Western Australia

Marine Oil Pollution Risk Assessment

Swan Zone Report

Prepared for Department of Transport

by Navigatus Consulting

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Interactive web map application: http://wamopra.navigatusconsulting.com/login

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  - Appendix A – Exposure Results by Category
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- WAMOPRA Midwest Zone Report (*in preparation*)
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1. Introduction

1.1. Overview

The Western Australian Department of Transport (DoT) is currently running a programme of work looking at matters around marine oil spills. One component of the work is the Western Australia Marine Oil Pollution Risk Assessment (WAMOPRA).

The WAMOPRA is being undertaken in two stages. In Stage One, Navigatus undertook a preliminary state-wide exposure assessment. Stage Two builds on the work developed in Stage One. It consists of specific zone-by-zone assessments and involves incorporating protection priorities and navigational hazard to create a full risk profile.

This document should be considered a companion report to the WAMOPRA web map application: http://wamopra.navigatusconsulting.com/. It summarises the context, methodology and results for the Swan Risk Assessment Zone. The other zones are: Kimberley, Pilbara, Midwest, South West and South Coast.

1.2. Programme Background

The purpose of the overall WAMOPRA programme is to build an assessment of the oil spill risk in Western Australian State waters. This assessment considers regional, national and international data for maritime activity and marine oil spills, current and future levels of activity and protection priorities including environmental sensitivities.

To undertake the WAMOPRA, DoT has commissioned two consultancies. Navigatus Consulting Limited is engaged to collect and analyse information on potential marine oil pollution exposure and build a risk model. Navigatus has special expertise in this field and has undertaken similar work in Victoria and New Zealand (Navigatus 2015).

The second consultant, Advisian, is collecting environmental data to identify protection priorities in the event of a marine oil spill. Protection Priority data is fed into the risk model developed by Navigatus to create a picture of oil spill risk including likelihood and consequence.

The results will guide oil spill contingency planning and will enable future resource allocations for oil spill response to take account of the level of identified risk. The main purpose of the risk profile is to inform:

- Decisions about resource allocation.
- Identification of areas where management is required to reduce risk.
- Evaluation of whether there is adequate spill response capability in areas of high risk.

Other requirements include:

- Fulfil obligations under WestPlan MOP.
- Ensure Western Australia is up to date with world standards in oil spill response.
- Complement the Oil Spill Response Atlas as a decision-making tool.

2. Scope

2.1. Swan Zone

This report summarises the context, methodology and results for the Swan Risk Assessment Zone. It builds on the work undertaken in the preliminary state-wide assessment. The geographical extents of the Swan zone shoreline are shown in Figure 2.1 along with the other zones.

Figure 2.1 - Marine Oil Pollution Risk Assessment Zones

The primary output of this assessment is the web map application located at: http://wamopra.navigatusconsulting.com. GIS attribute tables are also held by DoT for use in internal systems. This report is a companion report to the website. Outputs in this report are in the form of heat maps, charts and tables.

2.2. Report Outline

The remainder of this report is structured as follows:

- **Context** – a brief overview of the contextual background informing the WAMOPRA. This includes shipping trends, the current state of the offshore petroleum industry and discussion of short and long-term scenarios.
- **Data Sources** – a summary of the data sources used in the WAMOPRA. As the Swan zone report builds on the preliminary state-wide assessment some data sources are already discussed in the Stage One report. In these cases a shorter summary is provided and the reader is referred to the Stage One report.
- **Methodology** – a summary of the methodology used to develop the WAMOPRA. As with the data sources section there are elements of the methodology, which are covered in the Stage One report. In these cases a shorter summary is provided and the reader is referred to the Stage One report.
- **Results** – a presentation of the various results produced by the WAMOPRA:
  - *Exposure* – outputs relating to exposure, i.e. the expected amount of oil in a given shoreline or sea location. Includes breakdown by vessel types and spill sizes. Exposure is combined with protection priorities to produce the Swan zone risk profile (Section 6.2).
  - *Protection Priorities* – the primary profile shown is a heat map of the overall protection priority ratings for the Swan zone as provided by Advisian. These ratings are combined with exposure to produce the Swan risk profile (Section 6.3).
  - *Risk Profile* – the primary output shown is a heat map that combines exposure and protection priorities to form a full risk profile. The risk profile is the primary risk output in this report and is the synthesis of all inputs into the WAMOPRA (Section 6.4).
  - *Swan Zone Summary* – a short section on the Swan zone. A table is presented which shows, for each of the shoreline cells: cell name, overall risk rating, protection priorities ratings, a brief description of the overall protection priority rating and a brief comment on the key drivers of shoreline exposure. The key benefit of these tables is allowing trends in risk drivers to be seen across multiple cells (Section 6.5).
- **Conclusion** – a summary of the key findings, including an interpretation of the results with a focus key risk areas and risk drivers.

3. Context

3.1. Level of activity

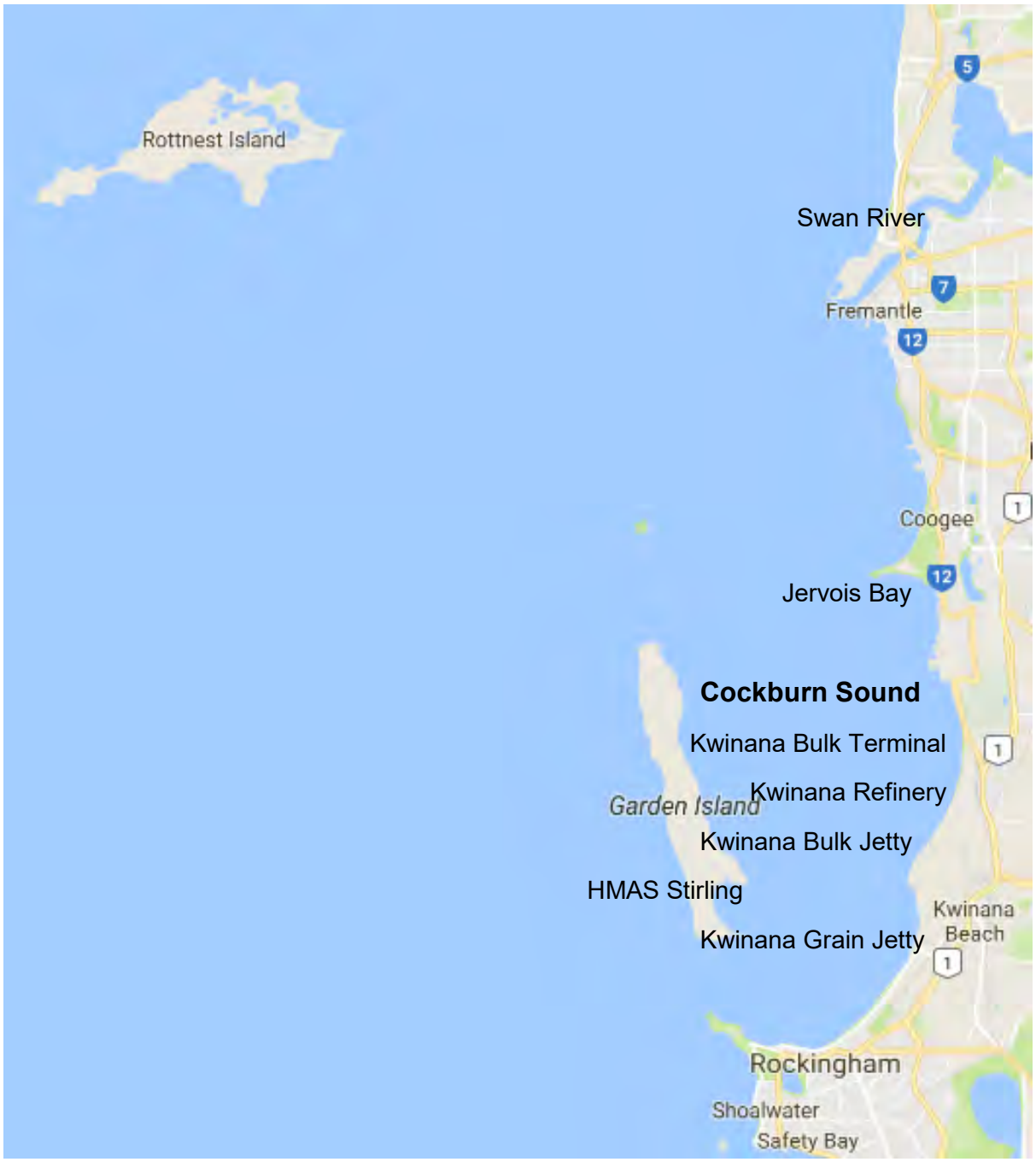
The level of general trade volumes in the Swan zone is similar to the southern part of the State and somewhat higher than the Midwest region. This is largely operating to and from a number of commercial ports centred at the mouth of the Swan River (Fremantle) and just south in Cockburn Sound (Kwinana). However, given HMAS Stirling (the RAN's largest fleet base), a marine support complex at Jervois Bay (Figure 3.2, Figure 3.3), as well as high levels of recreational and general maritime support activity, the level of shipping and vessel interactions are notably higher than the trade volumes alone would suggest. Recreational boating occurs throughout the local area including on the Swan River and out to Rottnest Island.

With no active offshore wells in the Southern Perth Basin, the level of offshore activity is limited. There is however reasonably high levels of passing traffic transiting to ports along the southern coast of Australia – albeit mostly at a reasonable distance from shore (Figure 3.9 and Figure 3.10). There are a number of minor ports to the south frequented by recreational users – however the vessels using these ports are not typically of a size that could be the source of large oil spills.

