Western Australia

Marine Oil Pollution Risk Assessment

Midwest Zone Report

Prepared for Department of Transport

by Navigatus Consulting

June 2018

This page is intentionally blank.

Prepared for:

Department of Transport Western Australia

Prepared by:

Navigatus Consulting Limited
347 Parnell Road
PO Box 137249
Parnell, Auckland 1052
+64 9 377 4132
www.navigatusconsulting.com

Quality Control

Prepared by: Matt Bilderbeck, Celia Cunningham, Jess Spinetto

Reviewed by: Kevin Oldham, Geraint Bermingham

Revision	Date	Authorised By	
		Name	Signature
Rev 1	25/9/2017	Kevin Oldham	
Rev 1.1	20/12/2017	Kevin Oldham	
Rev 1.2	7/06/2018	Kevin Oldham	

This page is intentionally blank.

Contents

Outputs in this Series

Web

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

Data

GIS attribute tables for DoT internal system.

Reports

- Navigatus, 2016 – WAMOPRA Preliminary State-Wide Assessment (*published*)
  - Appendix A – Exposure Results by Category
  - Appendix B – Web Based Interface
- WAMOPRA Pilbara Zone Report (*in preparation*)
- ***WAMOPRA Midwest Zone Report (this report)***
- WAMOPRA Swan Zone Report (*in preparation*)
- WAMOPRA Kimberley Zone Report (*scheduled FY 2018*)
- WAMOPRA South West Zone Report (*scheduled FY 2018*)
- WAMOPRA South Coast Zone Report (*scheduled FY 2018*)

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 Midwest Risk Assessment Zone. The other zones are: Kimberley, Pilbara, Swan, 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. Midwest zone

This report summarises the context, methodology and results for the Midwest Risk Assessment Zone. It builds on the work undertaken in the preliminary state-wide assessment. The geographical extents of the Midwest 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 Midwest 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 Midwest risk profile.
  - *Protection Priorities* – the primary output shown is a heat map of the overall protection priority ratings for the Midwest zone as provided by Advisian. These ratings are combined with exposure to produce the Midwest risk profile.
  - *Risk Profile* – the primary output shown is a heat map which 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.
  - *Sub-Zone Drill Down* – a short section on each of four sub-zones within the Midwest zone (refer Section 5.2 for an explanation of sub-zones). A table is presented for each sub-zone which shows, for each of the shoreline cells in that sub-zone: 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.
- **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

As can be seen from Figure 3.1, the Midwest region has just one commercial port of note – Geraldton, and so has a generally low level of trade compared with the other regions of WA. Maritime trade includes Useless Loop, a salt export facility and a salt and gypsum bulk terminal at Cape Cuvier.

There is limited oil production activity off the coast of the zone (Figure 3.12), including an unmanned offshore platform at Cliff Head that pipes onto an onshore processing plant. There is reasonably high levels of traffic offshore (Figure 3.8) – albeit mostly a reasonable distance from the coast. There are a number of minor ports frequented by recreational users – however the vessels using these ports are not of a size that could be the source of large oil spills.

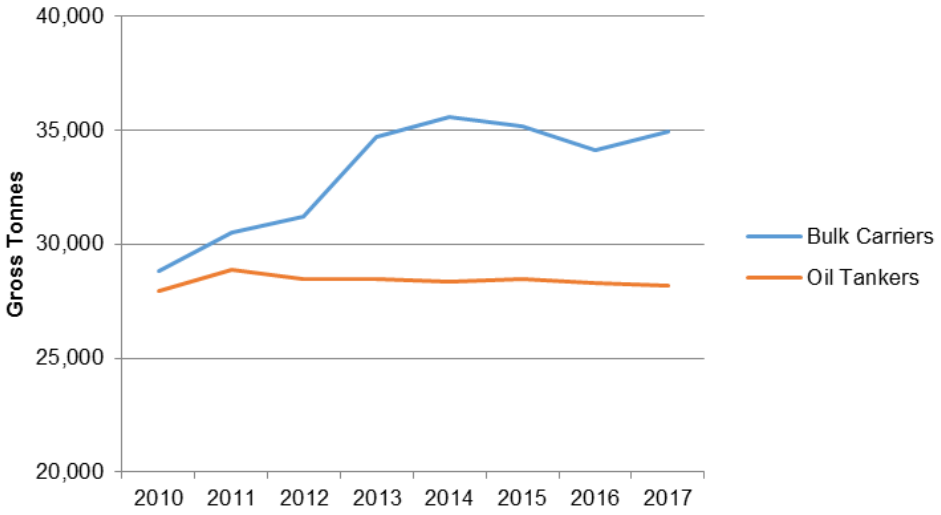
Figure 3.1 – Overview of WA trade volumes 2015– 2016

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 3.2 shows the change in average size of bulk carriers and oil tankers visiting the Port of Geraldton. Oil tanker visits represent only a small fraction of visits to the Port of Geraldton; however, the information may be indicative of trends in oil tankers which transit offshore.

Figure 3.2 - Average Bulk Carrier and Oil Tanker Size at Port of Geraldton, 2010 – 2017



Data source: AMSA

While the size of oil tankers has remained constant the size of bulk carriers has steadily increased. However, the average size of these vessels is relatively small compared to other regions, e.g. bulk carriers in Pilbara which can be up to three times as large.

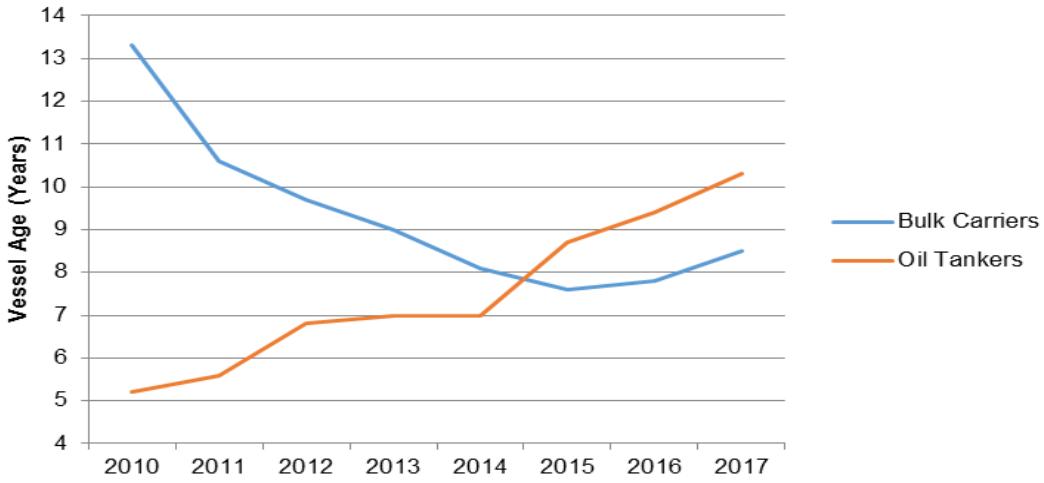
The Mid West Ports annual report states the following:

> *"Dead weight tonnage (DWT) of vessels calling to Geraldton Port has increased over the last seven years from 42,187 DWT to 56,453 DWT. In conjunction with Karara Mining, an initiative to gradually increase the size of ships handled within the harbour has been completed. A total of 168 ships with a LOA greater than 225m and 14 post Panamax ships greater than 230m LOA have been handled. A trial of ships up to 250m x 42m has been prepared for delivery."* (Mid West Ports 2016)

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 3.3 shows the average vessel age for bulk carriers and oil tankers visiting the Port of Geraldton. The average age of the bulk carrier fleet visiting the Port of Geraldton has decreased steadily over recent years. As seen in Figure 3.2 this has coincided with an increase in average size. Oil tankers have shown the opposite trend, with average age increasing from 5.2 years in 2010 to 10.3 years in 2017.

