdiction both inside and outside Harbour Limits. The placing of Harbour Limits on charts for NZ Waters can sometimes be overlooked, but they are in most cases Gazetted and internationally recognised (harbour liability case law is fundamental to such limits). Not all harbour limits appear on all of the LINZ charts and the risk assessment needed to manually add these in some cases. Accordingly this is a worthwhile area of policy review. The change in harbour responsibilities has also resulted in port companies no longer carrying out hydrographic surveys of non-commercial parts of harbours. Charted data of these areas has in some cases become outdated.

9) As ports expand and cater for larger vessels, small or shallow berths become redundant, while new berths are created in deeper water. A separate study could identify berths of high economic importance so that these may be prioritised for charting improvements. Charts in some harbour areas could be reviewed for relevance of existing berth coverage.

10) Similarly, parts of harbours that were once used by smaller coastal vessels may be unused by the larger vessels now frequenting these ports. Identifying the relevance of some harbour chart extents from a vessel usage point of view was not part of this project but could usefully contribute to charting reorganisation.

11) Several areas of navigational importance stood out during the risk assessment review: the northern tip of the Coromandel Peninsula in particular showed traffic approaching as close as a mile to the reef extending out from Cape Colville. Tankers have passed around 1nm from the protected nature reserve at Cuvier Island. There appears room for some improvements to the navigational safety management of vessels using coastal waters in areas of significant current (Colville Channel), or those of navigational complexity (for example Hole in the Wall - Mercury Islands; or Motuihe Channel, Auckland).
12) There is no quick or easy method of updating chart data in chart plotters. Recreational craft/ vessels and the majority of smaller commercial are required only to carry charts suitable for their intended voyage. Many use plotters with outdated data. A procedure for updating electronic charts on existing plotters would be beneficial to all mariners, but may be outside the scope of the current project.

References

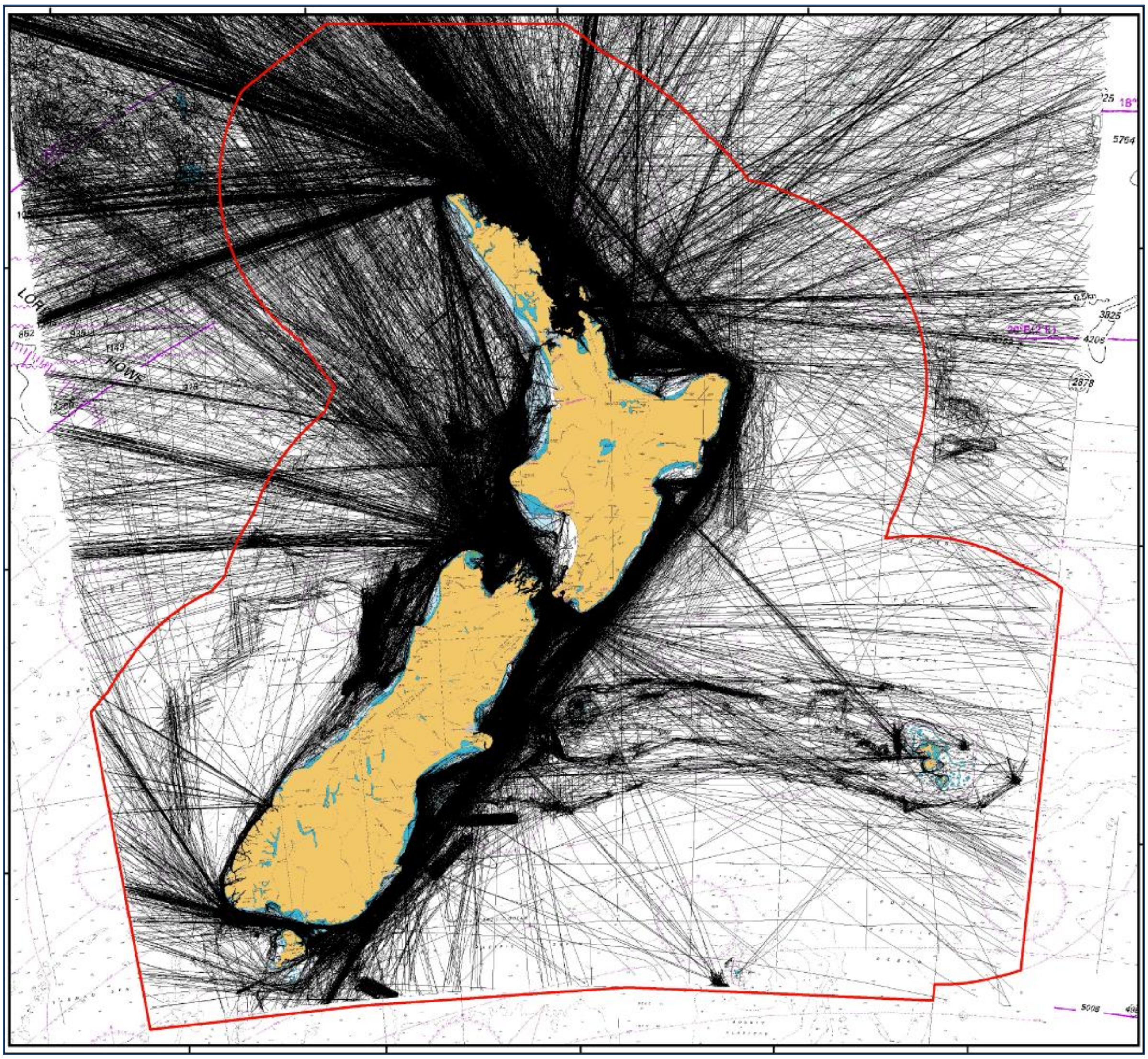
1) Auckland Transport websites
2) Cruise NZ websites
3) Department of Conservation websites
4) Marina Operators Association websites
5) Maritime NZ website
6) Media Articles – various websites
7) Ministry for Primary Industries website
8) Ministry of Transport - FIGS
9) NZ Meteorological Service website
10) Port Company Annual Reports
11) Port Company websites
12) Regional, City and District Council websites
13) Statistics NZ website
14) Regional Council and Unitary Authority Tier 2 Oil Spill Response Plans
15) LINZ Website
16) LINZ Nautical Charting portfolio – NZ EEZ
17) NZ Ports and Freight Yearbook 2015

Annex A New Zealand Hydrographic Methodology Summary

Hydrographic Authority

LAND INFORMATION NEW ZEALAND

NEW ZEALAND HYDROGRAPHIC RISK ASSESSMENT CRITERIA



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Date: 7 July 2016

MARICO MARINE NEW ZEALAND LTD

LAND INFORMATION NEW ZEALAND

NEW ZEALAND HYDROGRAPHIC RISK ASSESSMENT CRITERIA

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Checked By: **John Riding**

Date	Release	Prepared	Authorised	Notes
07/08/2015	Draft A	AR	JR	Draft release
06/04/2016	Issue 1	GP	JR	Updated risk criteria and updated charting benefit methodology.
07/07/2016	Issue 1	GP	JR	Minor updates to charting benefit section and introduction.

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07 July 2016

CONTENTS

FIGURES

TABLES

ABBREVIATIONS

Abbreviation	Detail
AIS	Automatic Identification System
ALARP	As low as reasonably practicable
EEZ	Exclusive Economic Zone
IMO	International Maritime Organisation
kt	Knot (unit of speed equal to nautical mile per hour , approximately 1.852 km/h)
LINZ	Land Information New Zealand
m	Metre
ML	Most Likely
nm	Nautical Mile
NRA	Navigation Risk Assessment
SAR	Search and Rescue
WC	Worst Credible
ZOC	Zone of Confidence

1 INTRODUCTION

This methodology document describes the methodological approach, criteria and weighting system developed for the New Zealand Hydrographic Risk Assessment. It is intentionally a summary overview to highlight the features of the New Zealand national assessment of hydrographic risk. For a full description of the Hydrographic Risk Assessment Methodology, and other documents, such as those produced on behalf of LINZ, consult the available reference materials at the IHO website[1].

1.1 NEW ZEALAND RISK MODEL

The risk model describes three factors necessary to measure risk **(Figure 1).** The exposure of vessel traffic, the likelihood of those vessels having an incident and the consequences of those incidents. The consequences of an incident are identified as either loss of life, pollution, salvage costs and damage to vessels and the economic impact to the wider economy.

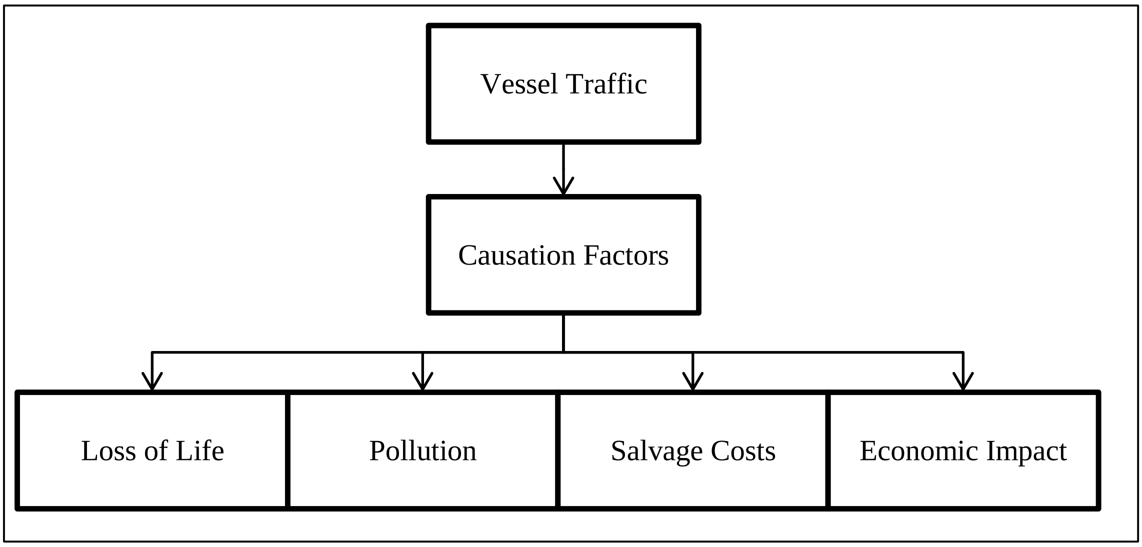


Figure 1: Risk Model.