Figure 3.1 – Cruise Ship Queen Elizabeth departing Fremantle

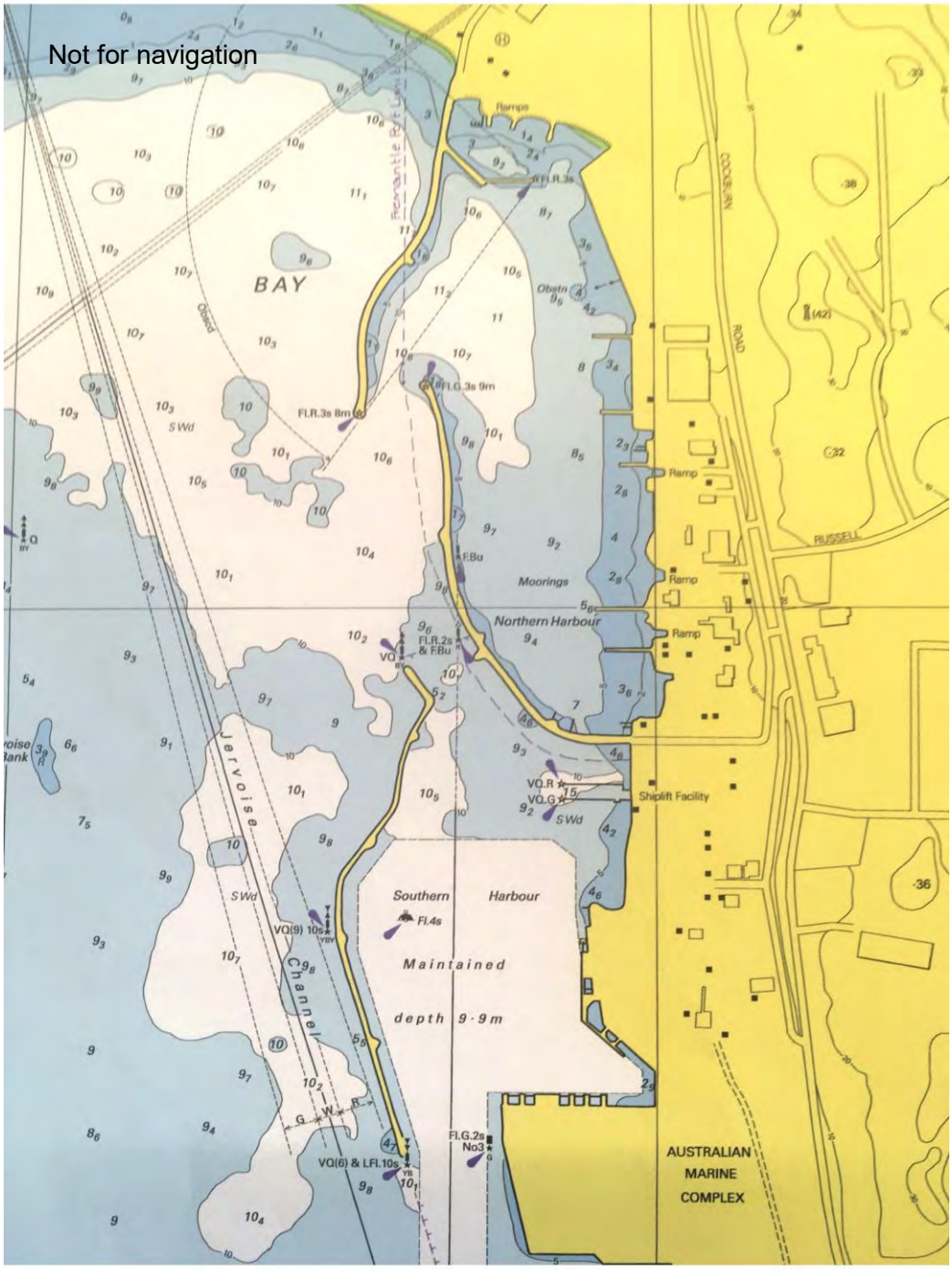
Tourism WA

Figure 3.2 – Swan River and nearby coastline



Cockburn Sound is entered from the North via a short dredged channel. This gives access to the Australian Marine Complex, various terminals and jetties and the RANs largest fleet base. HMAS Stirling is home port to 11 fleet units, including four Anzac class frigates all six of the Collins class submarines operated by the Royal Australian Submarine Service and a replenishment vessel.

Figure 3.3 – Chart image – Jervois Bay



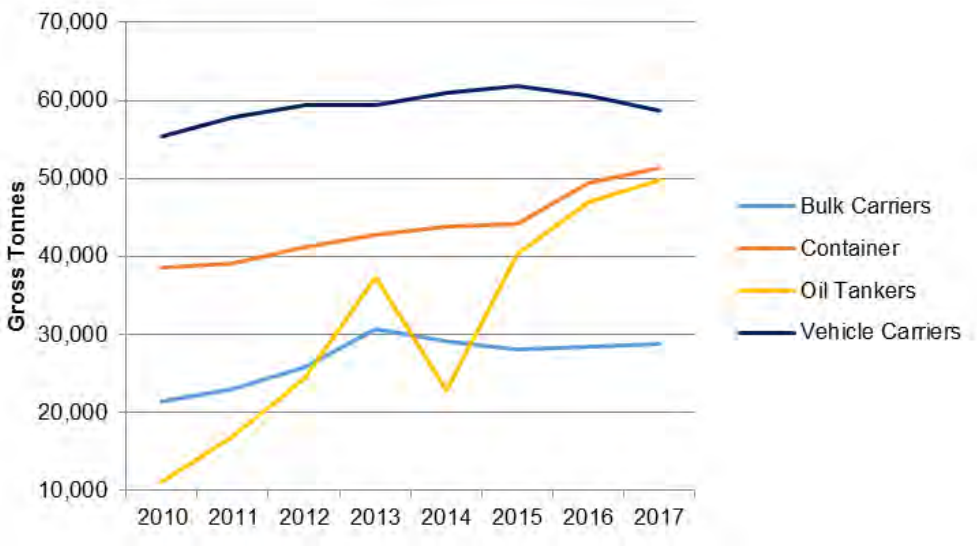
Jervois Bay is home to large amount of maritime support activity. The **Australian Marine Complex (AMC)** is a manufacturing, fabrication, assembly and maintenance facility and technology servicing the marine, defence, oil and gas, and resources industries.

3.2. Vessel Trends

Vessel Size

There is a general trend in shipping towards larger vessels as industry strives to realise gains from economies-of-scale. Figure 3.4 shows the change in average size of several different vessel types visiting the Port of Fremantle. Note that as described before there is a wide range of activity and vessel types in the zone – however the vessels included in the chart have been selected due to the high number of visits and/or the potential to contribute significantly to the risk profile.

Figure 3.4 - Average Sizes at Port of Fremantle, 2010 – 2017



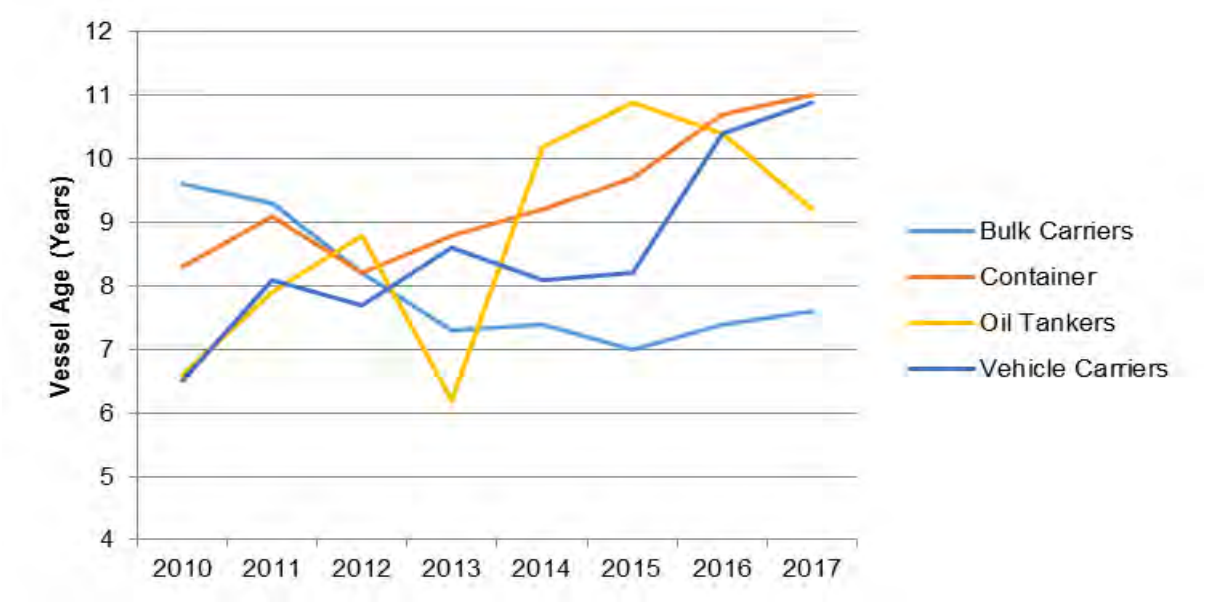
Data source: AMSA

The average size of visiting bulk carriers has increased although these vessels are relatively small compared to other regions, e.g. bulk carriers in Pilbara which can be up to three times as large. The average size of container ships has increased steadily, with the number of visits staying roughly similar over the same period of time. The increase in tanker size has coincided with an increase in the number of tanker visits to the Port of Fremantle, with a large step up from 2015 onwards. Vehicle carriers are some of the largest vessels visiting the Port of Fremantle. Their size has increased slightly over the period from 2010 to 2017.

Vessel Age

Vessel age is another factor to consider and has been identified by AMSA as one of the key predictive factors in overall vessel safety. Figure 3.5 shows the average age of different vessel types visiting the Port of Fremantle.

Figure 3.5 - Average Vessel Ages at Port of Fremantle, 2010 - 2017



Data source: AMSA

The average age of the bulk carrier fleet visiting the Port of Fremantle has decreased since 2010. Other vessel types have shown an overall upward trend over the period from 2010 to 2017.

Vessel Deficiencies

AMSA also collects data on the numbers of vessel deficiencies found by Port State Control and Flag State Control inspections. Figure 3.6 shows the average number of deficiencies found per inspection at the Port of Fremantle.

Figure 3.6 Average Deficiencies per Inspection at Port of Fremantle

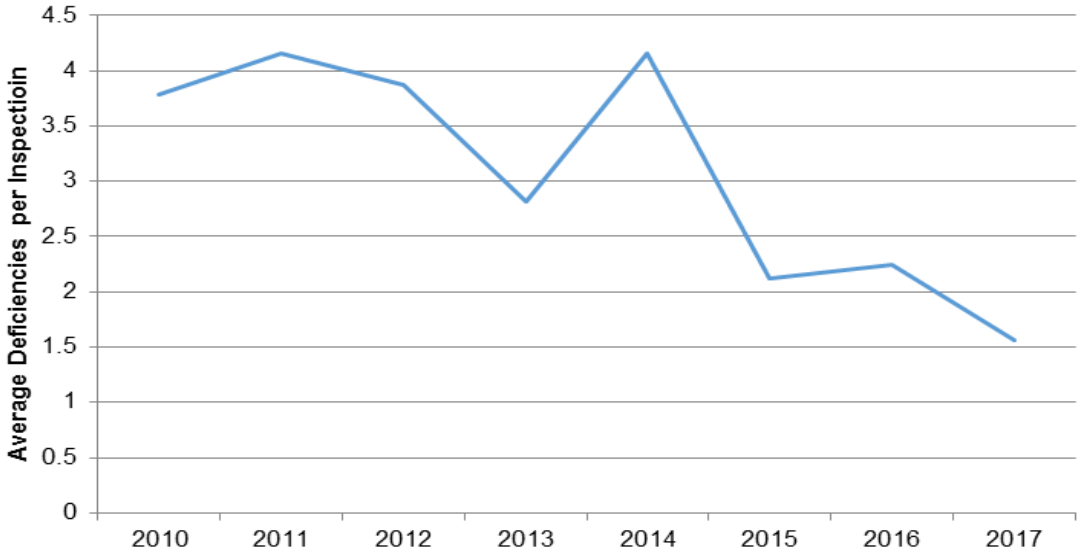
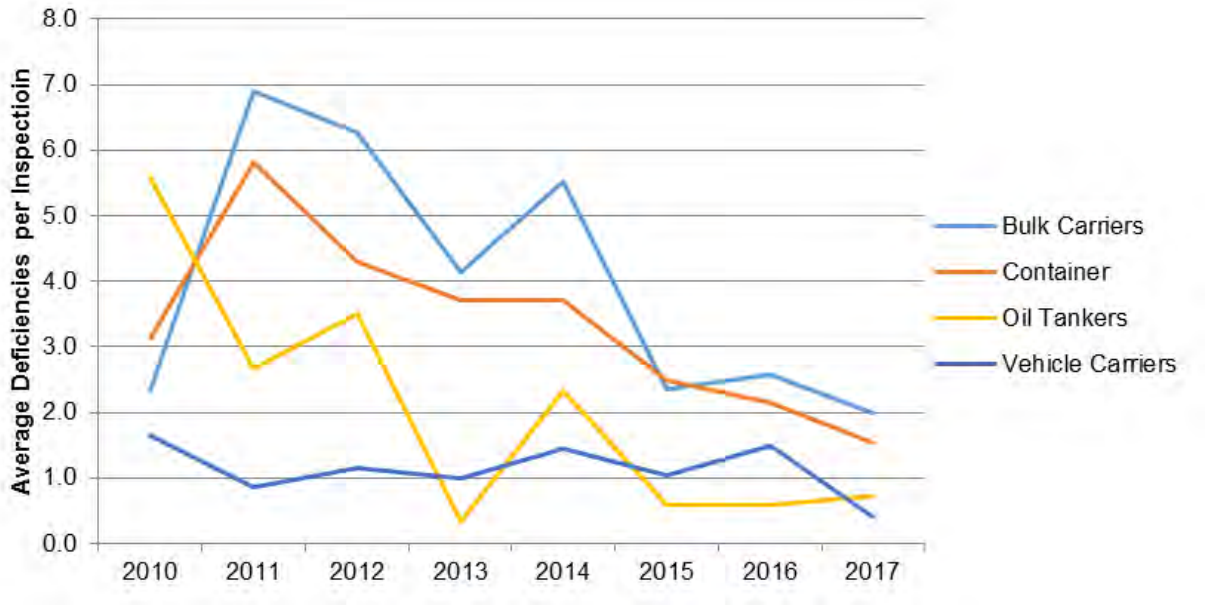