Figure 3.3 - Average Vessel Age, Bulk Carriers and Oil Tankers at Port of Geraldton, 2010 - 2017



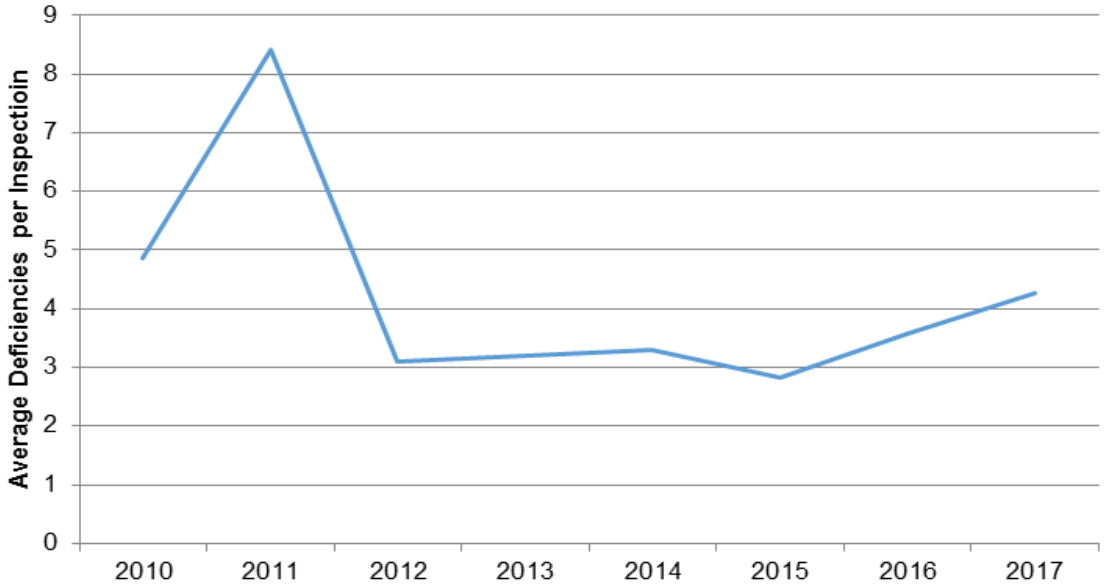
Data source: AMSA

Vessel Deficiencies

AMSA also collects data on the numbers of vessel deficiencies found by Port State Control and Flag State Control inspections. Over 90% of the inspections at the Port of Geraldton are directed towards bulk carriers. Figure 3.4 presents a view of the port. Figure 3.5 shows the average number of deficiencies found per inspection at the Port of Geraldton.

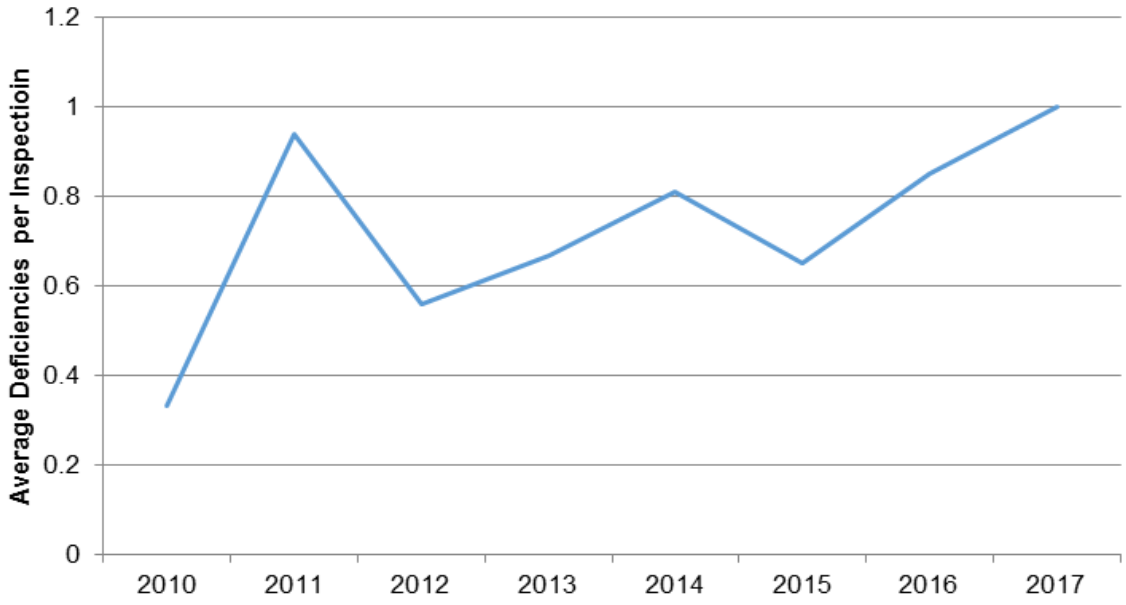
Figure 3.4 Satellite view of Port of Geraldton

Figure 3.5 Average Deficiencies per Inspection at Port of Geraldton



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 3.6 shows the average number of deficiencies per inspection categorised as 'Safety of Navigation' at the Port of Geraldton.

Figure 3.6 – Average 'Safety of Navigation' Deficiencies per Inspection at Port of Geraldton



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 Midwest coast. In particular large amounts of oil are moved by tankers offshore. A relatively small, but potentially significant, proportion of these vessels visit the Port of Geraldton or transit closer to shore. Figure 3.7 and Figure 3.8 show vessel tracks for medium and large tankers off the Western Australian coast.

Figure 3.7 - Medium Tankers

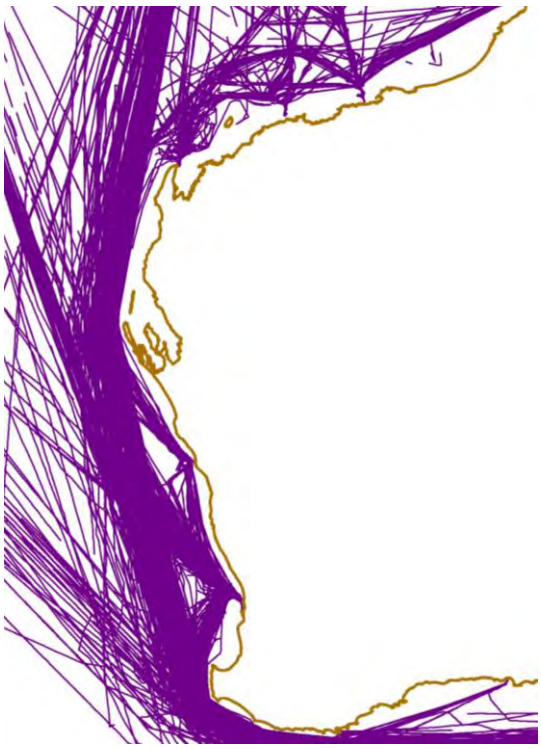
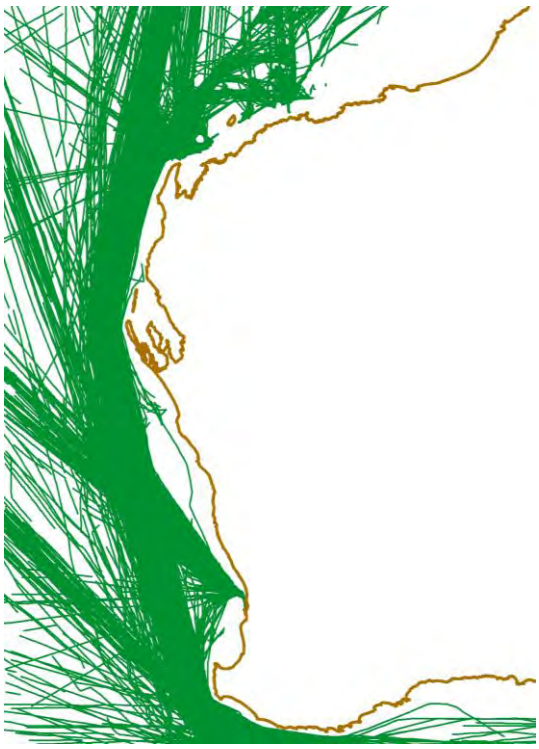


Figure 3.8 - Large Tankers



3.4. Port of Geraldton

The Port of Geraldton is the major port of the Midwest region.