1.2 VARIABLE CELL SIZES

The risk model developed used three resolutions of grids (see **Figure 2**):

- 3km^2 offshore (EEZ to 12nm limit);

[1] https://www.iho.int

- 1km^2 inside the 12nm territorial waters; and
- 500m^2 inside gazetted pilotage limits.

Each grid cell contains an attribute for each traffic condition, causation factor and consequence factors. All causation and consequence factors describe the presence or proximity to a feature and therefore variable scales do not alter the model. However, the presence of traffic in a cell is more likely with a larger cell size. To ensure consistency, a measure of traffic density was used, traffic per unit area. Therefore, if a cell size is twice as large as another, twice the number of vessel movements are required to measure the same traffic density.

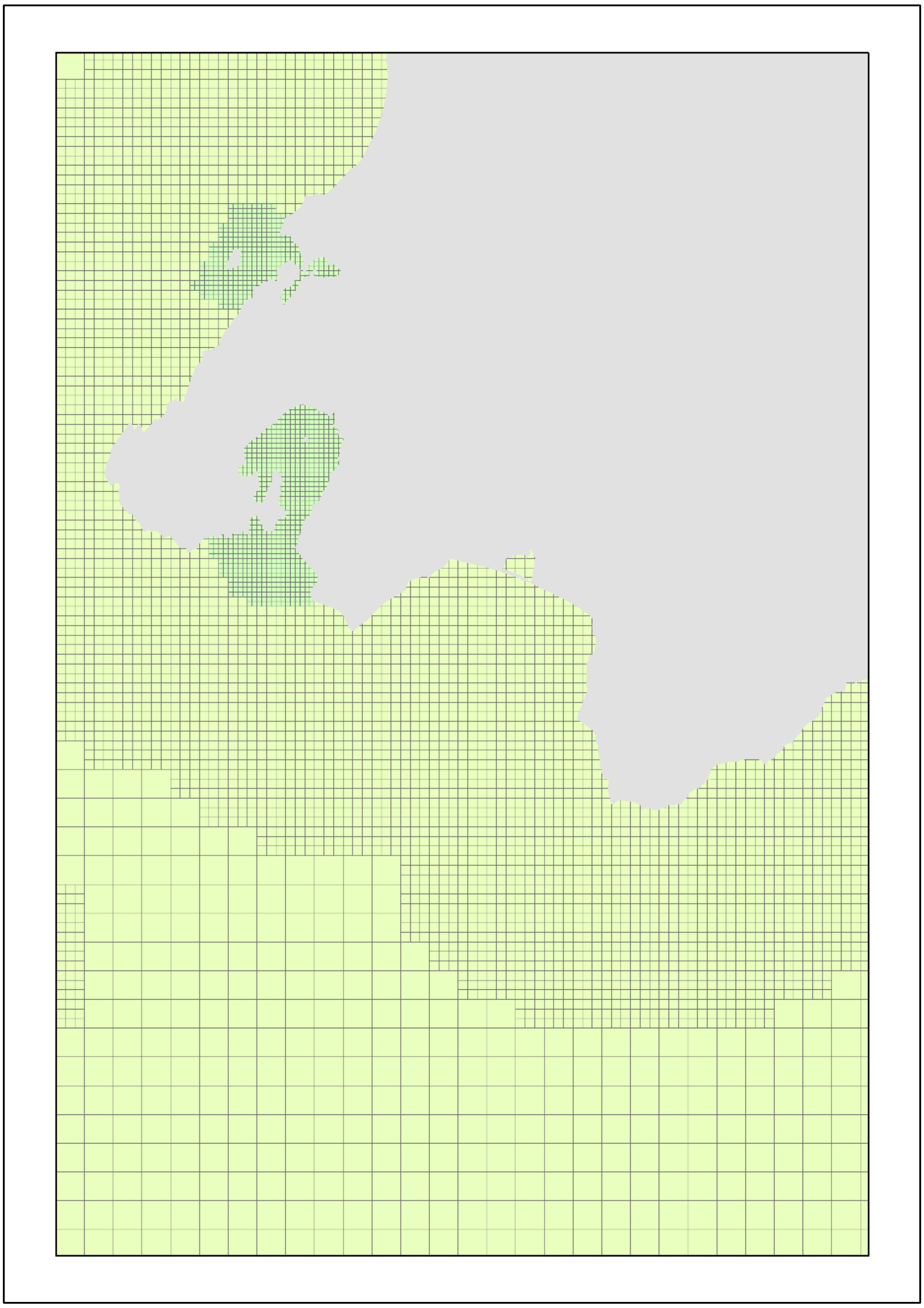


Figure 2: Example Variable Cell Sizes

1.3 PROXIMITY TO RISK FACTORS

Many of the causation and consequence risk factors are judged in terms of proximity. The closer vessel traffic is to the feature, the more likely an incident is and/or the more significant the consequence. Each feature when mapped is buffered at multiple distances as defined by the risk matrix and the greatest risk score in each cell recorded as that cell's attribute.

2 VESSEL TRAFFIC

2.1 VESSEL TRAFFIC ANALYSIS

Twelve months of vessel traffic has been analysed throughout the New Zealand Exclusive Economic Zone using data drawn from:

- Terrestrial AIS (Marico and Kordia);
- Satellite AIS (ExactEarth);
- Consultation with maritime authorities and harbour users; and
- Secondary research.

Each vessel was modelled by the type, size, passenger carriage and fuel carriage.

2.2 POTENTIAL IMPACTS

Event trees were produced for each vessel type and each vessel size to give the most likely and worst credible impacts following an incident. These event trees were used to assign a "potential" consequence to each vessel track in the dataset in terms of loss of life, pollution, salvage costs and economic impacts following most likely and worst credible incidents. Most likely and worst credible consequences were combined as a weighted average on the scale of nine most likely to one worst credible.

Each grid cell has the total potential consequence for each of the four categories. Each potential consequence are continuous, for example, from 0 tonnes spilt to 100,000 tonnes spilt.

2.2.1 POTENTIAL LOSS OF LIFE

Loss of life is measured as the total number of fatalities or injured equivalents. To allow comparison between other consequences, one loss of life is given implied cost of averting a fatality (ICAF). Figures derived from the New Zealand Ministry of Transport for 2014 gave a value of a statistical life of approximately 3.98 million NZD (Ministry of Transport, 2014).[2]

[2] Ministry of Transport (2014). Social cost of road crashes and injuries 2014 update. Available online at: http://www.transport.govt.nz/assets/Uploads/Research/Documents/Social-Cost-June-2014-update.pdf.

2.2.2 Potential Pollution

Pollution is measured by the total oil spill sizes in tonnes. The cost of an oil spill (adapted using inflation and USD to NZD exchange rates) is given by the non-linear equation proposed by the International Maritime Organisation as part of MEPC 62 (cited in Psaraftis, 2012)[3]:

$$\text{Spill cost} = \text{NZD } 71500 * \text{Volume (tonnes)}^{0.7233}$$

The equivalent costs for oil spills using this formula are given below:

Spill Size (Tonnes)	Cost
0.1	NZD 13,520
1	NZD 71,499
10	NZD 378,093
100	NZD 1,999,397
1,000	NZD 10,573,019
10,000	NZD 55,911,226
100,000	NZD 295,664,382

Table 1: Spill size costs.

2.2.3 Potential Salvage Costs

Salvage costs are measured as the total cost to remove a wreck or repair a damaged vessel.

2.2.4 Potential Economic Impact

The potential economic impact is the wider economic and societal consequences of an incident and is measured as a cost.

[3] Psaraftis, H.N. (2012). Formal Safety Assessment: an updated review. *Journal of Marine Science and Technology*.

2.3 CONSEQUENCE WEIGHTING

To ensure that loss of life, pollution and salvage/economic costs are compared, a monetary conversion was undertaken to ensure equivalency (see **Section 2.2.1** to **Section 2.2.4**). The monetary values for each consequence were then weighted in contribution to the risk model to reflect societal aversion to risk:

- Loss of Life: 42%;
- Pollution: 38%;
- Economic Impacts: 15%; and
- Salvage Costs: 5%.

The model states that for every dollar spent on salvage, an equivalent loss of life is 8.4 times less desirable, pollution is 7.6 times less desirable and economic costs are 3 times less desirable. Therefore, the prevention of loss of life is the most significant goal of maritime safety, followed by environmental damage from pollution. The impacts to the New Zealand economy are less important than the aforementioned two, but are more important than salvage costs applied to the insurers of a casualty vessel.