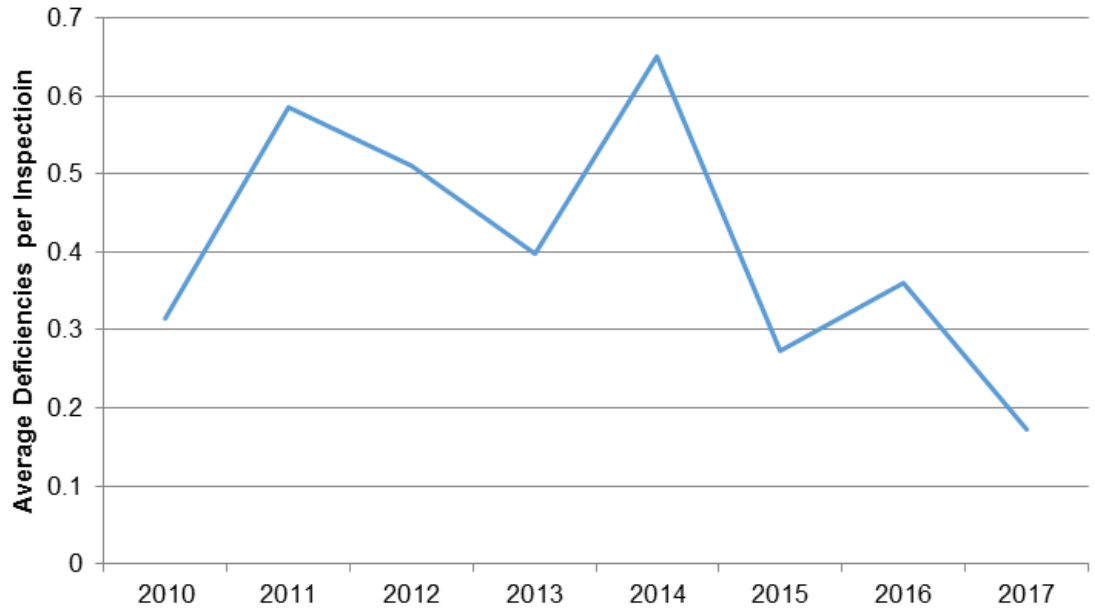
Figure 3.7 shows the average number of deficiencies found per inspection at the Port of Fremantle broken down by vessel types (note these are not all vessel types visiting the Port of Fremantle).

Figure 3.7 - Average Deficiencies per Inspection at Port of Fremantle



There are around 30 major deficiency categories in the AMSA data. These categories cover a wide range of administrative, procedural, structural and operational factors. Figure 3.8 shows the average number of deficiency per inspection categorised as 'Safety of Navigation' at the Port of Fremantle.

Figure 3.8 – Average 'Safety of Navigation' Deficiencies per Inspection at Port of Fremantle



Other trends such as changes from heavy bunker fuels to distillate fuels in response to IMO regulations are discussed in the state-wide report. It is not expected these will have an immediate effect on the risk profile.

3.3. Vessel Routes

A range of vessels transit north and south off the Swan coast. In particular large amounts of oil are moved by tankers transiting offshore. A relatively small, but potentially significant, proportion of these vessels visit the Port of Fremantle or transit closer to shore. Figure 3.9 and Figure 3.10 show vessel tracks for medium and large tankers off the Western Australian coast.

Figure 3.9 - Medium Tankers

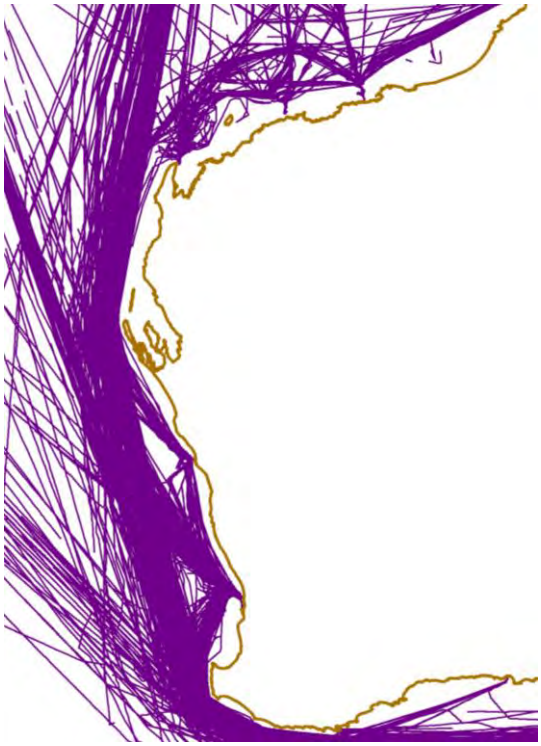
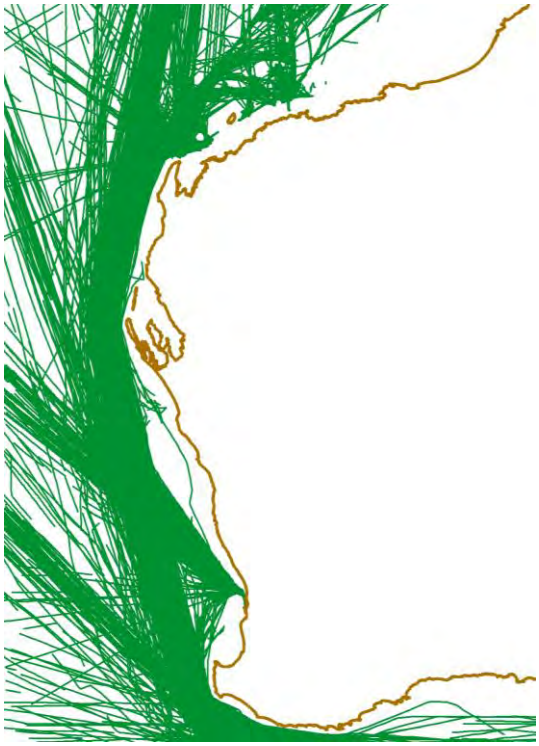


Figure 3.10 - Large Tankers



3.4. Port of Fremantle

The Port of Fremantle is the major port of the Swan region. It is the principal commercial port of Western Australia and is situated adjacent to the mouth of Swan River. The Port of Fremantle operates from two locations: the Inner Harbour at Fremantle and the Outer Harbour, south at Kwinana.

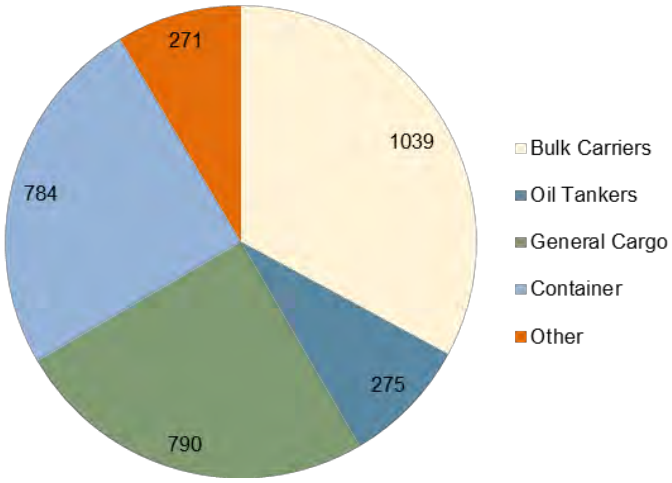
The Inner Harbour is an artificial harbour constructed within the estuary of Swan River, and handles mainly roll-on/roll-off (for wheeled cargo), container, general cargo and passenger traffic.

The approach to the Port of Fremantle is north of Rottnest Island through Gage Roads, which has an open form and is readily accessible for mariners in all weathers.

The north-going tidal stream runs from about 10 hours and the south-going stream for about 14 hours. The rate is usually small, but may be as much as 2 knots in unsettled weather in the winter months. The tidal height is strongly affected by wind direction with the potential for actual tides to be below charted datum.

As an indication of activity levels, Figure 3.11 shows the numbers of transits[1] by different vessel types. As with other major Western Australian ports, the Port of Fremantle is frequented by bulk carriers. However, there is also a wide variety of other vessel types as the port handles almost all of Western Australia's container trade as well as non-containerised cargo such as motor vehicles, steel and machinery imports and livestock exports. The Outer Harbour, which is located about 20 kilometres south at Cockburn Sound, Kwinana, plays an important role for the State in the import and export of bulk products.

Figure 3.11 – Annual Vessel Transits to and from Port Fremantle



3.5. Naval Activity

As noted before, HMAS Stirling is located on the Western shore of Cockburn Sound across from Kwinana. As the RANs largest fleet base, HMAS Stirling is home port to four Anzac class frigates, six of the Collins class submarines and a replenishment vessel. However, due to a range of factors, in particular; the high integrity of warship hulls, the limited fuel oil carried on-board most fleet fighting units, the relatively low number of naval movements into and out of Cockburn Sound when compared to merchant vessels, and the generally itinerant behaviour of naval units, the oil carried by these vessels has not be considered in the risk analysis. The fleet replenishment unit does carry a reasonable quantity of medium fuel oil but there are relatively few movements, which are itinerant in nature and are not recorded in AIS data. Thus direct consideration of a replenishment vessel has not been included in the analysis.

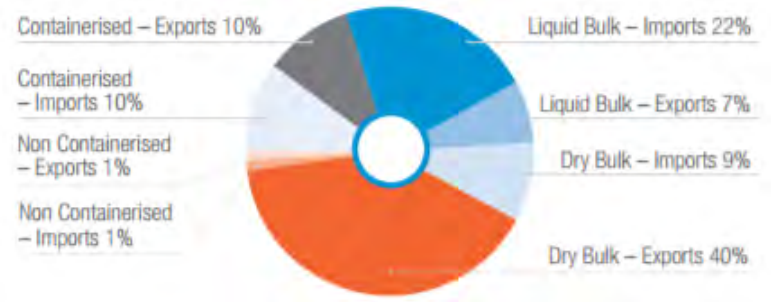
[1] A transit is defined as a single movement. A ship visiting a port will usually comprise two transits.

Figure 3.12, Figure 3.13 and Figure 3.14 show breakdowns of throughput at the Port of Fremantle.