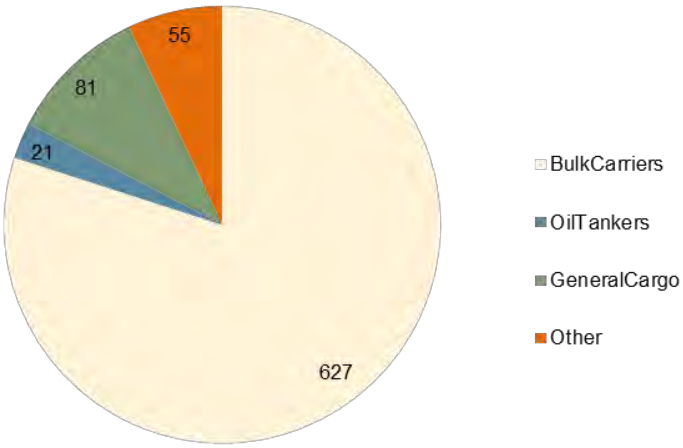
The maximum draughts of vessels that may enter this port are subject to conditions of swell and sea level. At times swells of up to 6m have been reported in the outer approaches. Northerly gales occur between May and November.

The dredged channel is 2.8 nautical miles long and 180m wide and there is a mean maximum tidal range of 0.5 metres (Figure 3.11).

Figure 3.9 – Image of nautical chart for approaches to Port Geraldton

As an indication of activity levels, Figure 3.10 shows the numbers of transits[1] by different vessel types. As with other major Western Australian ports, the Port of Geraldton is frequented by bulk carriers. There are also a small number of tanker visits, general cargo visits and other commercial vessel movements.

Figure 3.10 – Annual Vessel Transits to and from Port of Geraldton

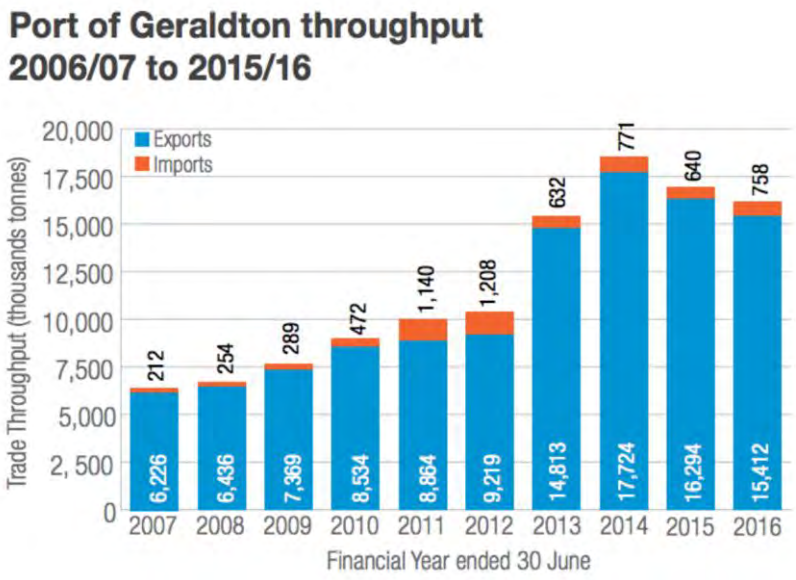


Iron ore dominates trade through the Port of Geraldton, representing 74 per cent of total trade. Other significant contributors to the overall trade result include grain (12 per cent), mineral sands (4 per cent) and concentrates (4 per cent). Imports to the Port of Geraldton primarily consist of fuel and mineral sands (both accounting for approximately 2 per cent of total trade each). Figure 3.11 shows a breakdown of trade throughput at the Port of Geraldton.

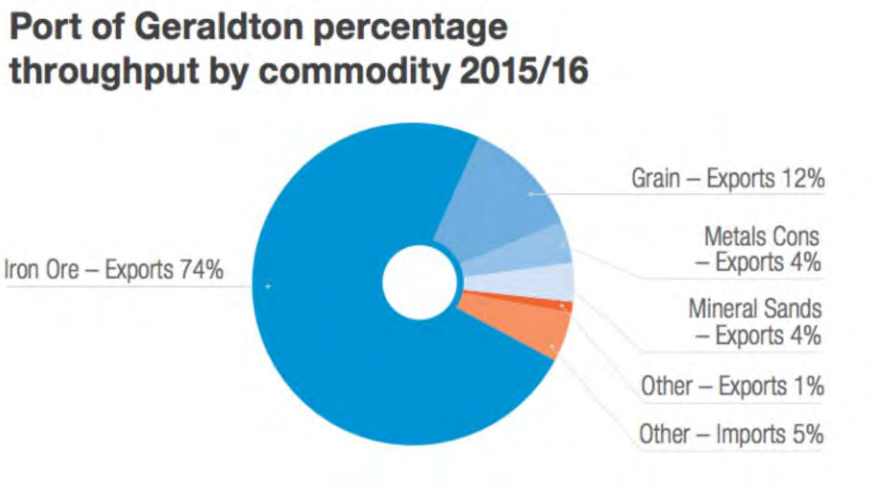
Midwest Port Authority

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

Figure 3.11 - Port of Geraldton Throughput



Source: (WA DoT 2016)



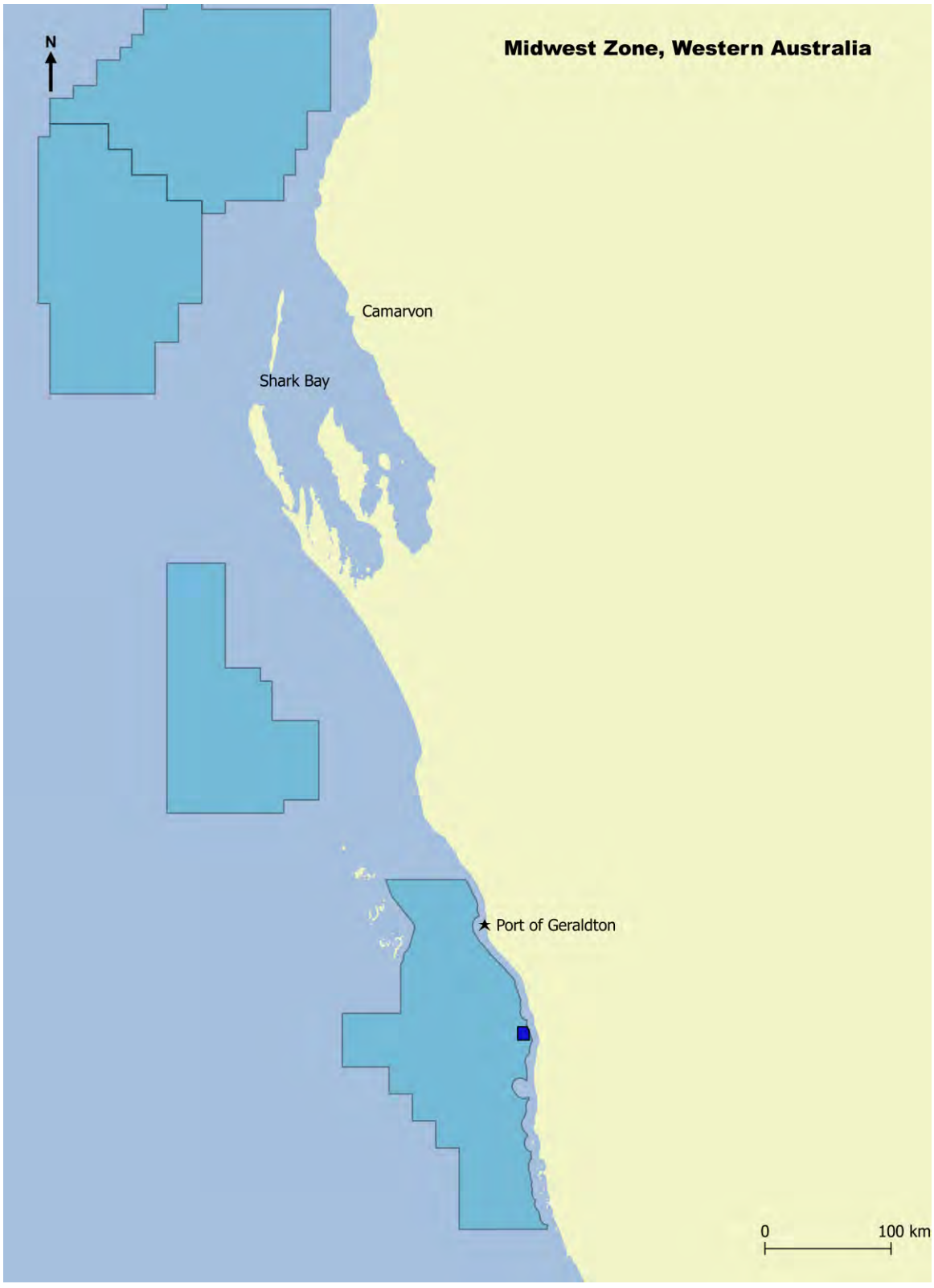
Source: (WA DoT 2016)