The equivalent values using a monetary conversion and model weightings are:

- 1 fatality is equal to;
- 828 tonnes of pollution is equal to;
- 13.97 million NZD of economic impact is equal to; and
- 41.9 million NZD of vessel salvage cost.

3 CAUSATION FACTORS

There are a number of factors which, in combination with inadequate charting coverage, could cause an incident to occur. Each category contains factor weightings and category weightings. Of the categories, charting is weighted as the most important category whilst the availability of mitigation and general bathymetry are rated less important than others. **Section 3.7** contains a comparison of all factors, including the category weightings.

3.1 CHARTING

The following graph demonstrates the components of charting adequacy that contribute towards the quality of charting **(Figure 3).**

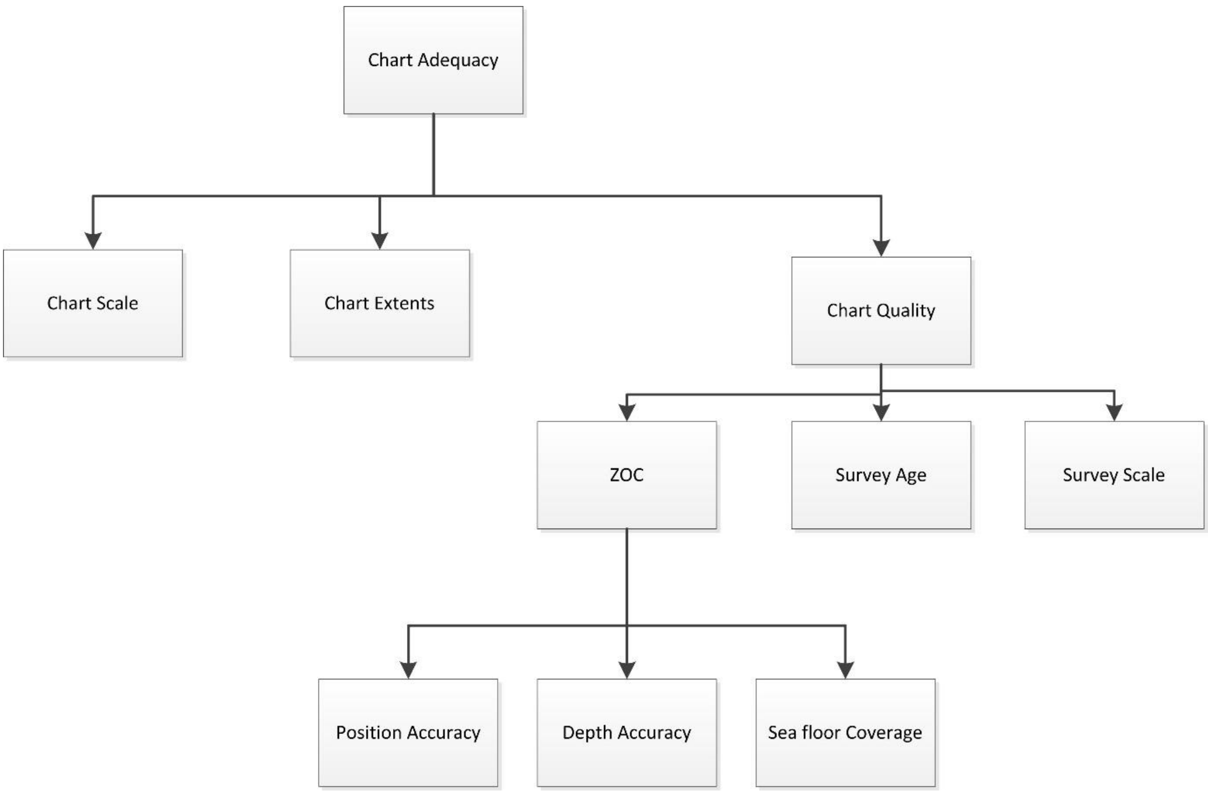


Figure 3: Components of Charting Adequacy

The quality of charting was the principal consideration of this study and therefore forms a prominent part of this model. The quality of charting was measured in three ways. Firstly, the assessed Chart Zone of Confidence (CATZOC) score was used to give a general assessment of the accuracy of charting in an area. The CATZOC on a scale of A to U was measured across the study area and since it includes several useful measures of chart quality, was weighted as the most important factor in the model.

Secondly, the date of the last hydrographic survey was used to judge the age of a chart. Natural change in the sea bed and human action will overtime make nautical charts inaccurate.

Finally, the chart scale and extents compares whether a chart is “fit for purpose”, that is fulfils the role it is designed for measured in terms of the chart scale and the required use scale.

Given that the purpose of this assessment was as a hydrographic risk assessment, the charting category as a whole is rated highly.

3.2 ROUTE CHARACTERISTICS

Route characteristics describe other external factors which may cause a vessel to have an incident. As the available navigable waters decreases around a vessel it becomes more likely that the failure to hold the required course will result in an incident. Route characteristics are measured in three ways; the navigational complexity, the proximity to shallow waters and the average density of traffic in the area.

The navigational complexity of a waterway identifies whether navigation is open (at sea) or constrained (in a port). The proximity to the 15 metre contour describes how likely a large commercial vessel may run aground. Finally as the density of traffic increases, it may cause a vessel to avoid a collision and therefore navigate outside of her planned route.

3.3 METOCEAN

MetOcean conditions are other factors such as wave, wind, tide and visibility which may force a vessel away from a safe route. The prevailing wave and wind conditions are used to describe how exposed a waterway is and therefore the degree of leeway a vessel may experience. Similarly tides and currents are measured and the longwave and surge conditions are identified. Finally, the frequency of poor visibility conditions in an area, which places considerable reliance on the accuracy of nautical charts by a navigator, has been weighted lower than other factors given the rarity of poor visibility in New Zealand’s waters.

3.4 NAVIGATIONAL HAZARDS

Navigational hazards describe localised dangers to vessels such as sea mounts, wrecks, breaking reefs and tidal races or overfalls. These hazards are mapped and the proximity of vessel traffic to these dangers were measured. Vessels which navigate closer to these hazards have a greater risk of an incident than those navigating further away. In terms of weighting large breaking reefs are weighted as the most important hazard whilst seamounts are weighted less important.

3.5 MITIGATION

The availability of other mitigation such as towage, pilotage and vessel monitoring services has an influence on the risks of a waterway. In locations where there is not pilotage, a navigator must place much greater reliance in the quality of charting to determine their passage plan, whereas with a local pilot on board, local knowledge can compensate for poor charting. The presence of absence of pilotage was therefore determined across the study area and is rated highly.

Furthermore, the availability of towage, vessel monitoring and other Aids to Navigation reduces the likelihood of an incident occurring.

3.6 BATHYMETRIC CHANGE

In some locations the seabed is in constant motion and therefore charting should be regularly reviewed. For example, at the mouths of river systems and estuaries, silt is deposited in shifting sand bars and the action of tides and currents can cause significant shifts in their location. The significance of this factor was rated across the study area.

Finally, the action of seismic and volcanic factors may cause sudden changes in sea conditions, the proximity to significant locations of this activity are measured.

3.7 COMPARISON

A ranked comparison of all causation factors between categories is shown in Table 2, below.

Factor	Weighting
Chart Quality	15.0%
Chart Scale and Extents	10.0%
Navigational Complexity	8.8%
Breaking Reefs	6.6%
Pilotage	6.0%
Depth of Water 15m Contour	5.8%
Prevailing Wave/Wind	5.8%
Tides/Current	5.8%
Survey Age	5.0%
Dynamic Seabed - Estuarial	4.5%
Isolated Dangers - Rocks/Wrecks/etc.	4.4%
Charted Tidal Hazards	4.4%
Harbour Risk Mitigation Resources	4.0%
Longwave/Surge	3.9%
Seismic/Volcanic Factors	3.0%
Traffic Density	2.9%
Sea Mounts	2.2%
Poor Visibility	1.9%

Table 2: Ranked Causation Factors

4 CONSEQUENCE FACTORS

Each incident has the potential for a consequence (measured in **Section 2**) and specific local conditions which may make the impacts much greater, these conditions represent consequence factors.

4.1 LOSS OF LIFE

The potential for loss of life in an incident as derived from the traffic analysis are multiplied by a response complexity rating which provides a judgement on the possibility of enacting a Search and Rescue exercise. Certain locations, with dedicated SAR assets or other available vessels, are much less likely to have high loss of life events than an equivalent incident in a remote location. This response complexity factor is judged as a percentage and no weighting was required at this stage.

4.2 POLLUTION

The potential oil outflow of an incident depends on the size and type of a vessel but the environmental and societal impact that oil may cause once it reaches the water can be considerable if certain factors are present.

The proximity of an oil spill to world heritage sites, marine reserves and coastal reserves were used to weight the environmental significance of different sites using their formal designations. Other wetland resources not formally designated are mapped to consider a variety of ecosystems.

The proximity to important economic sites such as aquaculture, fishing grounds and shellfish harvest sites were used to judge the impact on the fishing industry following an incident. Furthermore, the locations of significant tourist sites including beaches, waterfronts, dive sites and other attractions were mapped. Finally, sites of important recreational and social amenity value were mapped to include waterfronts, residential sites and recreational activities such as sailing.

Cultural sites and locations with important historical value were mapped and the proximity of an oil spill to these locations are taken into account.