Figure 3.12 - Port of Fremantle Throughput 2015/16

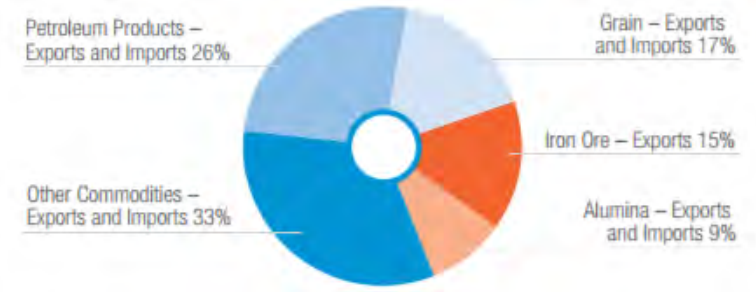
Source: (WA DoT 2016)

Figure 3.13 - Port of Fremantle Throughput by Cargo Class 2015/16



Source: (WA DoT 2016)

Figure 3.14 - Port of Fremantle Throughput by Commodity Class 2015/16



Source: (WA DoT 2016)

References: *Australian Hydrographic Service & United Kingdom Hydrographic Office 2014; WA DoT 2016; Fremantle Ports 2016; Fremantle Ports 2011*

4. Data Sources

4.1. Overview

The analysis requires a wide range of data inputs, including:

- Vessel activity:
  - Vessel types, routes and number of transits.
  - Vessel cargo types and volumes.
- Ports and marine terminals:
  - Port locations, bunkering and transfers.
- Petroleum industry activity - locations, purpose, phase, oil types and related activity for; wells, platforms, pipelines, FPSOs.
- Spill events:
  - Event occurrence frequencies for vessels and offshore infrastructure.
  - Resulting spill size probability density functions.
- Environmental conditions - wind and current data.
- Oil classifications.

These data sources are discussed in the preliminary state-wide report and a brief outline of vessel activity, petroleum industry data and navigational hazard data is provided below as these data sources have seen updates since the state-wide report.

4.2. Vessel Activity

Vessel activity inputs in the model are primarily based on Automatic Identification System (AIS) data, which is collected and held by AMSA. Navigatus commissioned AMSA to interrogate the AIS information system and provide three years of processed data in a suitable format for further pre-processing and incorporation into the model. The steps taken by AMSA were:

- Filter data set for relevant geographic scope and three-year time period from 2013 to 2015.
- Use ship inspections ('ShipSys') database to populate vessel type and size information missing from AIS data.
- Use GIS tool to convert individual AIS 'point' reports to 'line' voyages based on report time.

The resulting data was then provided to Navigatus and a density analysis was undertaken on the vessel tracks. This determined the number of vessel transits per year through each 10km hexagon sea cell for each vessel type/size category. The process included grouping vessels into the following categories for the WAMOPRA outputs:

- Bulk Carriers
- Chemical Tankers
- General Cargo
- Container
- Gas Carrier

- MODUs FPSOs Transit
- Commercial
- Oil Tankers
- Passenger

The use of AIS data to populate vessel activity information is further described in the state-wide report (Navigatus, 2016). This stage also saw the incorporation of vessels closer to shoreline and outside of traditional shipping routes. An algorithm was used on AIS data to simulate the presence of vessels off track as well as coastal operations of smaller vessels whose behaviour is less predictable. Vessels smaller than 100GT are not considered in the analysis for the following reasons:

- Smaller vessel activity is typically more erratic and unpredictable.
- Below this size vessels tend to store fuel in separate tanks rather than against the hull so are less likely to spill in the event of a collision.
- To reduce the 'noise' from small vessels which do not have the potential to add significantly to the risk profile (although, as discussed in Section 6.2 spill responders will typically respond to spills from smaller vessels with greater frequency than larger vessels).

4.3. Navigational Hazard

This stage of the WAMOPRA incorporated a navigational hazard factor. This was determined through the following formats:

- Examination of navigation charts and the Australian Pilot *(Admiralty Sailing Directions Australian Pilot Volume 1).*
- A workshop with expert mariners who are familiar with the Western Australian coastline facilitated by Navigatus and held in Fremantle.
- Interviews with WA State Harbourmasters conducted by Navigatus in Fremantle and in the respective ports.

The development of the navigational hazard ratings and incorporation into the model are outlined in the Methodology section.

5. Methodology

5.1. Overview

The following sections outline key elements of the WAMOPRA methodology, or elements that have been introduced or modified in Stage Two. These include:

- Spatial Framework – the spatial basis for the WAMOPRA modelling and outputs.
- Navigational Hazard
- Exposure and Risk – an explanation of two key output measures, how they are defined and displayed.
- Limitations – a brief note on the limitations of the WAMOPRA given its primary use as a strategic-level tool.

5.2. Spatial Framework

The model is based on two layers of cells; shoreline cells and a hexagonal sea cell grid.

Shoreline cells are used for visualising shoreline risk and exposure. The shoreline cell layer consists of cells which are 20km long (along the coast) by 10km wide (seaward extent) and which are compliant with shoreline features and shape.

The shoreline cells display exposure, protection priorities and risk for shoreline areas that could credibly be affected by contact with, or proximity to, either floating or dissolving oil. Therefore, the 10km width is a nominal distance, rather than representing the true seaward extent of oil impact, and primarily set for visualisation purposes.

There are 10 shoreline cells in the Swan zone Given the small size of the Swan zone shoreline cells are not grouped ‘sub-zones’ as with the other risk assessment zones. The Swan shoreline cells are shown in Figure 5.1.

Figure 5.1 - Swan Shoreline Cells

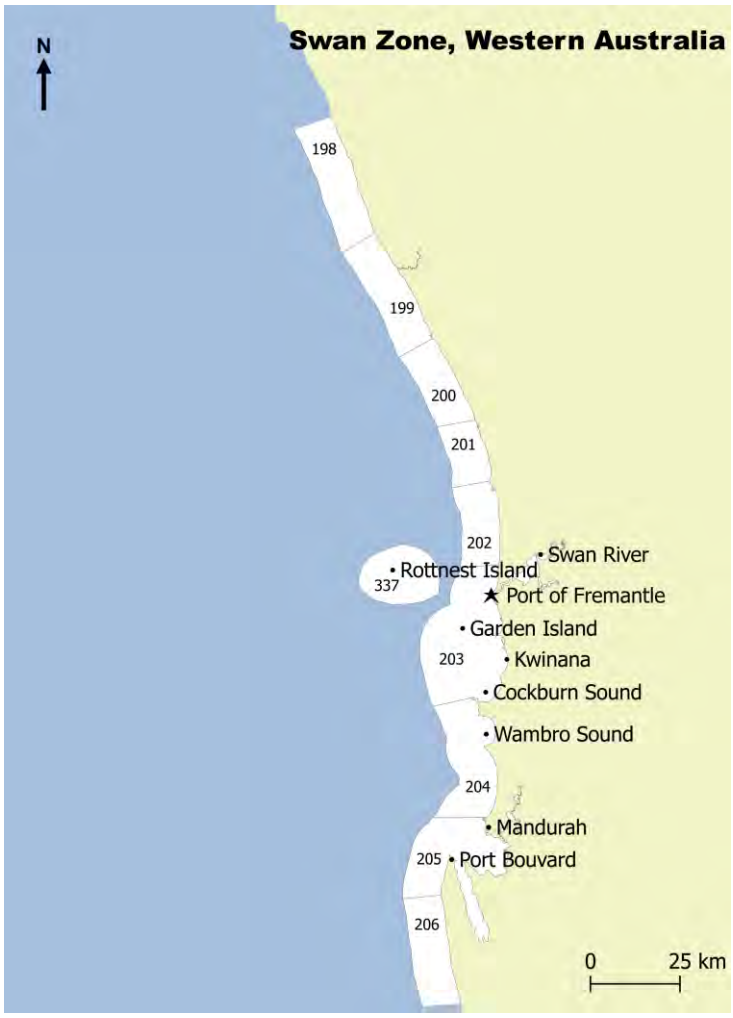


Table 5.1 – Cell identity numbers to names listing

Cell ID	Cell Name
198	Ledge Point – Edward Island
199	Ledge Point – Guilderton
200	Quinns Rocks – Wreck Point
201	Pinnaroo Point – Quinns Rocks
202	Rottnest Island, Carmac Island, Garden Island (A)
203	Rottnest Island, Carmac Island, Garden Island (B)
204	Cape Peron – Challenger Beach
205	Robert Point – Cape Peron
206	Binnningup – Cape Bouvard (A)
337	Rottnest Island, Carmac Island, Garden Island (C)

The hexagon grid is an underlying system of 10km hexagon cells representing open water ocean areas. It is used for visualising and analysing activity and exposure. The grid covers all of WA's shoreline and extends approximately 200-300km seaward off all shorelines. It enables modelling of potential oil release, oil dispersion and the likelihood of reaching shore.

The grid is used for storing vessel activity information, positions of offshore elements and environmental factors of the modelling. This system includes flags for cells representing ports and harbours to account for vessel related activity, oil-handling-processes and constrained waterways. The hexagon grid is also the basis of Navigatus modelling of oil dispersion, with the geometry enabling the computational efficiency needed for such a large geographic area.

The state-wide report contains additional information on the shoreline and hexagon cells.

5.3. Navigational Hazard

Overview

The overall navigational hazard factor is comprised of the following factors:

- **Physical Features** – in particular submerged and non-drying features. Considerations include likelihood of groundings, collisions, ease of navigation using radar.
- **Complexity** – reflects multifaceted operations / mix of vessel types and activities as well as environmental conditions such as wind, currents, swell and lee shore.
- **Activity Density** – this includes number of vessel movements and other marine activities.

These factors are combined to form an overall navigational hazard rating.

The navigational hazard for each cell around the Western Australia coastline was rated as minor, moderate, significant, major or critical for each of the above factors according to Table 5.2.

Table 5.2 - Rating System and Values

Issue Rating	Description	Value Assigned
Critical	Expected to lead to a future incident.	25
Major	Expected to be a key factor in contributing to an incident.	16
Significant	Individually controllable, but in combination with other factors could contribute to an incident.	9
Moderate	A factor that can be managed in normal operations.	4
Minor	Well within normal operation to manage or respond to (minor matter).	1

The following describes how each of the factors was determined:

Physical: Physical hazards were identified in workshops with expert mariners. All non-surface physical features have the potential to be hazardous should a vessel be in the close vicinity. To account for this all shoreline areas received a higher default rating than open sea areas (Low instead of Very Low) and subsequent efforts were focussed around areas with higher traffic density, e.g. ports.

Complexity: Complexity ratings were identified in workshops with expert mariners. The complexity rating includes the complexity of approach operations as well as environmental conditions wind, currents, swell and lee shore.

Activity Density: The model uses annual vessel transits through a cell as a key input for calculating exposure and risk. This is an arithmetic calculation and increases linearly as transits increase (e.g. two transits give rise to twice the risk of one transit).

However, as shipping density increases other factors come into play such as the interaction between ships. These interactions can mean higher risk of collision, lower margins of error and the potential need for evasive manoeuvring. Overall, this results in a further increase in risk. This additional risk is captured in the model through the activity density rating.

Strictly the number of vessel transits is incorporated only once in the model, however, the activity density measure represents the risk through the interaction between ships. Activity density was determined based on vessel tracks generated from AIS data.

Synthesis of Hazard Factors

The three separate factors are combined to form an overall Navigational Hazard Rating. This is determined by summing the individual rating values as shown in Table 5.3.