References: *(Australian Hydrographic Service & United Kingdom Hydrographic Office 2014; WA DoT 2016; Mid West Ports 2016; AMSA & WA DoT 2011; Geraldton Port Authority 2009)*

3.5. Petroleum Industry

There is a low level of petroleum industry activity in the Midwest zone compared to other areas such as Pilbara. Figure 3.12 shows active exploration and production permits in the Southern Carnarvon Basin and the Perth Basin (based on NOPTA petroleum titles released in November 2016).

Figure 3.12 - Active Exploration and Production Petroleum Titles



Key

Exploration Permit

Production Permit

Lower oil prices means exploration activity is currently suppressed in the whole of Western Australia. Statistics show that recovery in exploration activity is usually around 18 months after the recovery in oil prices. By this measure, even if the oil price were to recover in the short term, the low level of exploration is likely to continue (DMP 2017).

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 for each 'cell' within the model 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.[2]

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

4.4. Petroleum Industry

Western Australian petroleum producers were contacted with a request to provide data for the WAMOPRA. Operators were asked to fill out a questionnaire designed to gather information on offshore petroleum assets and activities. The primary focus was to capture the location, status and product type of offshore assets that each organisation operates. Operators were also asked to provide contextual comments relating activity levels at wells and the number of exploration and development wells drilled per year.

As mentioned above, the Stage Two assessment involved moving from public data sources of petroleum activities from prior years to acquisition of information directly from operators about current and future operations. Key differences from the data used in Stage One are:

[2] Expert mariners had good navigational knowledge of navigational hazards at the Geraldton Port.

- Product types are lighter than those originally input into the model. There is a greater proportion of facilities producing gas and condensate (Group I), as well as Group II oils. These oils are defined as dissolving and do not travel as far as Group III and Group IV oils. The change in oil types from the data used in the state-wide assessment may be due to the natural progression of fields over time as product is extracted. The Wheatstone LNG project also means there are more gas facilities coming on board. These have been included in the current analysis.
- Some producing facilities have been decommissioned or suspended. This is due to a combination of lower oil prices and facilities being towards the end of their producing lifespan.
- There was a notable reduction in exploration activity compared to the public data sets used in Stage One which were based on earlier years. This is a result of three years of lower oil prices. As noted in Section 3.5 exploration activity tends to rebound around 18 months after oil prices recover. Therefore, the profile resulting from these inputs remains relevant for the near to medium term future.

Data was obtained from operators on the basis that individual operators would not be identified in the outputs of this study due to commercial sensitivities.

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.

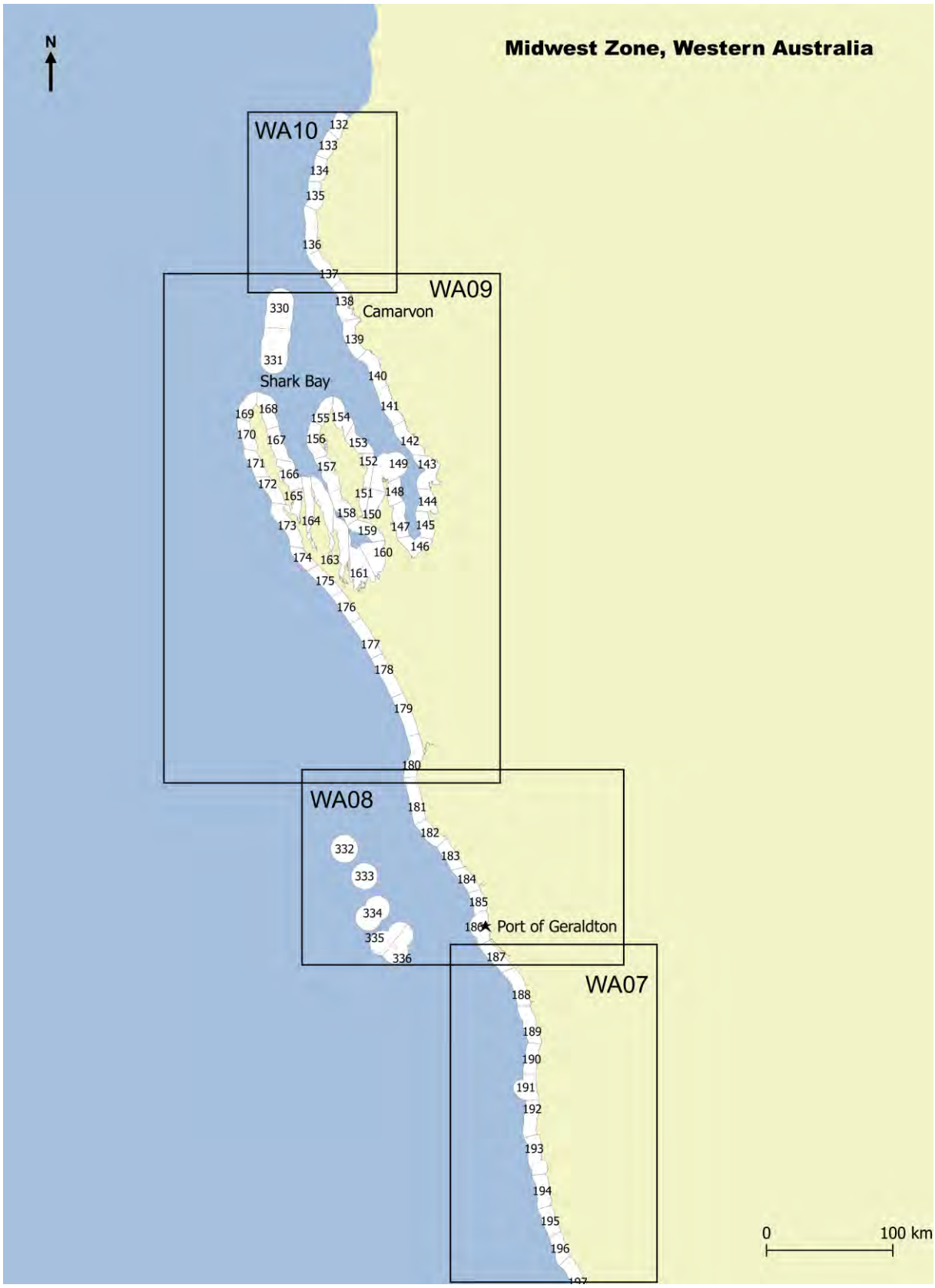
Shoreline cells are used for visualising shoreline risk and exposure. The shoreline cell layer consists of cells which are 20km long (along the coast) by 10km wide (seaward extent) and which are compliant with shoreline features and shape.