4.3 SALVAGE COSTS

The potential salvage costs of a vessel are dependent on the type and size of a vessel in an incident; however certain locations may make salvage impossible. The possibility of salvaging a vessel without a total loss or minimising damage was judged taking into account the local conditions of each location. As this consequence contains only a single factor no weighting was applied at this stage.

4.4 ECONOMIC IMPACTS

The final consequence category is for economic impacts not related to the previous three. The first factors considered relate to the proximity of an incident to an important shipping channel or port access fairway which may become blocked following an incident having significant impacts on port operations. The importance of berths and other critical infrastructure were rated in terms of their economic contribution, namely the TEU or tonnage throughput, to assess the economic impact a casualty vessel would have if the berth was denied for normal operations. In terms of weighting, an access channel is rated highly compared to an individual berth as if blocked it would deny all berths.

Further impacts include reputational factors whereby an incident may dissuade future traffic from transiting to that location, tourist site or port. The proximity to sites of high and moderate economic contribution which may have their reputations damaged by an incident were assessed; these are weighted according to their importance. Furthermore, the proximity to significant cruise ship stops are considered where an incident may dissuade other operators from using that route.

Finally, the proximity of an incident to major economic infrastructure such as pipelines, oil and gas facilities and cable routes which may be impacted by an incident were mapped. The reliance of the economy of New Zealand to these infrastructures has given this factor the highest rating.

5 MODEL COMBINATION

5.1 SCORING

Each risk criteria factor was scored on a scale of 0 (absence) to 5 given the risk matrix presented in this report. All grid cells used in the analysis have a score for each of the risk factors.

5.2 WEIGHTING

Weightings between the risk factors are also provided in the risk matrix and they judge the relative significance of factor amongst others.

5.3 CATEGORY VALUES

The traffic, causation and consequence impact factors produce nine scores between 0 and 5.

- Traffic:
  - The highest consequence score (in terms of monetary equivalent) is identified and used as the maximum score of 5. All potential scores are then transformed to a 0 to 5 continuous scale; and
  - This produces 4 potential consequences scores for life/pollution/salvage/economic between 0 and 5.
- Causation:
  - The cell scoring for each factor are multiplied by the factor weighted and the sum calculated to give a single cell causation score between 0 and 5.
- Consequence:
  - Response complexity and wreck removal complexity are single cell scores of between 1 and 5;
  - Environmental significance and economic impact are calculated by multiplying the factor scores by the factor weights and summed.
  - This produces 4 impact scores between 0 and 5.

5.4 CUMULATIVE MODEL

The final model is the total of the four consequences multiplied by the causation factor. In each of the four consequences, the potential is 25% of the model, the causation factor is 25% of the model and the consequence factor is 50% of the model. Each consequence has been weighted in **Section 2**.

The total score is the summation of:

- Potential loss of life * response complexity * causation factor * 0.42;
- Potential pollution * environmental significance * causation factor * 0.38;
- Potential salvage costs * salvage complexity * causation factor * 0.05; and
- Potential economic impact * economic significance * causation factor * 0.15.

Given the variable cell sizes and the traffic therefore represented as a density (see **Section 1.2**); the final result is a risk map with each cell showing a hydrographic risk score with each cell directly comparable.

5.5 WORKED EXAMPLE

This worked example takes a single grid cell to show how the final risk score was derived. This grid cell contained:

- 4 potential consequence scores from traffic, divided by the area of the cell, transformed on a scale of 0 to 5 determined by the highest model value;
- 18 causation factor scores between 0 and 5;
- 16 consequence scores between 0 and 5.

The weighting matrix was applied to multiply each factor scoring by its weighting (i.e. a factor score of 3 weighted as 10% becomes 0.3). The summation of each category was given to provide the following values:

- 4 potential consequence scores from traffic, divided by the area of the cell, transformed on a scale of 0 to 5 determined by the highest model value;
- 1 causation factor score between 0 and 5; and
- 4 consequence factor scores:
  - Unweighted response complexity (0 to 5);
  - Unweighted salvage complexity (0 to 5);
  - Weighted environmental significance (0 to 5); and
  - Weighted economic significance (0 to 5).

Taking the example of loss of life, the model therefore has a potential consequence (0 to 5), causation factor (0 to 5), consequence factor score (0 to 5) and the weighting of loss of life in terms of the cumulative model (42%). The cell loss of life score becomes potential consequence multiplied by causation factor, giving a score between 0 and 25. If divided by 5 this score transforms back to a 0 to 5 scale. The consequence factor score multiplied by this combined likelihood score ensures that consequence makes 50% of the risk. This combined risk score for loss of life was multiplied by the weighting of 42%. Each consequence was calculated this way and the summation gave a final risk score between 0 and 5.

6 CHARTING BENEFIT MODEL

6.1 INTRODUCTION

The figure below outlines the components of the charting benefit model.

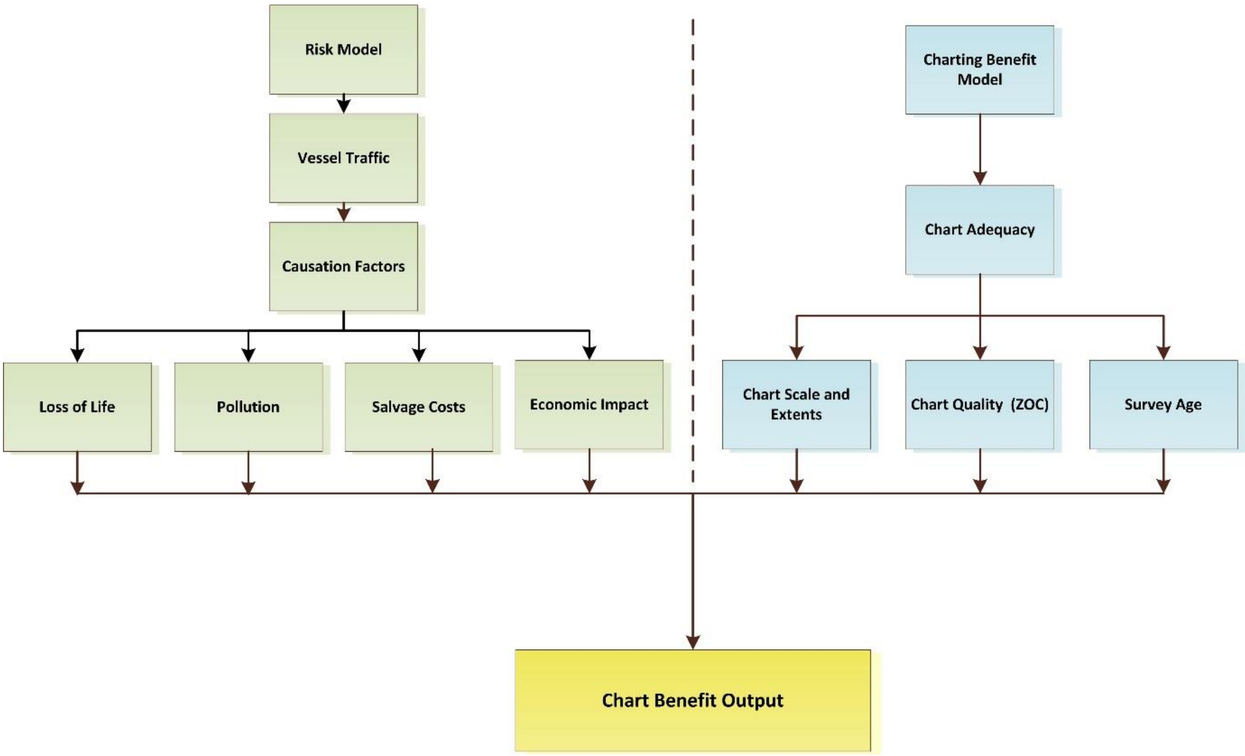


Figure 4: Charting Benefit Model Outline

Whilst the risk model measures the risk across the New Zealand EEZ, the charting benefit model (CBM) identified those areas that would significantly improve by charting improvements. The improvements can take the form of hydrographic surveys and/or navigational purpose scale upgrades.

The CBM functions the same way as the risk model while applying a set of charting criteria with suitable standards of chart adequacy across the study area.

Using charted depths as a benchmark, the requirements for a charting benefit were drawn based on expert judgement and hydrographic standards. The following sub-section explains the parameters for the input scores of the charting criteria.

6.2 PARAMETERS

Three charting criteria were used to effectively measure the benefit. These are the following:

- Chart Scales and Extents (LINZ Navigational Purpose Scale Ranges – see **Table 3**);
- Chart Quality (ZOC rating) ;
- Survey Age (the year of a hydrographic survey completed).