Table 5.3 - Overall Navigational Hazard Ratings

Sum of Individual Factors	Overall Rating	Overall Value	Risk Modifier	Display Colour
>30	Very High	25	25/9 = 2.78	
21-30	High	16	16/9 = 1.78	
11-20	Moderate	9	9/9 = 1	
6-10	Low	4	4/9 = 0.44	
<=5	Very Low	1	1/9 = 0.11	

In the WAMOPRA model, each vessel type in a given cell is assigned a base accident / spill rate. This base accident rate is adjusted up or down according to the navigational hazard in the area. To do this the base accident rate in each cell is multiplied by a modifier (Risk Modifier above). The modifier is normalised to the ‘Moderate’ level to reflect that operational safety in Western Australia is high relative to global standards.

5.4. Exposure and Risk

Key measures of output are exposure and risk. The first step in calculating risk is determining exposure. Exposure can be considered statistically as the total 'expected' amount of spilled oil that would be spilled in or arrive at a given cell in an 'average' one year period.

Fundamentally exposure is based on:

- Likelihood of a vessel being present (number of transits per year) OR presence of offshore petroleum infrastructure.
- Likelihood of a spill event (e.g. grounding, collision, well blowout) conditional on the above.
- Likelihood of different spill size possibilities (ranging from 1 tonne through to 500,000 tonnes) conditional on the above.
- Movement of oil (taking into account wind, currents and degradation) conditional on the above.

Exposure is presented according to the following continuous scale:

Figure 5.2 - Exposure Scale

In turn, risk is determined by combining exposure with protection priorities in the following manner:

Figure 5.3 - Calculation of Risk

Risk outputs are provided for each shoreline cell on a five-step scale ranging from very low to very high. The risk scales are shown in Figure 5.4.

Figure 5.4 - Risk Scales

Very Low	Low	Moderate	High	Very High

The information presented assesses the risk and exposure for all sources of oil that may end up on the shore in that cell. Some of the oil may originate from spills in other nearby cells, or from more distant seaward sources.

Shoreline risk and exposure outputs are for areas within state waters only.

5.5. Limitations

The WAMOPRA study has the following key limitations:

- The study was carried out at a level of detail appropriate for a strategic level study. The range of spill sizes considered was 1 tonne up to 500,000 tonnes and the physical discrimination for impacts was based upon a 20km coastline distance and 10km hexagonal open water cells.
- The calculated risk profile is built upon available local and global information. Analysis cannot predict specific future events, only likely outcomes over time based on the balance of probabilities. This study is based upon the data available – either via public sources, or as supplied by stakeholders - and the quality of the findings is determined in part by the quality of that data.
- Naval activity not included.

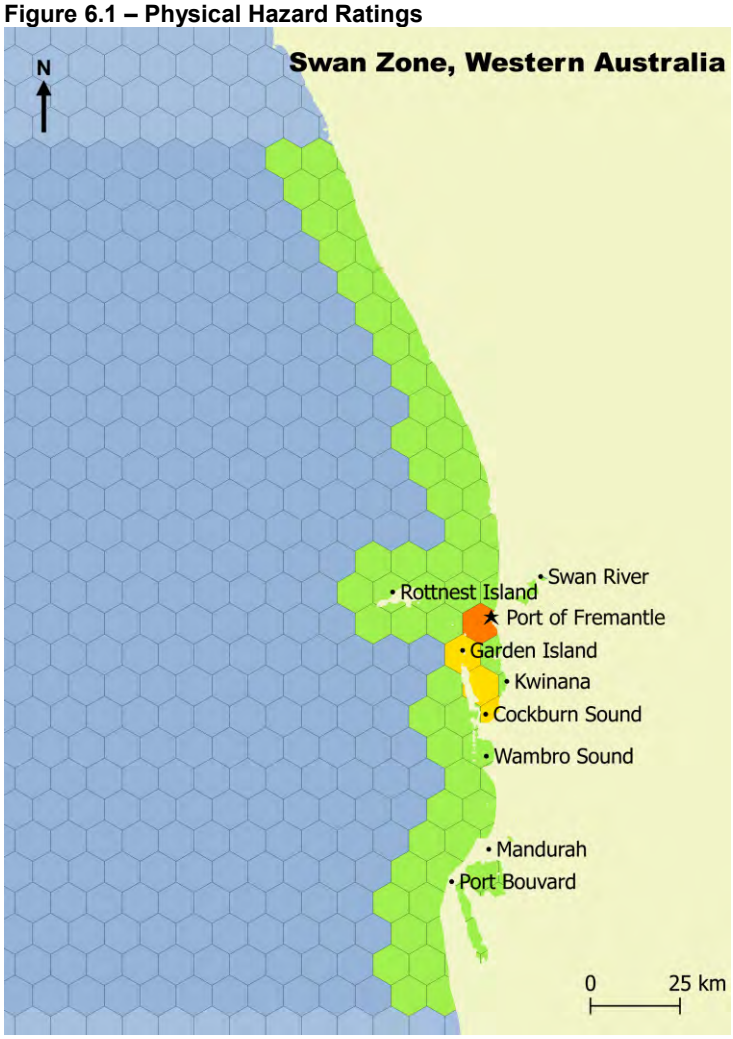
6. Results

6.1. Navigational Hazard Results

Navigational Hazard Factors

The results for the individual physical, complexity and activity density factors are shown respectively in Figure 6.1, Figure 6.2 and Figure 6.3. The overall navigational hazard heat map is shown and discussed in the following section. Note that in each of the heat maps navigational hazard information for hexagon cells outside of the Swan zone is not shown.

Figure 6.1 – Physical Hazard Ratings



Physical hazards ratings

For passing traffic, the coast of the Swan zone can be generally considered to have few areas where specific physical hazards present to mariners. However once within about 5 nautical miles of some parts of the coast, there are areas of reefs and shoals that are hazardous to vessels making port at the various small harbours and recreational facilities along the coast. The area near by the mouth of the Swan River and for about 50 nautical miles south (100km) includes areas where reefs and other natural features present physical hazards to those navigating close to shore. Rottnest Island is the only off shore hazard of note. This is reflected in the ratings shown in Figure 6.1. Given the inshore reefs and as with any lee shore, navigating close-in can be hazardous.

Figure 6.2 – Complexity Ratings

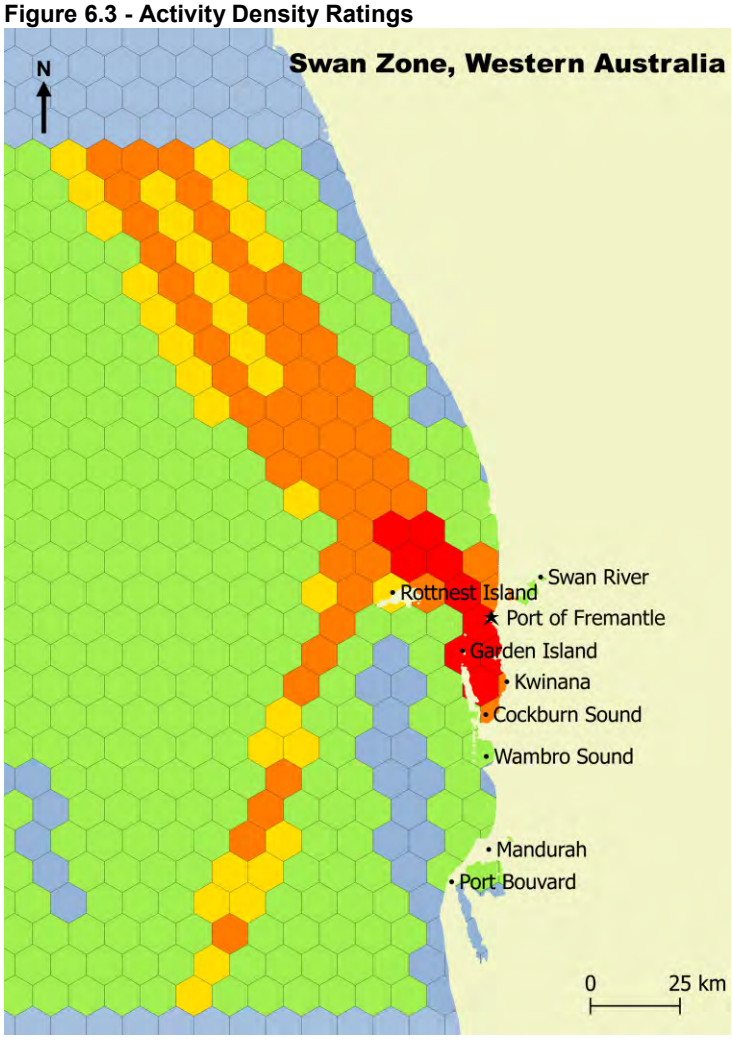
Complexity ratings

Most of the zone has very low navigational complexity. However the mouth of the Swan River has some complexity due to the restricted width of the channel and turning basin, together with the mix of traffic types.

Cockburn Sound has notable complexity for navigators and masters due to the channel entrance and wide range of maritime activities and vessel types that transit and manoeuvre in the Sound. Port Bouvard has a narrow entrance but is not navigable by larger vessels.

The ratings in the model reflect the above aspects of the zone.

Figure 6.3 - Activity Density Ratings



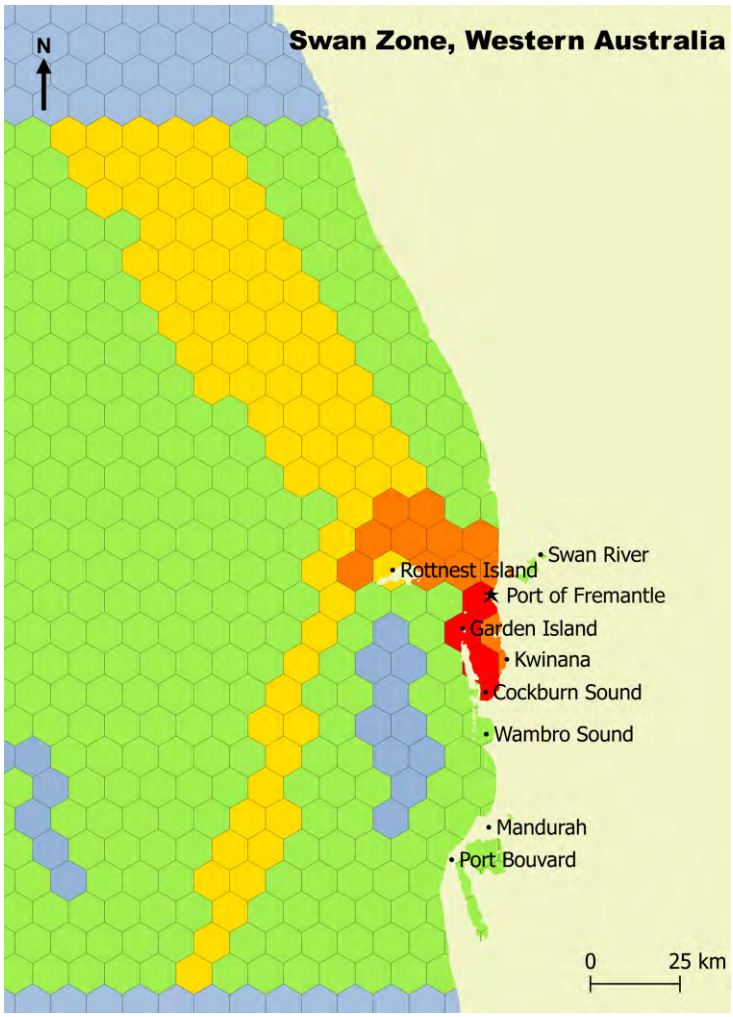
Traffic Density

Maritime traffic density off the coast of the zone is much as would be expected given the concentration of commercial facilities in the Swan River mouth and Cockburn Sound. Most of the traffic heads north from, and south to, Fremantle, while a proportion plots a course to and from the south rounding north of Rottnest Island in doing so. The density profile shown in Figure 6.3 has been derived from AMSA traffic data. Although not within the area shown, further offshore there is also passing vessel traffic.