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 73 shoreline cells in the Midwest region. For the purposes of this report, shoreline cells are also grouped into four ‘sub-zones’ to facilitate comparisons between wider areas in the Midwest zone.

The four sub-zones from South to North are: WA07, WA08, WA09 and WA10. The shoreline cells and sub-zones within the Midwest zone are shown in Figure 5.1 below.

Figure 5.1 - Midwest Shoreline Cells and Sub-Zones



The cells representing open water ocean areas are formed by a hexagon (10km) grid. 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.

This grid system 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. A list of the cell identifying numbers and names for cells in the Midwest zone are given in Table 5.1.

Table 5.1 – Cell identity numbers to names listing

Cell ID	Cell Name	Cell ID	Cell Name
132	Gnarraloo Bay - Alison Point (B)	171	Steep Point - Quoin Head (C)
133	Red Bluff - Gnarraloo Bay (A)	172	Steep Point - Quoin Head (D)
134	Red Bluff - Gnarraloo Bay (B)	173	Steep Point - Quoin Head (E)
135	Red Bluff - Gnarraloo Bay (C)	174	Kakura Dunes coast - Zuytdorp Point (A)
136	Point Quobba - Cape Cuvier (A)	175	Kakura Dunes coast - Zuytdorp Point (B)
137	Point Quobba - Cape Cuvier (B)	176	Kakura Dunes coast - Zuytdorp Point (C)
138	South Bejaling Hill - Point Quobba	177	Kakura Dunes coast - Zuytdorp Point (D)
139	West Side Creek - South Bejaling Hill	178	Nunginjay Spring coast N - Kakura Dunes coast (A)
140	Grey Point - West Side Creek	179	Nunginjay Spring coast N - Kakura Dunes coast (B)
141	Wooramel coast - Grey Point (A)	180	Nunginjay Spring coast N - Kakura Dunes coast (C)
142	Wooramel coast - Grey Point (B)	181	Broken Anchor Bay - Shoal Point (A)
143	Kopke Point S - Wooramel coast	182	Broken Anchor Bay - Shoal Point (B)
144	Yaringa Point - Kopke Point S (A)	183	Broken Anchor Bay - Shoal Point (C)
145	Yaringa Point - Kopke Point S (B)	184	Bowes River - Little Bay
146	Booldah well - Nilemah coast E	185	Coronation Beach - Bowes River
147	Petit Point - Booldah well (A)	186	Glenfield Beach - Coronation Beach
148	Petit Point - Booldah well (B)	187	9 Mile Beach - Head Butts (A)
149	Taillefer Spit - Petit Point	188	9 Mile Beach - Head Butts (B)
150	Monkey Mia - Taillefer Spit (A)	189	White Point - Leander Point
151	Monkey Mia - Taillefer Spit (B)	190	Cliff Head - White Point
152	Monkey Mia - Taillefer Spit (C)	191	Illawong - Cliff Head
153	Monkey Mia - Taillefer Spit (D)	192	Leeman - Coolimba
154	Middle Bluff - Cape Peron North (A)	193	Green Head - Leeman
155	Middle Bluff - Cape Peron North (B)	194	Booker Valley - Island Point
156	Goulet Bluff - Middle Bluff (A)	195	Thirsty Point - Booker Valley
157	Goulet Bluff - Middle Bluff (B)	196	Grey - Thirsty Point
158	Goulet Bluff - Middle Bluff (C)	197	Wedge Island point - Grey
159	Goulet Bluff - Middle Bluff (D)		
160	Fording Point - Goulet Bluff	330	Dorre Island and Bernier Island (A)
161	Cararang Peninsular N point - Giraud Point	331	Dorre Island and Bernier Island (B)
162	Cape Heirisson - Cararang Peninsular N point	332	Bowes River - Broken Anchor Bay (A)
163	Goulet Bluff - Middle Bluff (E)		
164	Goulet Bluff - Middle Bluff (F)	333	Bowes River - Broken Anchor Bay (B)
165	Steep Point - Quoin Head (A)	334	Glenfield Beach - Bowes River (A)
166	Herald Bay N - Tumbledown Point (A)	335	Glenfield Beach - Bowes River (B)
167	Herald Bay N - Tumbledown Point (B)	336	Glenfield Beach - Bowes River (C)
168	Cape Inscription - Herald Bay N (A)		
169	Cape Inscription - Herald Bay N (B)		
170	Steep Point - Quoin Head (B)		

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

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.

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 6.3 and Figure 6.4. 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 Midwest region is not shown.

Figure 6.1 – Physical Hazard Ratings

The low physical hazard rating across the region reflects the simple coast form and general lack of hazards that would not be expected by a competent mariner. Aside from the natural hazards of the coastline close to shore, the only key hazardous area is created by the reefs and islets of the Houtman Abrolhos archipelago (See Figure 6.2).

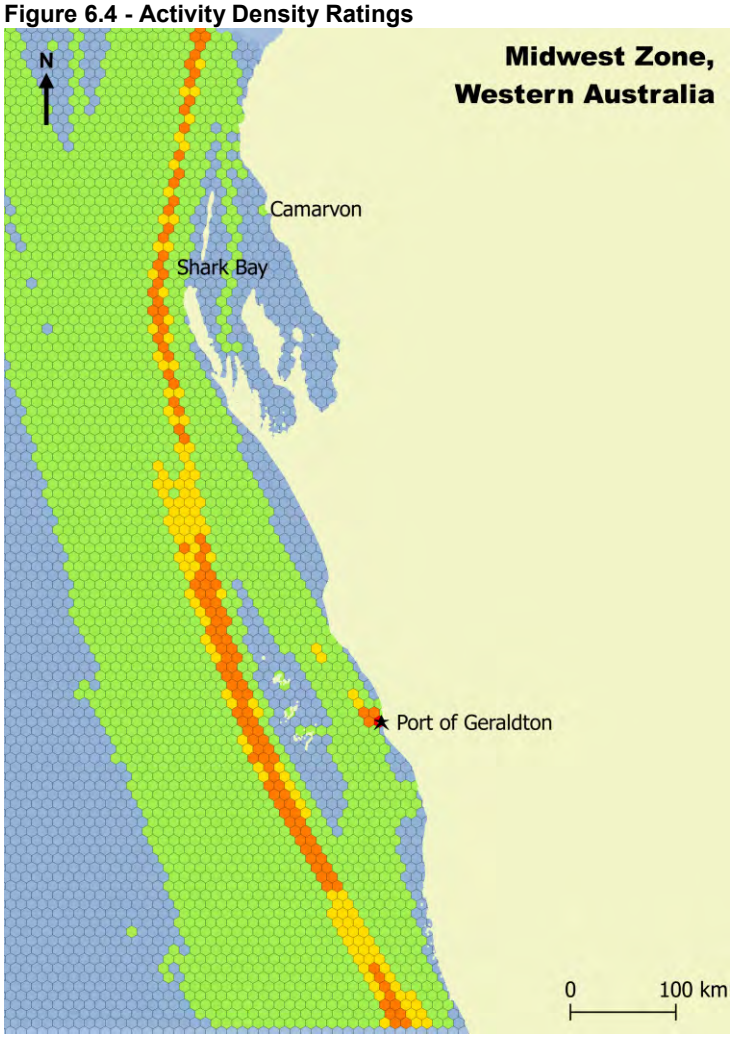
Figure 6.2 – Ariel view of part of the Houtman Abrolhos archipelago

Figure 6.3 – Complexity Ratings

The northern part of the region includes Shark Bay. Although relatively shallow, the bay has been rated of low complexity due to the fairly consistent depth and reasonable sea room.

However, the immediate area of the small port of Carnarvon has been rated Moderate complexity factor to reflect a mix of commercial fishing activity and recreational craft together with reports of shifting sand banks and hence channel marking not necessarily being correct.