Subfield	Navigation Purpose	LINZ Scale Ranges
1	Overview	>=3,000,001
2	General	800,001 – 3M
3	Coastal	80,001 – 800K
4	Approach	25,001 – 80K
5	Harbour	8,001 – 25K
6	Berthing	>=8K

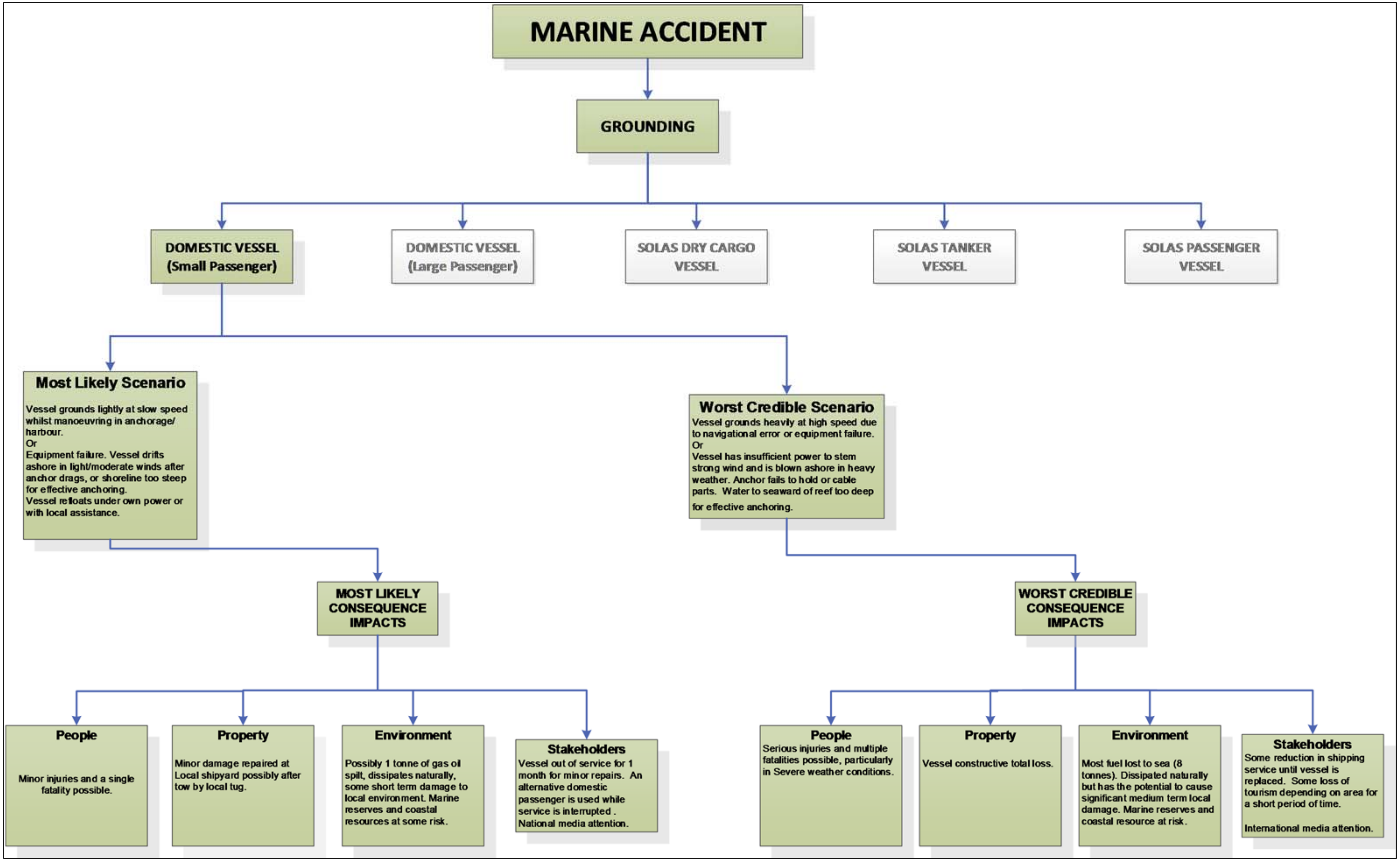
Table 3: LINZ Navigational Purpose Scale Ranges for Paper Charts

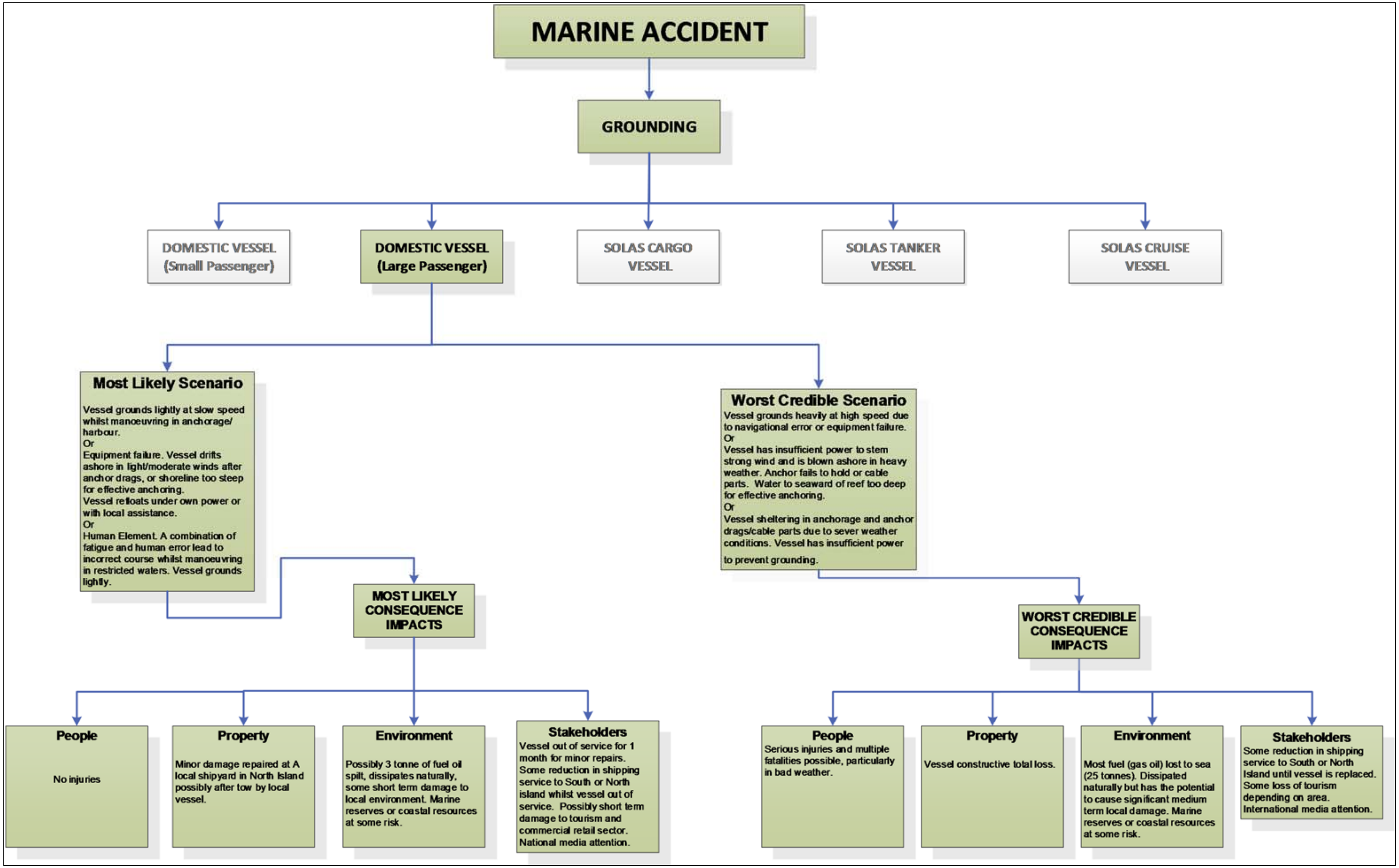
In order to properly estimate the benefit, a set of parameters have been established (see Table 4). Setting a suitable standard for every charting criterion in the respective depth category, the charting benefit results were compared against those of the risk model. In this case a charting benefit output was produced to recommend areas of charting improvements. The output was categorised into Negative, Marginal (ALARP), Moderate, and Positive.

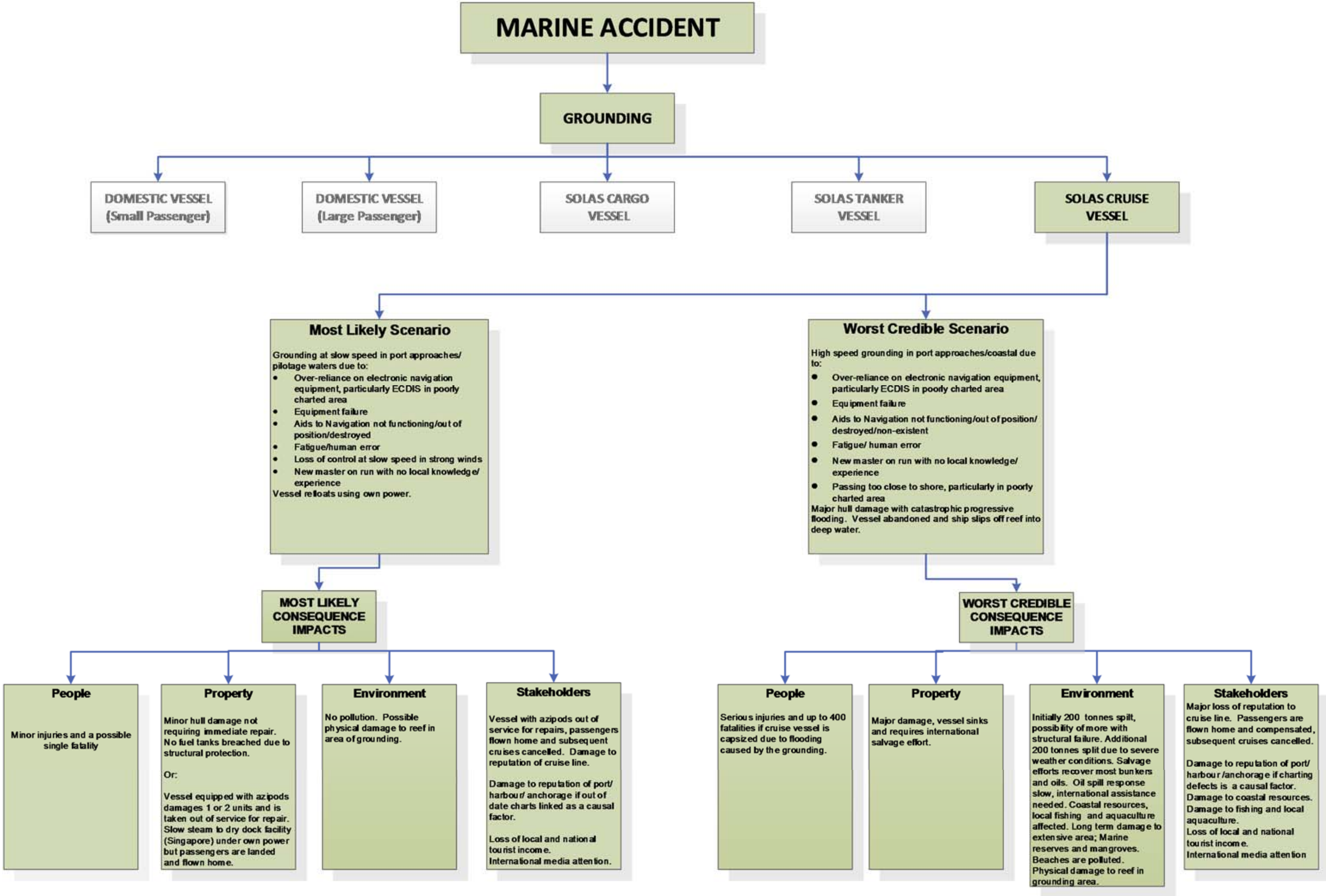
Charted Depth	Chart Scale and Extents	Chart Quality (ZOC)	Survey Age
0m - 40	All Chart Scales within the boundaries of Coastal charts.	A1 or A2	Up to 10 years
40m – 500m		B	Up to 10 years
>500m		C/D	Up to 20 years