Overall Navigational Hazard

The method for combining the three factors to produce an overall rating as described in Section 5.3. This overall navigational hazard rating is shown in Figure 6.4.

Figure 6.4 - Overall Navigational Hazard Ratings



Contextual comments for the Port of Fremantle can be found in Section 3.4. Factors influencing the navigational ratings are:

- Channel entrance
- Mixed activity including naval
- Recreational vessels and related activity

Offshore navigational hazard ratings are driven by activity density from ships transiting up and down the coast as well as visiting the port.

6.2. Oil Exposure

Overview

Exposure represents the likely volume of oil that could arrive at a given area, taking into account both the size of spill and the probability of spill (including the influence of navigational hazard). While the likelihood of any particular spill is low, exposure allows the

contribution of different sources to the risk profile to be compared. The oil exposure in both the shoreline and hexagon cells is dominated by floating oils, although dissolving oils are likely to increase in the future. Oil exposure can be viewed by floating or dissolving oils at the web map application: http://wamopra.navigatusconsulting.com

In this section results are presented for exposure to both shoreline cells and hexagon cells.

Shoreline Exposure

Figure 6.5 shows the shoreline exposure profile for the Swan zone.

Figure 6.5 - Shoreline Exposure

Key for Exposure

Figure 6.6 shows the proportion of shoreline exposure generated by each spill size band. The majority of oil expected to arrive at the Swan shoreline is due to potential spills in the 500 – 5,000 tonne band and in the 5,000 to 50,000 spill size band.

Figure 6.6 – Proportion of Shoreline Exposure by Spill Size (tonnes)

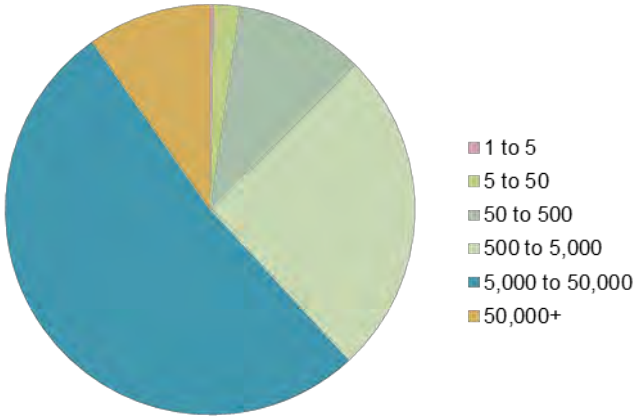


Figure 6.7 is similar to the above in that it shows the proportion of shoreline exposure generated by each spill size band. However, this measure of exposure is further broken down by shoreline cell.

Figure 6.7 – Swan Shoreline Exposure by Spill Size (tonnes) and Shoreline Cell

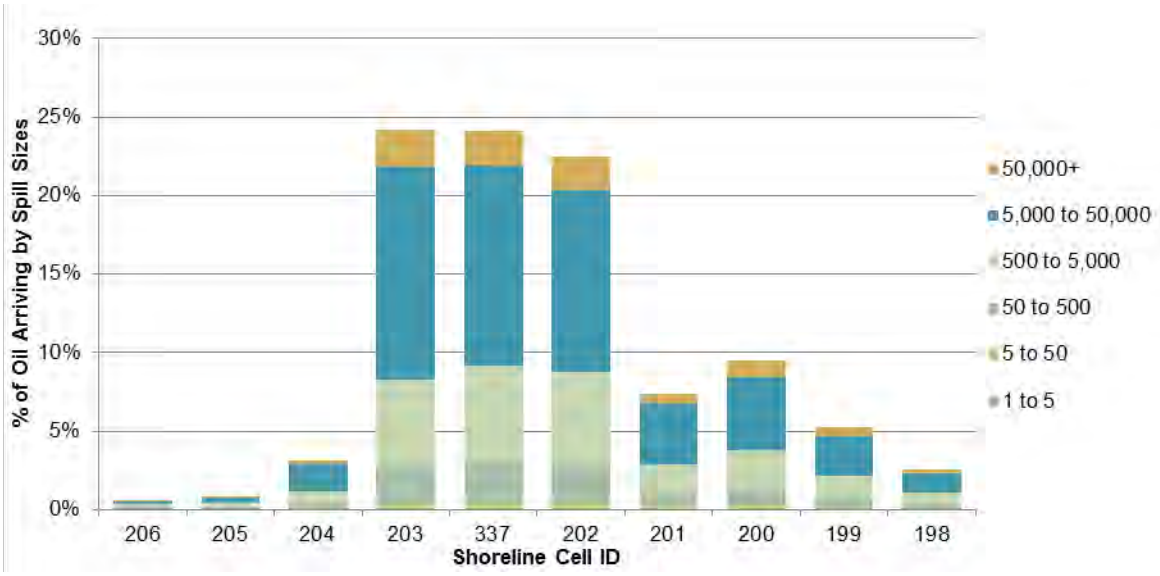
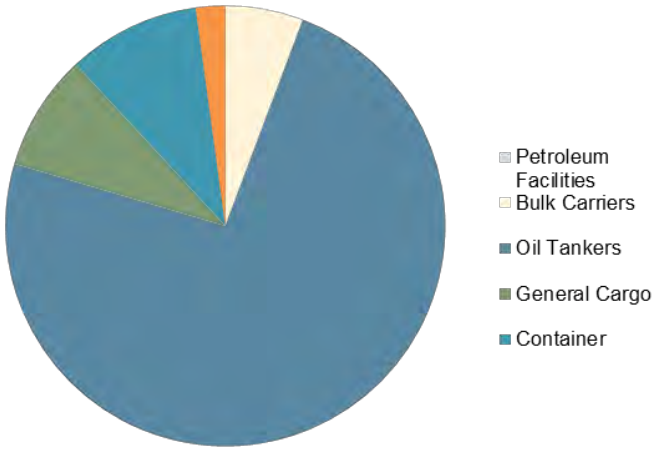


Figure 6.8 shows the proportion of shoreline exposure generated by each spill source. The majority of oil statistically expected to arrive at the Swan shoreline is due to potential spills from oil tankers visiting the Port of Fremantle and transiting off the coast. General cargo and container vessels represent the next highest source of shoreline exposure.

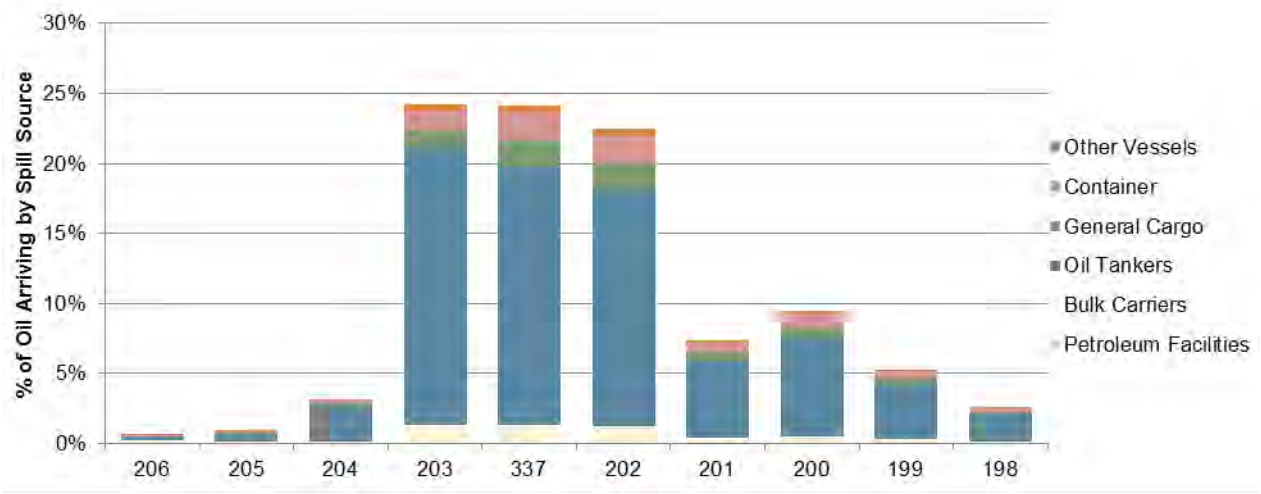
Figure 6.8 – Proportion of Shoreline Exposure by Source (tonnes)



Note that the Other Vessels category consists of a range of commercial vessels and well as chemical tankers, gas carriers and passenger vessels.

Figure 6.9 is similar to the above in that it shows the proportion of shoreline exposure generated by each spill source. However, this measure of exposure is further broken down by shoreline cell.

Figure 6.9 – Swan Shoreline Exposure by Source and Shoreline Cell

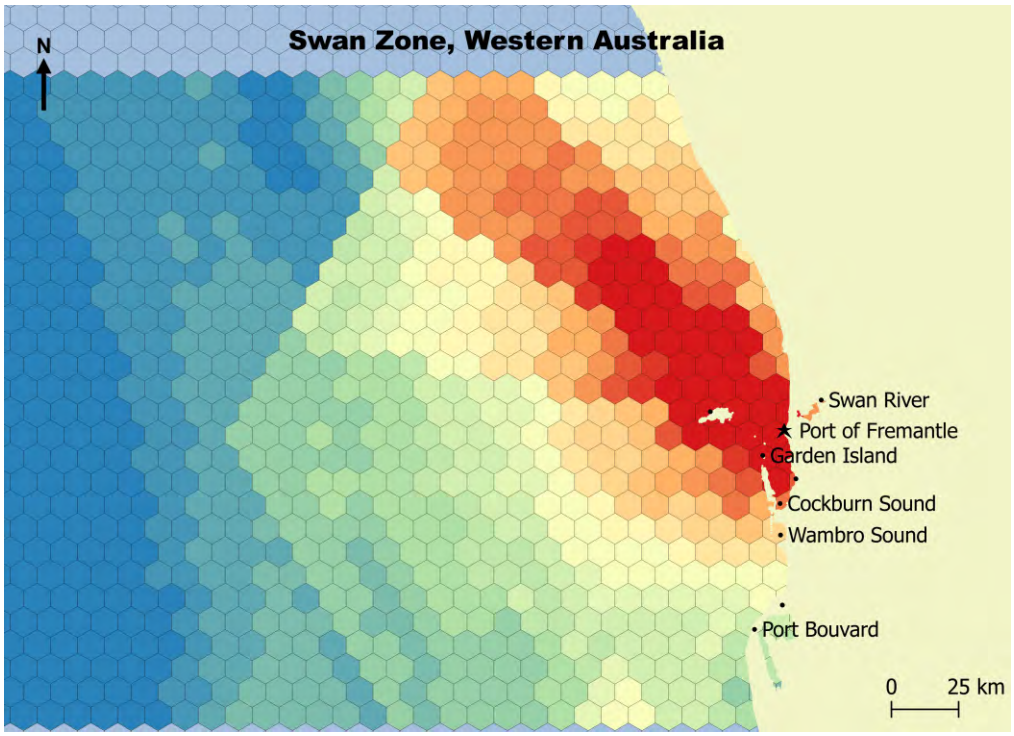


Exposure is primarily driven by the potential for rare but large spills from oil tankers transiting visiting the Port of Fremantle and transiting offshore. There is very low shoreline exposure south of the port.