Figure 6.4 - Activity Density Ratings



The activity density rating reflects the recorded level of activity. It is evident that most of the rating is driven by the passing off-shore traffic, while the traffic to and from Geraldton is evident. Limited activity is seen in Shark Bay and at Carnarvon.

Overall Navigational Hazard

The combination of the three factors produces an overall rating as described in Section 5.3. This overall calculated navigational hazard rating is shown in Figure 6.5 and a brief description of the driving factors for the major port area is provided below.

Figure 6.5 - Overall Navigational Hazard Ratings

Contextual comments for the Port of Geraldton can be found in Section 3.4. Overall the Port of Geraldton does not pose significant 'out of the ordinary' navigational challenges. Navigational hazard ratings for the Port of Geraldton and approaches are primarily driven by the complexity inherent in any port operation and access by dredged channel. The offshore navigational hazard ratings are driven by activity density from ships transiting offshore past the region.

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 6.6 shows the shoreline exposure profile for the Midwest zone. The numbering and naming of these cells is given in Table 5.1.

Figure 6.6 - Shoreline Exposure

Key for Exposure

Lowest — Highest

Figure 6.7 shows the proportion of shoreline exposure generated by each spill size band. The majority of oil expected to arrive at the Midwest 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 6.7 – Proportion of Shoreline Exposure by Spill Size (tonnes)

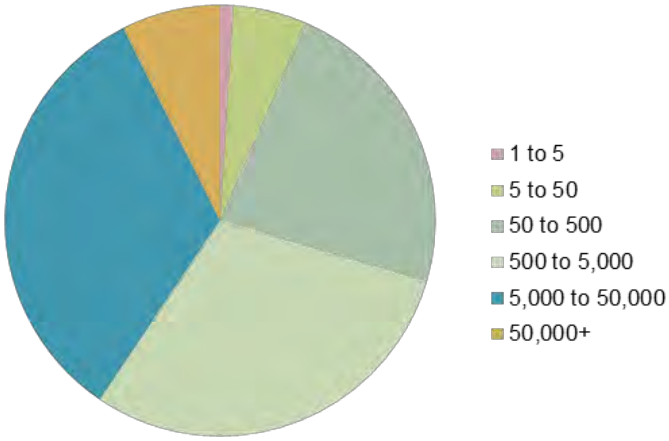


Figure 6.8 is similar to the above in that it shows the proportion of shoreline exposure generated by each spill size band. However, this measure of exposure is further broken down by sub-zone.

Figure 6.8 – Midwest Shoreline Exposure by Spill Size (tonnes) and Sub-Zone

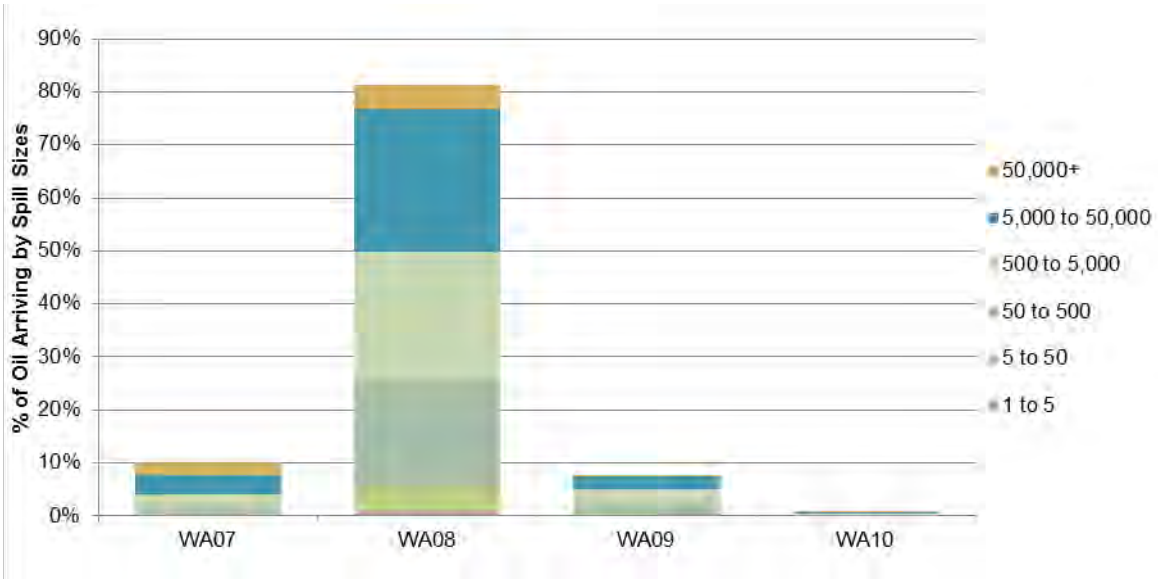
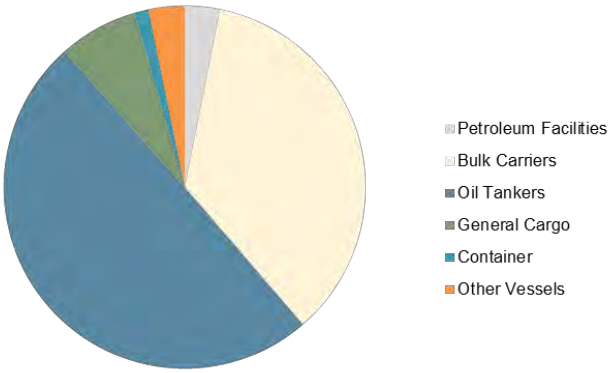


Figure 6.9 shows the proportion of shoreline exposure generated by each spill source. About half of the oil statistically expected to arrive at the Midwest shoreline is due to potential spills from oil tankers transiting off the coast. Bulk carriers represent the next highest source of shoreline exposure.

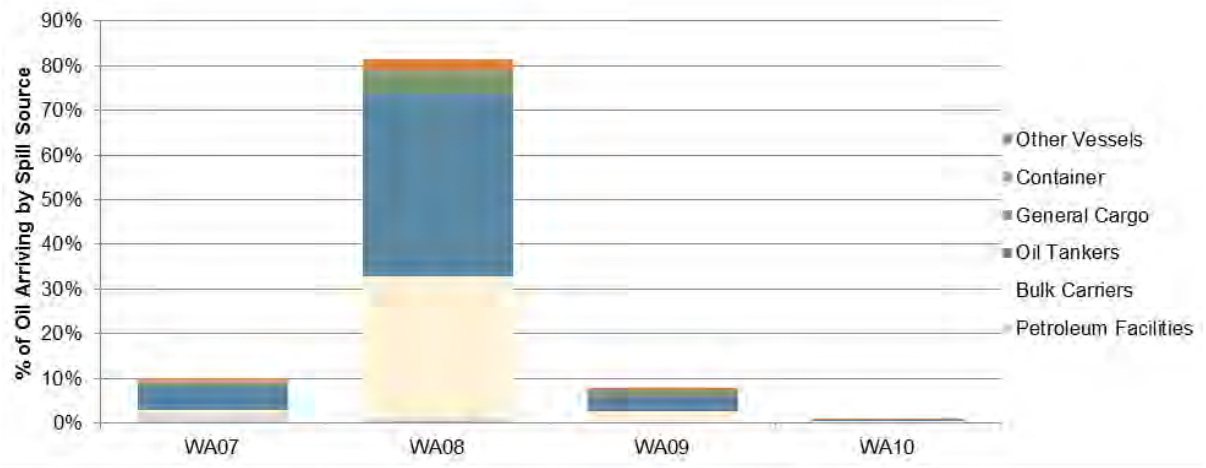
Figure 6.9 – Proportion of Shoreline Exposure by Source (tonnes)



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

Figure 6.10 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 sub-zone.