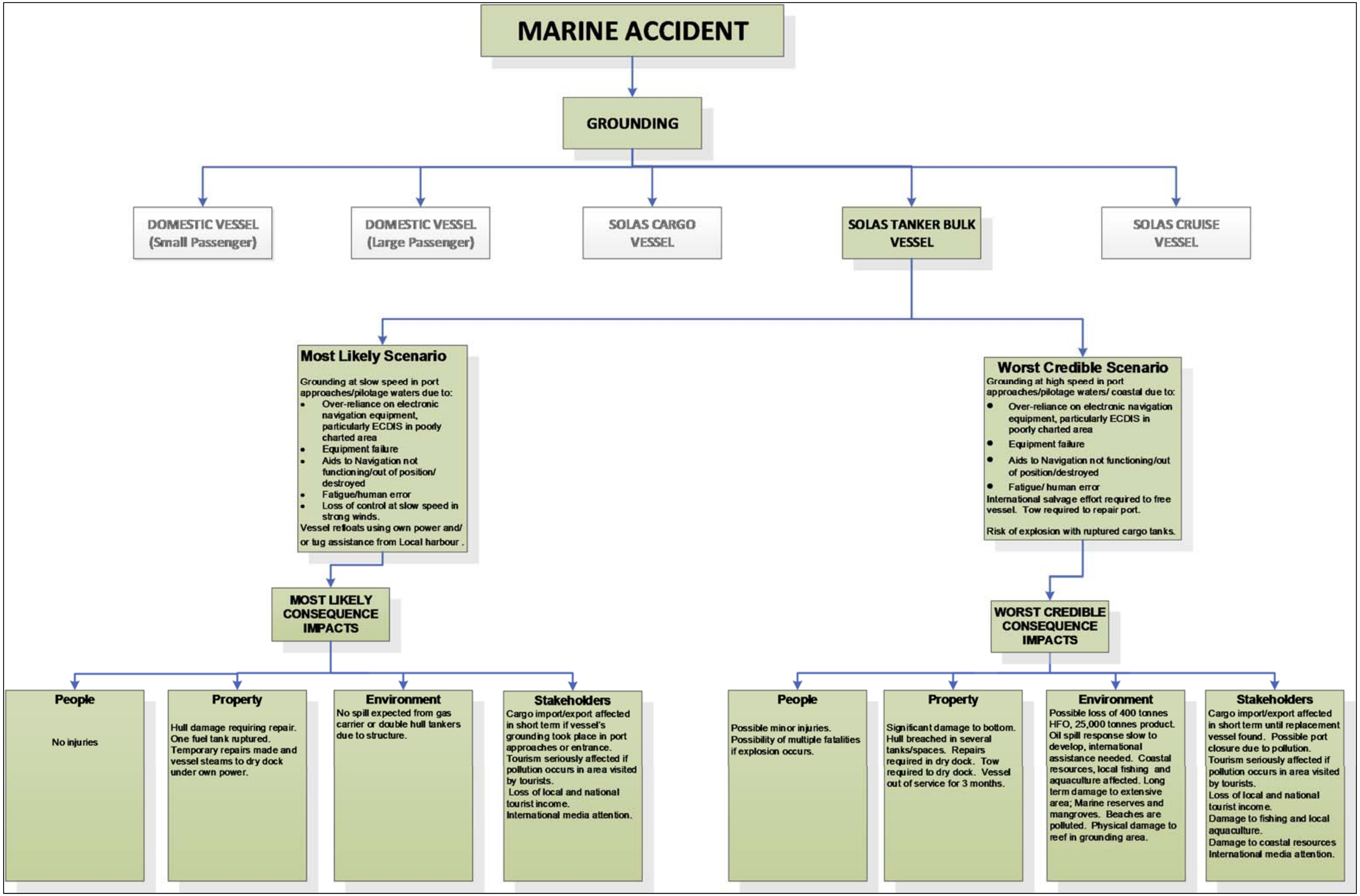
Table 4: Charting Benefit Parameters.