Sea Cell Exposure

Figure 6.10 shows the exposure profile for the hexagon sea cells within the Swan zone. No data is shown for areas outside the Swan zone.

Figure 6.10 - Exposure Profile



Key for Exposure

Figure 6.11 shows the proportion of offshore exposure generated by each spill size band.

Figure 6.11 – Proportion of Sea Cell Exposure by Spill Size (tonnes)

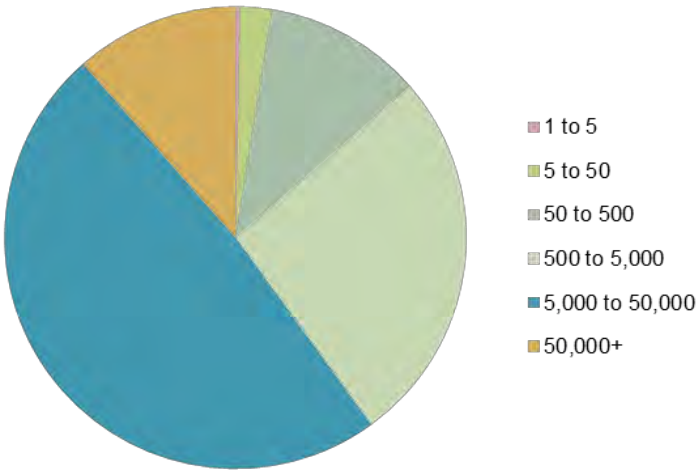
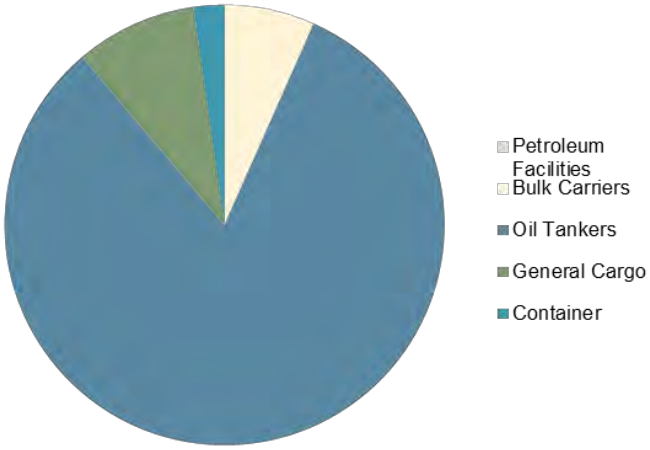


Figure 6.12 shows the proportion of offshore exposure generated by each spill source.

Figure 6.12 – Proportion of Sea Cell Exposure by Source (tonnes)



The majority of exposure in the Swan zone is due to the potential for rare but large spills from oil tankers.

Note that the Other Vessels category consists of a range of commercial vessels and well as chemical tankers, gas carriers and passenger vessels.

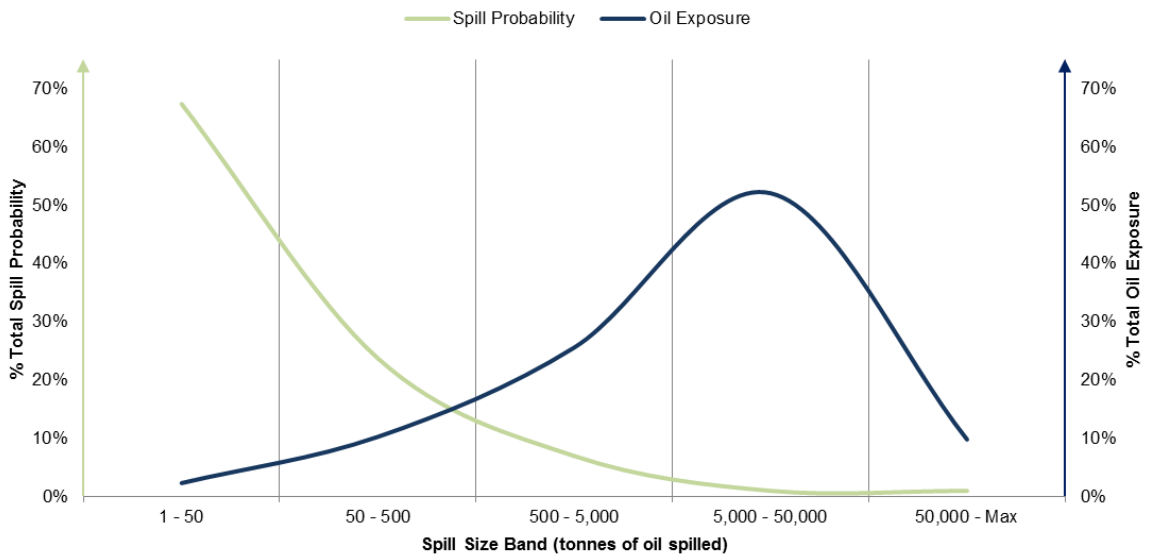
Exposure and Probability

The previous sections find that oil spill exposure in the Swan zone is primarily driven by spills in the 5,000 – 50,000 tonne band and to a lesser extent the 500 - 5,000 tonne band. This would seemingly conflict with the typical experience of an oil spill responder who is likely to attend smaller spill events more frequently. Yet the result is sound because exposure takes into account both the likelihood and size of spills. Exposure is the expectation of how much oil will arrive at a given area over a very long period of time.

Although smaller spills are much more frequent, over a very long time period, the majority of oil spilled in the Swan zone is statistically likely to come from larger incidents.

This is conceptually illustrated in Figure 6.13. This chart shows relative spill probability (in green) and relative oil exposure (in blue) for different spill size bands. Spill probability is very high in the first spill size band. After the first band, spill probability decreases rapidly as spill size increases. Put simply; smaller spills are more frequent than larger spills.

Figure 6.13 – Conceptual Comparison of Spill Probability vs. Expected Oil



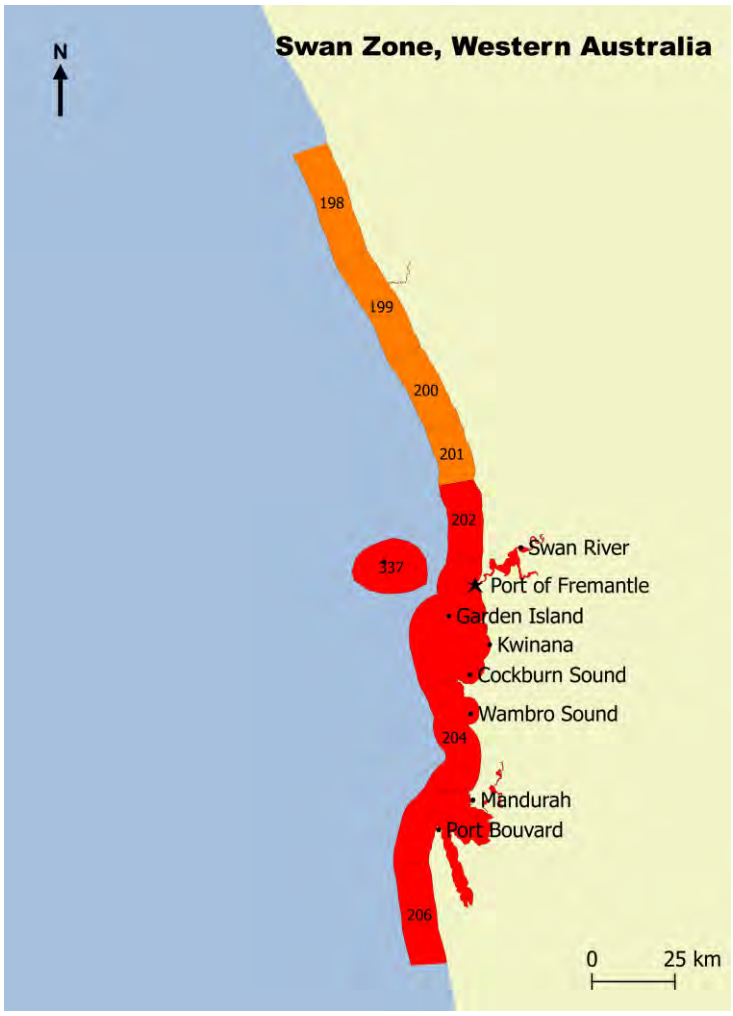
On the other hand, relative oil exposure (the blue curve) is relatively low for smaller spill sizes. Although these spills are more frequent, their contribution to the statistically expected amount of oil is small. As spill size increases the contribution to total exposure also gradually increases, peaking at the 5,000 – 50,000 tonne band and then decreasing.

This leaves spill responders with the challenge of regularly dealing with small spills while also ensuring adequate training, capability and resources to respond effectively to a range of larger spills.

6.3. Protection Priority Results

Protection Priority data was developed by Advisian and is fed into the risk model developed by Navigatus to create a picture of oil spill risk including likelihood and consequence. Figure 6.14 shows the overall rating for Protection Priorities in the Swan zone.

Figure 6.14 - Protection Priorities Overall Ratings



Key

Very Low	Low	Moderate	High	Very High

A sample of protection priority data is shown for major ports in Table 6.1. The table is based on Protection Priority data provided by Advisian. It shows the protection priorities ratings and comments for the Port of Fremantle. Ratings and comments are provided by Advisian for potential spills of floating oils (e.g. bunker fuel) and dissolving oils (e.g. diesel); however, these columns have been merged as in the case of the Port of Fremantle they are the same.

Information on protection priorities can be viewed at the web map application: http://wamopra.navigatusconsulting.com as well as in the Swan zone summary section of this report. The Swan zone report prepared by Advisian for the Department of Transport (Advisian 2017) should be consulted for more context and information.

Table 6.1 – Sample of Protection Priorities at Fremantle (based on Advisian 2017 data)

Category	Protection Priorities Floating Ranking	Protection Priorities Dissolved Ranking	Protection Priorities Overall Ranking	Brief Description for Spills of Floating Oils / Dissolving Oils*	Data Sources
Protected Fauna	*High*	*Moderate*	*High*	Birds: Thalassarche carteri (Indian yellow-nosed albatross) & (EN) Thalassarche melanophris (black-browed albatross) (EN) Known to occur, Puffinus huttoni (Hutton's shearwater) (EN) Known to occur, Phoebetria fusca (sooty albatross) (EN) Known to occur, Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur, Anous tenuirostris melanops (Australian lesser noddy) (EN) Known to occur, Calidris ferruginea (Curlew Sandpiper) (EN) Known to occur Reptiles: Caretta caretta (loggerhead turtle) (EN) Known to occur Mammals: Eubalaena australis (Southern Right Whale) (EN) Breeding in the area, Balaenoptera musculus brevicauda (blue whale) known to occur Fish: Carcharodon carcharias (Great White Shark) (VU) Known to occur	DotE SNES (22 February 2017), DPaW Protected Fauna (2 March 2017)
Protection Areas	**Very High**	**Very High**	**Very High**	World Heritage (Australian Convict Sites (Fremantle Prison Buffer Zone))	DotE World Heritage Areas (14 October 2015)
Cultural Heritage	**Moderate**	**Moderate**	**Moderate**	Cmlth Historic: J Gun Battery, Cliff Point; Cmlth Natural Site: Garden Is. Conservation Order: Peel Town Archaeological Sites, Site of Long Jetty, Le Fanu, Cockburn Sound Anti-Sub Boom; State Protected Heritage: Colwyn/Claremont, Heathcote Hospital, Sunset Hospital, Challenger Battery, Success Harbour, Ulidia Shipwreck, Riverfront gardens & Palm Trees, Mosman Bay Foreshore, Johannah St Foreshore Reserve, Milua Nature Reserve and Marine Park, Z-Force Memorial/Rockingham, Mead's Fish Gallery, SS Kwinana - Shipwreck, Wells Park, White Beach, Round House and Arthur Head Reserve, Site of Original Palm Beach Jetty, Tawarri Reception Centre, Bay View Park, Oyster Beds, Point Resolution Reserve, South Fremantle Power Station, Cape Peron Battery Complex [more]; Cmlth Protected Shipwreck: Abemama, Alacrity, ALC40 Barge, Amur, Anti-submarine boom net tower, Blackwall Reach Barge, Blackwall Reach Boat, Blackwall Reach Yacht, Cambria, Camilla, Carnac, City of Perth [more]	DotE National Heritage (Public) (22 January 2016) ; DotE Australian National Shipwrecks Database (3 February 2016)
Economic	**Moderate**	**Moderate**	**Moderate**	Port: Fremantle Port	DPI Port Authorities (25 October 2010)
Social Amenity and Recreation	**Moderate**	**Low**	**Moderate**	Beach: Cottesloe	Surf Lifesaving WA Beach data (18 April 2016)
Overall	**High**	**Moderate**	**High**	World Heritage (Australian Convict Sites (Fremantle Prison Buffer Zone))	DotE World Heritage Areas (14 October 2015)

*Note description for floating and dissoving oils is the same each instance for this cell.