Figure 6.10 – Midwest Shoreline Exposure by Source and Sub-Zone



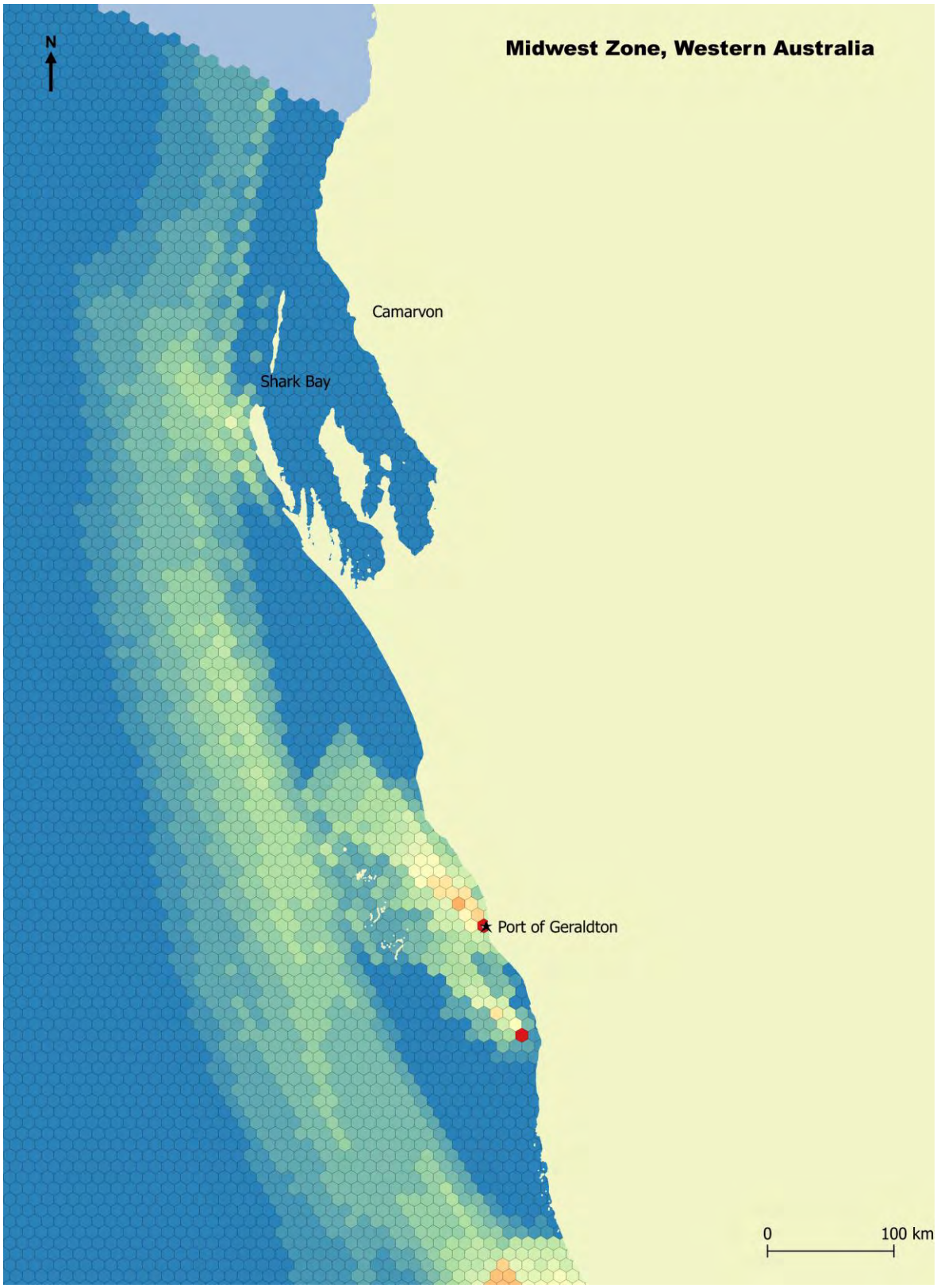
In the WA08 sub-zone exposure is primarily driven by the potential for large spills from oil tankers transiting offshore and occasionally visiting the Port of Geraldton. The potential for medium sized spills from the bulk carriers visiting the Port of Geraldton is another key driver of exposure. There is very low shoreline exposure throughout most of the Midwest zone (WA07, WA09 and WA10).

There is a low level of petroleum production and exploration activity in the Midwest zone as discussed in Section 3.5.

Sea Cell Exposure

Figure 6.11 shows the exposure profile for the hexagon sea cells within the Midwest zone. No data is shown for areas outside the Midwest zone.

Figure 6.11 - Exposure Profile



Key for Exposure

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

Figure 6.12 – Proportion of Hexagon Cell Exposure by Spill Size (tonnes)

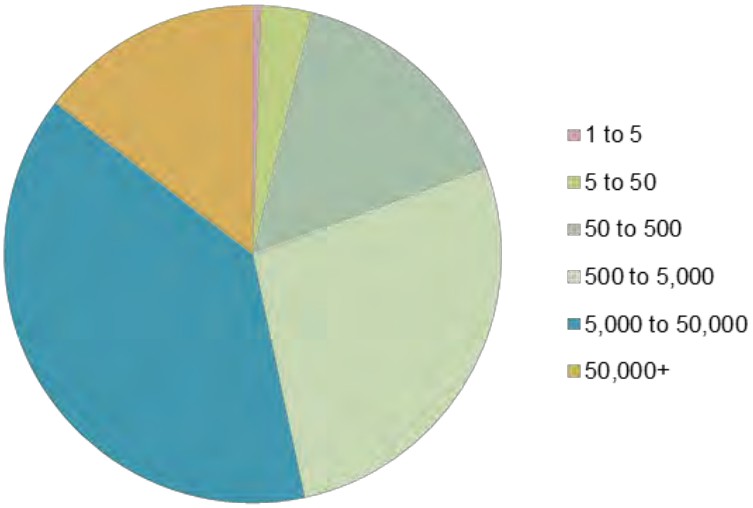
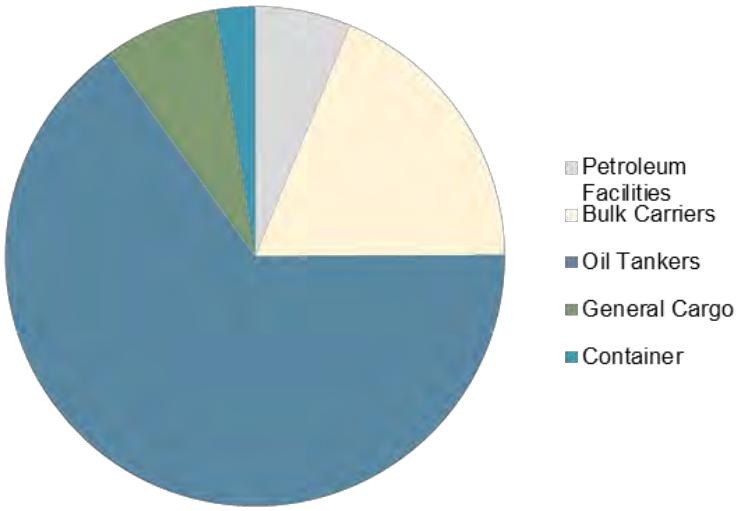


Figure 6.13 shows the proportion of offshore exposure generated by each spill source.

Figure 6.13 – Proportion of Hexagon Cell Exposure by Source (tonnes)



The majority of exposure in the Midwest zone is due to the potential for rare but large spills from oil tankers. These spills are more likely to occur a significant distance from the shore.