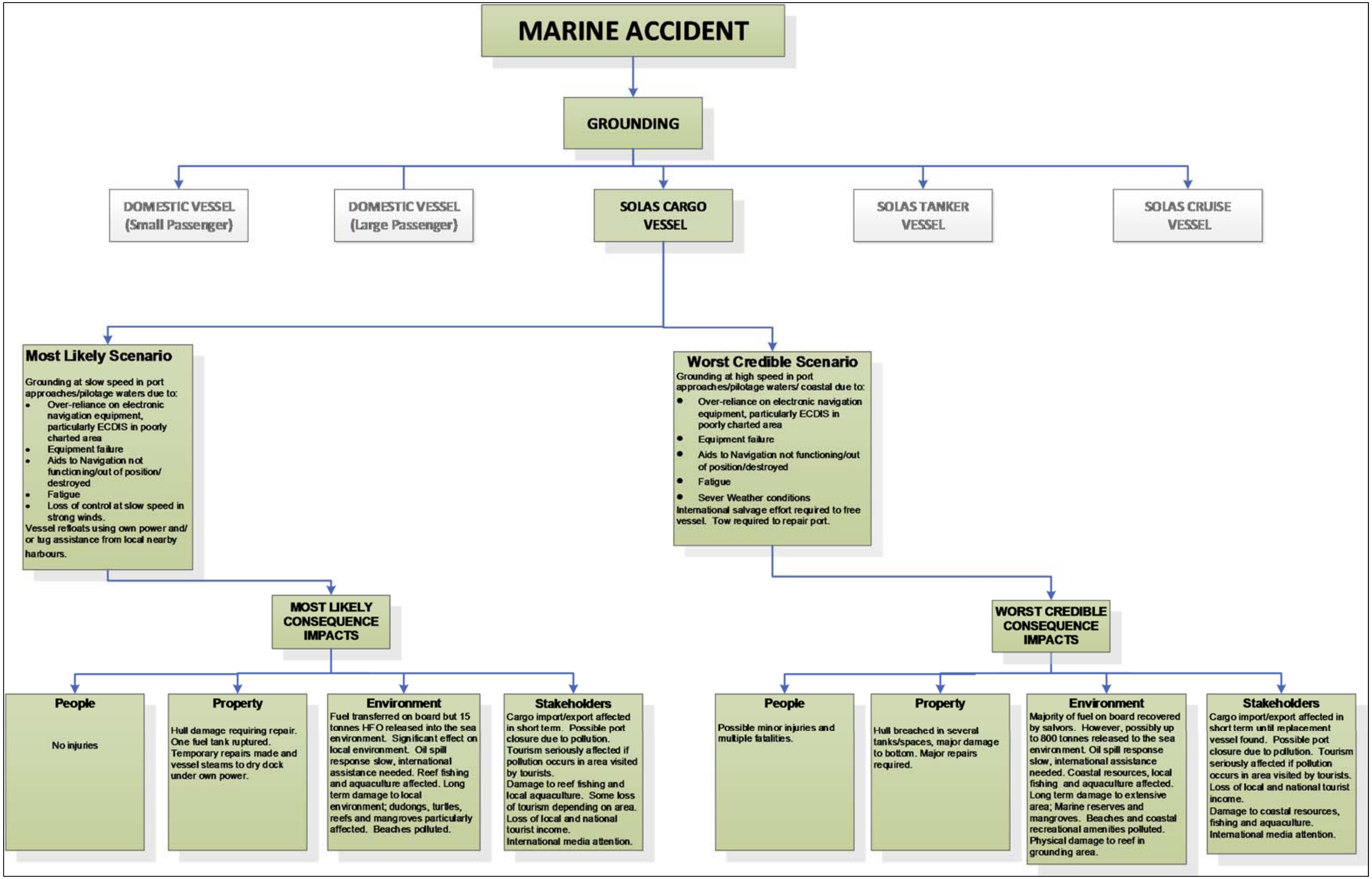
Annex B Event Trees


MARINE ACCIDENT
GROUNDING
DOMESTIC VESSEL (Small Passenger)
DOMESTIC VESSEL (Large Passenger)
SOLAS DRY CARGO VESSEL
SOLAS TANKER VESSEL
SOLAS PASSENGER VESSEL
Most Likely Scenario
Vessel grounds lightly at slow speed whilst manoeuvring in anchorage/ harbour. Or Equipment failure. Vessel drifts ashore in light/moderate winds after anchor drags, or shoreline too steep for effective anchoring. Vessel refloats under own power or with local assistance.
Worst Credible Scenario
Vessel grounds heavily at high speed due to navigational error or equipment failure. Or Vessel has insufficient power to stem strong wind and is blown ashore in heavy weather. Anchor fails to hold or cable parts. Water to seaward of reef too deep for effective anchoring.
MOST LIKELY CONSEQUENCE IMPACTS
WORST CREDIBLE CONSEQUENCE IMPACTS
People
Minor injuries and a single fatality possible.
Property
Minor damage repaired at Local shipyard possibly after tow by local tug.
Environment
Possibly 1 tonne of gas oil spilt, dissipates naturally, some short term damage to local environment. Marine reserves and coastal resources at some risk.
Stakeholders
Vessel out of service for 1 month for minor repairs. An alternative domestic passenger is used while service is interrupted. National media attention.
People
Serious injuries and multiple fatalities possible, particularly in Severe weather conditions.
Property
Vessel constructive total loss.
Environment
Most fuel lost to sea (8 tonnes). Dissipated naturally but has the potential to cause significant medium term local damage. Marine reserves and coastal resource at risk.
Stakeholders
Some reduction in shipping service until vessel is replaced. Some loss of tourism depending on area for a short period of time.
International media attention.


MARINE ACCIDENT
GROUNDING
DOMESTIC VESSEL (Small Passenger)
DOMESTIC VESSEL (Large Passenger)
SOLAS CARGO VESSEL
SOLAS TANKER VESSEL
SOLAS CRUISE VESSEL
Most Likely Scenario
Vessel grounds lightly at slow speed whilst manoeuvring in anchorage/ harbour.
Or
Equipment failure. Vessel drifts ashore in light/moderate winds after anchor drags, or shoreline too steep for effective anchoring.
Vessel refloats under own power or with local assistance.
Or
Human Element. A combination of fatigue and human error lead to incorrect course whilst manoeuvring in restricted waters. Vessel grounds lightly.
Worst Credible Scenario
Vessel grounds heavily at high speed due to navigational error or equipment failure.
Or
Vessel has insufficient power to stem strong wind and is blown ashore in heavy weather. Anchor fails to hold or cable parts. Water to seaward of reef too deep for effective anchoring.
Or
Vessel sheltering in anchorage and anchor drags/cable parts due to sever weather conditions. Vessel has insufficient power to prevent grounding.
MOST LIKELY CONSEQUENCE IMPACTS
WORST CREDIBLE CONSEQUENCE IMPACTS
People
No injuries
Property
Minor damage repaired at A local shipyard in North Island possibly after tow by local vessel.
Environment
Possibly 3 tonne of fuel oil spilt, dissipates naturally, some short term damage to local environment. Marine reserves or coastal resources at some risk.
Stakeholders
Vessel out of service for 1 month for minor repairs. Some reduction in shipping service to South or North island whilst vessel out of service. Possibly short term damage to tourism and commercial retail sector. National media attention.
People
Serious injuries and multiple fatalities possible, particularly in bad weather.
Property
Vessel constructive total loss.
Environment
Most fuel (gas oil) lost to sea (25 tonnes). Dissipated naturally but has the potential to cause significant medium term local damage. Marine reserves or coastal resources at some risk.
Stakeholders
Some reduction in shipping service to South or North Island until vessel is replaced. Some loss of tourism depending on area. International media attention.


MARINE ACCIDENT
GROUNDING
DOMESTIC VESSEL (Small Passenger)
DOMESTIC VESSEL (Large Passenger)
SOLAS CARGO VESSEL
SOLAS TANKER VESSEL
SOLAS CRUISE VESSEL
Most Likely Scenario
Grounding at slow speed in port approaches/ pilotage waters due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/destroyed
• Fatigue/human error
• Loss of control at slow speed in strong winds
• New master on run with no local knowledge/ experience
Vessel refloats using own power.
Worst Credible Scenario
High speed grounding in port approaches/coastal due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/ destroyed/non-existent
• Fatigue/ human error
• New master on run with no local knowledge/ experience
• Passing too close to shore, particularly in poorly charted area
Major hull damage with catastrophic progressive flooding. Vessel abandoned and ship slips off reef into deep water.
MOST LIKELY CONSEQUENCE IMPACTS
WORST CREDIBLE CONSEQUENCE IMPACTS
People
Minor injuries and a possible single fatality
Property
Minor hull damage not requiring immediate repair. No fuel tanks breached due to structural protection.
Or:
Vessel equipped with azipods damages 1 or 2 units and is taken out of service for repair. Slow steam to dry dock facility (Singapore) under own power but passengers are landed and flown home.
Environment
No pollution. Possible physical damage to reef in area of grounding.
Stakeholders
Vessel with azipods out of service for repairs, passengers flown home and subsequent cruises cancelled. Damage to reputation of cruise line.
Damage to reputation of port/ harbour/ anchorage if out of date charts linked as a causal factor.
Loss of local and national tourist income.
International media attention.
People
Serious injuries and up to 400 fatalities if cruise vessel is capsized due to flooding caused by the grounding.
Property
Major damage, vessel sinks and requires international salvage effort.
Environment
Initially 200 tonnes spilt, possibility of more with structural failure. Additional 200 tonnes split due to severe weather conditions. Salvage efforts recover most bunkers and oils. Oil spill response slow, international assistance needed. Coastal resources, local fishing and aquaculture affected. Long term damage to extensive area; Marine reserves and mangroves. Beaches are polluted. Physical damage to reef in grounding area.
Stakeholders
Major loss of reputation to cruise line. Passengers are flown home and compensated, subsequent cruises cancelled.
Damage to reputation of port/ harbour/anchorage if charting defects is a causal factor.
Damage to coastal resources.
Damage to fishing and local aquaculture.
Loss of local and national tourist income.
International media attention


MARINE ACCIDENT
GROUNDING
DOMESTIC VESSEL (Small Passenger)
DOMESTIC VESSEL (Large Passenger)
SOLAS CARGO VESSEL
SOLAS TANKER BULK VESSEL
SOLAS CRUISE VESSEL
Most Likely Scenario
Grounding at slow speed in port approaches/pilotage waters due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/ destroyed
• Fatigue/human error
• Loss of control at slow speed in strong winds.
Vessel refloats using own power and/ or tug assistance from Local harbour .
Worst Credible Scenario
Grounding at high speed in port approaches/pilotage waters/ coastal due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/destroyed
• Fatigue/ human error
International salvage effort required to free vessel. Tow required to repair port.
Risk of explosion with ruptured cargo tanks.
MOST LIKELY CONSEQUENCE IMPACTS
WORST CREDIBLE CONSEQUENCE IMPACTS
People
No injuries
Property
Hull damage requiring repair. One fuel tank ruptured. Temporary repairs made and vessel steams to dry dock under own power.
Environment
No spill expected from gas carrier or double hull tankers due to structure.
Stakeholders
Cargo import/export affected in short term if vessel's grounding took place in port approaches or entrance. Tourism seriously affected if pollution occurs in area visited by tourists. Loss of local and national tourist income. International media attention.
People
Possible minor injuries. Possibility of multiple fatalities if explosion occurs.
Property
Significant damage to bottom. Hull breached in several tanks/spaces. Repairs required in dry dock. Tow required to dry dock. Vessel out of service for 3 months.
Environment
Possible loss of 400 tonnes HFO, 25,000 tonnes product. Oil spill response slow to develop, international assistance needed. Coastal resources, local fishing and aquaculture affected. Long term damage to extensive area; Marine reserves and mangroves. Beaches are polluted. Physical damage to reef in grounding area.
Stakeholders
Cargo import/export affected in short term until replacement vessel found. Possible port closure due to pollution. Tourism seriously affected if pollution occurs in area visited by tourists. Loss of local and national tourist income. Damage to fishing and local aquaculture. Damage to coastal resources International media attention.