6.4. Swan Risk Profile Results

This section contains the main risk results for the Swan zone. Figure 6.15 shows a heat map of risk ratings in each of the Swan zone shoreline cells.

Risk ratings in the heat map are determined relative to the risk score in the highest shoreline cell.

This section also contains a column chart showing relative risk[2] between each of the shoreline cells and another column chart showing relative risk between the top three major ports.

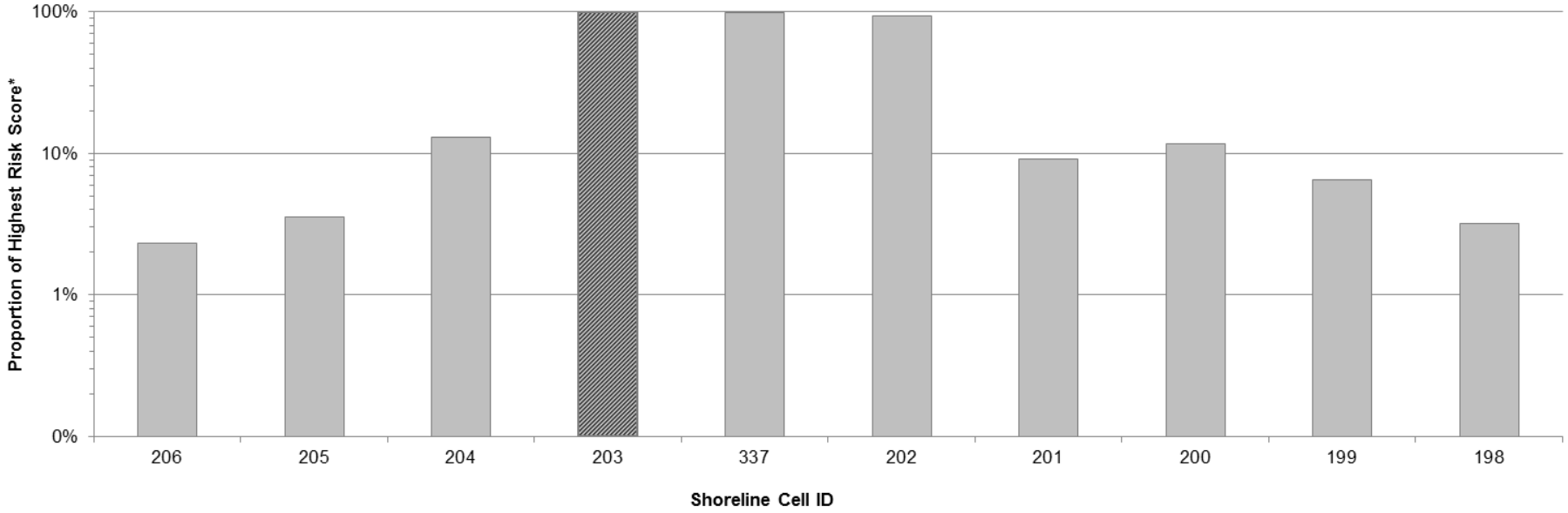
[2] The relative risk scores presented in Figure 6.16 are indexed to the highest cell in the Swan Zone and so are not directly comparable to other zones. However, in general the risk results are presented relative across all zones (for example, the risk as shown in the heat maps).

Figure 6.15 - Swan Risk Profile Heat Map

Figure 6.16 shows a column chart of relative risk scores for each of the shoreline cells.

The black column represents shoreline cell ID 203, the cell with the highest risk score.

Figure 6.16 – Swan Risk Profile Relative Risk Scores



* Note use of log scale.

The cells with the highest risk levels are:

1. ID #203 *Port of Fremantle* - Rottnest Island, Carnac Island, Garden Island (B)
2. ID #337 Rottnest Island, Carnac Island, Garden Island (C)
3. ID #202 *next to Port of Fremantle* - Rottnest Island, Carnac Island, Garden Island (A)

6.5. Swan Zone Summary

Overview

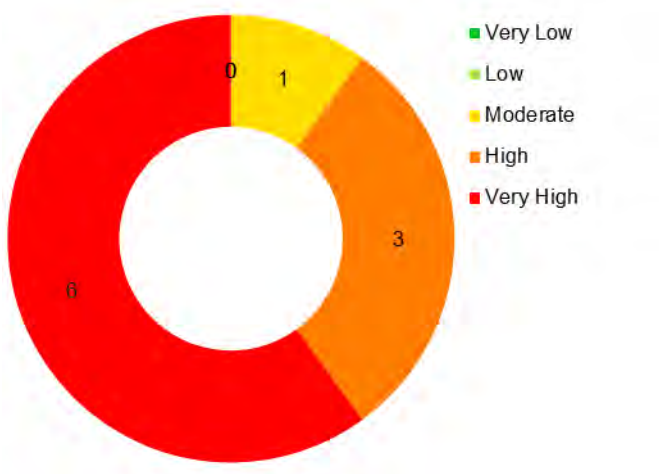
The following section contains a brief summary of the Swan zone.

Cell counts are shown below and a summary table is also presented for the Swan zone. The key benefit of this table is to allow trends in risk drivers to be seen across multiple cells. The tables contain the following fields:

- **ID** – the shoreline cell identification number.
- **Name** – the name assigned to the shoreline cell.
- **Overall Risk Rating** – the primary measure of risk – shown on a five-step rating scale which ranges from Very Low to Very High.
- **Exposure** – represented as a colour on a continuous spectrum which transitions from blue – yellow – red as the level of exposure increases.
- **Overall Protection Priorities Rating** – as determined by Advisian, shown on a five-step rating scale which ranges from Very Low to Very High.
- **Protected Fauna; Protection Areas; Heritage; Economic; Social Amenity Recreation** – these fields show the ratings for each of the protection priority categories as determined by Advisian. The ratings are shown on a five-step rating scale which ranges from Very Low to Very High. In some cases the Advisian data contains an 'N/A' where no features were included in the assessment and no rating was given for that particular category. This 'N/A' is shown in the summary table.
- **Brief Description of Overall Protection Priority Rating** – the protection priorities attribute table provided by Advisian contains a brief overall comment for spills of floating oils and spills of dissolving oils in each shoreline cell. This field represents each of the unique features mentioned in the two overall comments. It is intended to provide a brief overview of key protection priorities in the shoreline cell.
- **Key Drivers of Shoreline Exposure** – this field lists the potential spill sources which contribute most to the risk profile in the given shoreline cell.

Figure 6.17 shows the count of each cell rating within the Swan Zone.

Figure 6.17 – Swan Zone Counts



Swan Zone Summary Table

ID	Name	Overall Risk Rating	Exposure	Overall Protection Priorities Rating	Protected Fauna	Protection Areas	Heritage	Economic	Social Amenity Recreation	Brief Description of Overall Protection Priority Rating	Key Drivers of Shoreline Exposure
198	Ledge Point - Edward Island	High		High					N/A	*Nature Reserve (Lancelin And Edwards Islands) (IUCN IA), Seagrass*	Oil Tankers, Container
199	Wreck Point - Guilderton	High		High					N/A	*Birds: Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur Mammals: Eubalaena australis (Southern Right Whale) (EN) Species known to occur in the area*	*Oil Tankers, Container*
200	Quinns Rocks - Wreck Point	Very High		High						*Birds: Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur Mammals: Eubalaena australis (Southern Right Whale) (EN) Breeding in the area. Fish: Carcharias taurus (grey nurse shark) (VU) Known to occur in the area*	*Oil Tankers*
201	Pinnaroo Point - Quinns Rocks	Very High		High						*Birds: Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Known to occur in the area. Mammals: Eubalaena australis (Southern Right Whale) (EN) Breeding in the area Fish: Carcharias taurus (grey nurse shark) (VU) Known to occur in the area*	*Oil Tankers*
202	Rottnest Island, Carnac Island, Garden Island (A)	Very High		Very High						*Port: Fremantle Port*	*Oil Tankers*
203	Rottnest Island, Carnac Island, Garden Island (B)	Very High		Very High						*World Heritage (Australian Convict Sites (Fremantle Prison Buffer Zone))*	*Oil Tankers*
204	Cape Peron - Challenger Beach	Very High		Very High						*Ramsar Wetland (Becher Point Wetlands, Peel-Yalgorup System)*	*Oil Tankers*
205	Robert Point - Cape Peron	High		Very High						*Mammal: Pseudocheirus occidentalis (western ringtail possum, nguara) (CR) Known to occur (sighting,certain)*	*Oil Tankers, Bulk Carriers*
206	Binningup - Cape Bouvard (A)	Moderate		Very High					N/A	*Ramsar Wetland (Peel-Yalgorup System)*	*Oil Tankers, Bulk Carriers, General Cargo*
337	Rottnest Island, Carnac Island, Garden Island (C)	Very High		Very High						*Port: Fremantle Port*	*Oil Tankers*

Key for Risk and Protection Priorities

Very Low	Low	Moderate	High	Very High

Key for Exposure

7. Conclusion

The WAMOPRA combines regional, national and international data for maritime activity and marine oil spills, levels of activity and protection priorities including environmental sensitivities to develop an overview of oil spill risk in the Swan zone. This report summarises the context, methodology and results for the Swan Risk Assessment Zone. It builds on the work undertaken in the preliminary state-wide assessment.

From an oil spill risk assessment perspective, distinctive features of the Swan zone include: high ecological values and a wide variety of activity at the Port of Fremantle.

The highest risk area is around the Port of Fremantle where there is a high level varied of shipping traffic combined with high protection priorities. Complexity at the port is generated by the traffic mix, which includes commercial, navy and recreational activity. In particular, potential spills from oil tankers are key driver of risk in this area. In addition to visiting the port, oil tankers transit off the coast of the Swan zone generating a relatively low but constant level of exposure along most of the Swan shoreline.

Petroleum production and exploration activity is not a driving factor in the Swan zone.

This companion report summarises the WAMOPRA results for the Swan Risk Assessment Zone. Further risk outputs are available via an interactive website at http://wamopra.navigatusconsulting.com (contact Team Leader Planning and Public Information for username and password).

8. References

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