MARINE ACCIDENT
GROUNDING
DOMESTIC VESSEL (Small Passenger)
DOMESTIC VESSEL (Large Passenger)
SOLAS CARGO VESSEL
SOLAS TANKER VESSEL
SOLAS CRUISE VESSEL
Most Likely Scenario
Grounding at slow speed in port approaches/pilotage waters due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/ destroyed
• Fatigue
• Loss of control at slow speed in strong winds.
Vessel refloats using own power and/ or tug assistance from local nearby harbours.
Worst Credible Scenario
Grounding at high speed in port approaches/pilotage waters/ coastal due to:
• Over-reliance on electronic navigation equipment, particularly ECDIS in poorly charted area
• Equipment failure
• Aids to Navigation not functioning/out of position/destroyed
• Fatigue
• Sever Weather conditions
International salvage effort required to free vessel. Tow required to repair port.
MOST LIKELY CONSEQUENCE IMPACTS
WORST CREDIBLE CONSEQUENCE IMPACTS
People
No injuries
Property
Hull damage requiring repair. One fuel tank ruptured. Temporary repairs made and vessel steams to dry dock under own power.
Environment
Fuel transferred on board but 15 tonnes HFO released into the sea environment. Significant effect on local environment. Oil spill response slow, international assistance needed. Reef fishing and aquaculture affected. Long term damage to local environment; dudongs, turtles, reefs and mangroves particularly affected. Beaches polluted.
Stakeholders
Cargo import/export affected in short term. Possible port closure due to pollution. Tourism seriously affected if pollution occurs in area visited by tourists. Damage to reef fishing and local aquaculture. Some loss of tourism depending on area. Loss of local and national tourist income. International media attention.
People
Possible minor injuries and multiple fatalities.
Property
Hull breached in several tanks/spaces, major damage to bottom. Major repairs required.
Environment
Majority of fuel on board recovered by salvors. However, possibly up to 800 tonnes released to the sea environment. Oil spill response slow, international assistance needed. Coastal resources, local fishing and aquaculture affected. Long term damage to extensive area; Marine reserves and mangroves. Beaches and coastal recreational amenities polluted. Physical damage to reef in grounding area.
Stakeholders
Cargo import/export affected in short term until replacement vessel found. Possible port closure due to pollution. Tourism seriously affected if pollution occurs in area visited by tourists. Loss of local and national tourist income. Damage to coastal resources, fishing and aquaculture. International media attention.

Annex C Hydrographic Risk Criteria Matrix

			0	1	2	3	4	5	Rating	Category Weighting	Model Weighting	Overall Weighting
Traffic						*CONTINUOUS SCALES*						
		Potential Loss of Life		Insignificant	Low	Moderate	High	Catastrophic		42.0%		25%
		Potential Oil Outflow		Insignificant	Low	Moderate	High	Catastrophic		38.0%		
		Vessel Damage + Salvage Costs		Insignificant	Low	Moderate	High	Catastrophic		5.0%		
		Economic Costs		Insignificant	Low	Moderate	High	Catastrophic		15.0%		
						LIKELIHOOD SCALES						
Causation Risk Criteria	Charting	Chart Quality		A	B	C	D	U	3	30.0%	15.00%	25%
		Survey Age		<5 years	5-10 years	10-20 years	20-30 years	>30 years	1		5.00%	
		Chart Scale and Extents		Excellent	Good	Moderate	Poor	Unacceptable	2		10.00%	
	Route Characteristics	Navigational Complexity		Open Sea >10nm	Offshore Navigation (5-10nm)	Coastal Navigation (1-5nm)	Port Approaches	Constrained Navigation (<1nm)	3	17.5%	8.75%	
		Depth of Water 15m Contour	>10nm	5-10nm	2.5-5nm	1.5-2.5nm	1-1.5nm	Within 1nm	2		5.83%	
		Traffic Density		Insignificant	Low	Moderate	High	Catastrophic	1		2.92%	
	MetOcean	Prevailing Wave/Wind		Sheltered at Most Times	Mainly Sheltered	Moderate Exposure	Mainly Exposed	Exposed on Most Days	3	17.5%	5.83%	
		Tides/Current	Open Sea	1-2kts	2-3kts	3-4kts	4-5kts	>5kts	3		5.83%	
		Longwave/Surge		Very Unlikely	Unlikely	Occasional	Often Poor	Frequent	2		3.89%	
		Poor Visibility		Very Unlikely	Unlikely	Occasional	Often Poor	Frequent	1		1.94%	
	Navigational Hazards	Sea Mounts	>10nm	5-10nm	2.5-5nm	1.5-2.5nm	1-1.5nm	Within 1nm	1	17.5%	2.19%	
		Isolated Dangers - Rocks/Wrecks/etc.	>2.5nm	2.5-2nm	1.5-2	1-1.5nm	500m-1nm	<500m	2		4.38%	
		Charted Tidal Hazards	>2.5nm	2.5-2nm	1.5-2	1-1.5nm	500m-1nm	<500m	2		4.38%	
		Breaking Reefs	>10nm	5-10nm	2.5-5nm	1.5-2.5nm	1-1.5nm	Within 1nm	3		6.56%	
	Mitigation	Harbour Risk Mitigation Resources		Available				Absent	2	10.0%	4.00%	
		Pilotage		Pilotage				No Pilotage	3		6.00%	
	Bathymetry	Dynamic Seabed - Estuarial		Insignificant	Low	Moderate	High	Significant	3	7.5%	4.50%	
		Seismic/Volcanic Factors	>10nm	5-10nm	2.5-5nm	1.5-2.5nm	1-1.5nm	Within 1nm	2		3.00%	
						CONSEQUENCE SCALES						
Consequence Risk Criteria	Loss of Life	Response Complexity		100.0%	102.5%	105.0%	107.5%	110%	N/A	N/A		50%
	Property	Salvage Complexity		100.0%	102.5%	105.0%	107.5%	110%	N/A	N/A		
	Environmental Impact	Formal Reserves - World Heritage	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	3	N/A	17.65%	
		Marine Reserves	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2.5		14.71%	
		Coastal (Sensitive Resources)	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		11.76%	
		Wetland Resources	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	1.5		8.82%	
		Aquaculture/Fishing Grounds/Shellfish Harvest Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		11.76%	
		Tourism	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		11.76%	
		Cultural (Iwi)/Treaty History Sites	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		11.76%	
		Recreational/Social Amenity	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		11.76%	
	Economic Impact	Port Access Channels	>2.5nm	2.5-2nm	1.5-2nm	1 to 1.5nm	500m to 1nm	<500m	3	N/A	24.00%	
		Critical Infrastructure (Berths) - Economic Contribution	Absent	Very Low	Low	Moderate	High	Critical	1		8.00%	
		Proximity to Sites of High Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		16.00%	
		Proximity to Sites of Moderate Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	1		8.00%	
		Proximity to Sites of Low Economic Contribution	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	0.5		4.00%	
		Cruise Ship Stops	>20nm	10-20nm	5-10nm	2.5-5nm	1-2.5nm	<1nm	2		16.00%	
		Pipelines/Cables	>10nm	5-10nm	2.5-5nm	1.5-2.5nm	1-1.5nm	Within 1nm	3		24.00%	

Annex D Stakeholders

PORT AUTHORITIES, HARBOUR MASTERS, LOCAL CONTACTS		
Northland	Northport	Chief Executive Officer Terminal Facilities Manager
	Northland Regional Council	Harbour Master, Deputy Harbour Master Coopers Beach, Warden for Harbour Master
	Refining NZ	Business Opportunities Manager Asset Manager, Off Plots
	Dive Tutukaka	Director
	Explore Group, Paihia	Office Manager
	Fullers Group, Paihia	Manager
Auckland	Ports of Auckland Ltd	Marine Manager/Pilots Hydrographic surveyor
	Auckland Transport	Harbour Master, Deputy Harbour Master
	Fullers Group Ltd	Commercial Analyst
	ISS McKay Ltd	National Manager, Cruise Services Cruise Operations Manager
	Sanford Ltd, Auckland	
Waikato	Environment Waikato	Navigation Safety Manager, Harbour Masters Whitianga, Coromandel
Bay of Plenty	Port of Tauranga Ltd	Operations Manager, Pilots
	Bay of Plenty Regional Council	Harbour Master, Deputy Harbour Master, Maritime Officer
	Sanford Ltd	Vessel Coordinator
	Tauranga Marina Society	Manager
	Tauranga Bridge Marina	Manager
	Skookum Ferries	
Gisborne	Port of Gisborne	Marine Manager, Pilots
	Gisborne DC	Harbour Master Pollution/Planning/GIS
Hawke's Bay	Hawkes Bay Regional Council	Harbour Master GIS/Planning Pollution Response
	Port of Napier	Marine Manager, Pilots Operations

PORT AUTHORITIES, HARBOUR MASTERS, LOCAL CONTACTS		
Manawatu-Wanganui	Wanganui Port	Marine Manager Port Operations
Wellington	Greater Wellington Regional Council	Harbour Master, Deputy Harbour Master
	Centreport Ltd	Marine Manager, Pilots
Taranaki	Port Taranaki	Marine Services, Pilots
Tasman	Tasman District Council	Environment, GIS
Nelson	Port Nelson	Harbour Master & Operations
	Marina Manager	
Marlborough	Port of Marlborough	Port Manager, Pilots
	Marlborough Regional Council	Harbour Master, Deputy Harbour Master
Canterbury	Environment Canterbury	Regional Harbour Master, Deputy Harbour Master
	Lyttelton Port Company	Pilots, Engineering Services
	Prime Port	Operations
Otago	Port Otago Ltd	Marine Services
	Otago Regional Council	Corporate Services
Southland	Environment Southland	Harbour Master
	South Port NZ Ltd	Port Operations Manager
West Coast	Port of Greymouth	Harbour Supervisor
	Westport Harbour	Port Manager/ Harbour Master

INDUSTRY GROUPS
Coastguard NZ and local Volunteer Coastguard Units
NZ Shipping Federation
Marina Association of NZ

STATE SECTOR
Department of Conservation
Ministry for the Environment
Ministry of Primary Industries
NZ Customs Service
Statistics NZ
MPI