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

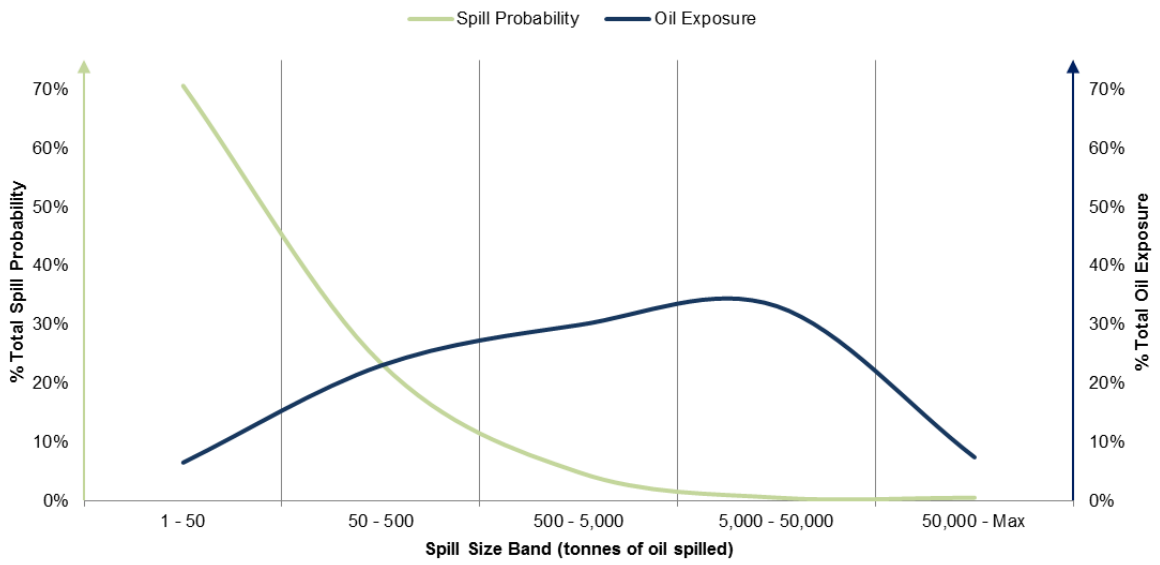
Exposure and Probability

The previous sections find that oil spill exposure in the Midwest region 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 Midwest region is statistically likely to come from larger incidents.

This is conceptually illustrated in Figure 6.14. 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 6.14 – 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.

The flatness of the Midwest exposure curve is notable when compared to the more ‘peaked’ curve in the Pilbara region.

Nevertheless spill responders are faced 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 6.15 shows the overall rating for Protection Priorities in the Midwest zone. This figure shows shoreline cells (read from North to South). Table 5.1 lists these cells by name:

A sample of protection priority data is shown for the major port 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 Geraldton. 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 Port of Geraldton 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 Sub-Zone Drill Down sections of this report. The Midwest zone report prepared by Advisian for the Department of Transport (Advisian 2017) should be consulted for more context and information.

Figure 6.15 - Protection Priorities Overall Ratings

Key

Very Low	Low	Moderate	High	Very High

Table 6.1 – Sample of Protection Priorities at Geraldton (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	**Moderate**	**Low**	**Moderate**	Birds: Sterna nereis nereis (Fairy Tern) (VU) Known to occur in the area (vouchered), Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding likely to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding likely to occur within area, Cyclodomorphus branchialis (common slender blue-tongue) (VU) Known to occur in the area Mammals: Neophoca cinerea (Australian sea-lion) (VU) Known to occur in the area (sighting), Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Invertebrates: Idiosoma nigrum (shield-backed trapdoor spider) (VU) Known to occur in the area Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area	DotE SNES (22 February 2017), DPaW Protected Fauna (2 March 2017), DotE BIA (26 April 2016)
Protection Areas	**High**	**Moderate**	**High**	Nature Reserve (Unnamed WA33799) (IUCN IA)	DotE CAPAD - Terrestrial and Marine (30 June 2014) with DPaW update (30 June 2016)
Cultural Heritage	**Moderate**	**Moderate**	**Moderate**	Cmlth Protected Shipwreck: African, Bertha, Betty Robin, Geraldton unidentified barge, Hampton, Maybelle, Mayhill, Ocean Queen, Samson II, Sleeping Beauty, South Tomi, Unidentified Lighter 1, Unidentified Lighter Boat, Victory, African (Sunset Beach wreck)	DotE Australian National Shipwrecks Database (3 February 2016)
Economic	**Moderate**	**Moderate**	**Moderate**	Port: Geraldton Port	DPI Port Authorities (25 October 2010)
Social Amenity and Recreation	**Very Low**	**Very Low**	**Very Low**	Beach: Champion Bay, Geraldton	Surf Lifesaving WA Beach data (18 April 2016)
Overall	**High**	**Moderate**	**High**	Nature Reserve (Unnamed WA33799) (IUCN IA)	DotE CAPAD - Terrestrial and Marine (30 June 2014) with DPaW update (30 June 2016)

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

6.4. Midwest Risk Profile Results

This section contains the main risk results for the Midwest zone. Figure 6.16 shows a heat map of risk ratings in each of the Midwest zone shoreline cells. Numbering and names of the shoreline cells are given before in Table 5.1.

Risk ratings in the heat map in Figure 6.16 are determined relative to the risk score in the highest shoreline cell.

Figure 6.17 shows a column chart of relative risk[3] scores for each of the shoreline cells. The striped column represents shoreline cell #186 (Glenfield Beach – Coronation Beach), the cell with the highest risk score. It is important when interpreting this chart that the use of a log scale for the vertical axis is noted. Compared to cell #186, no other cell reaches 10% of that risk level and only 23 cells exceed 1% of the risk level of that for cell #186.

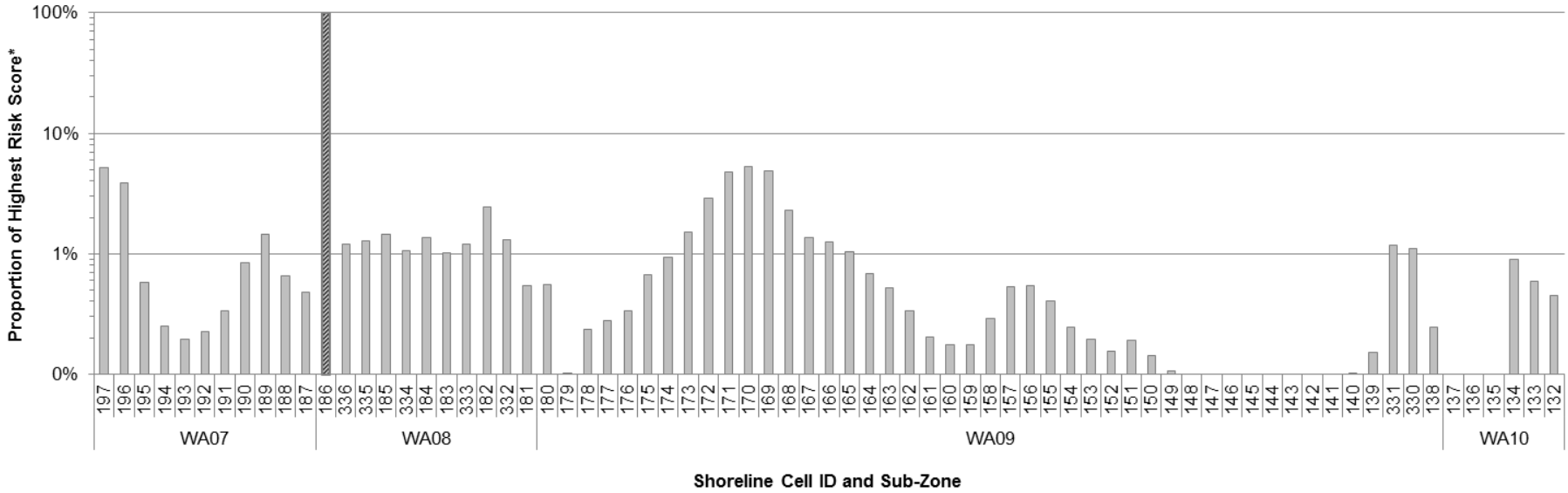
[3] The relative risk scores presented in Figure 6.17 are indexed to the highest cell in the Midwest Zone and so are not directly comparable to other zones. However, in general the risk results are presented relative across all zones (for example, the risk as shown in the heat maps).

Figure 6.16 - Midwest Risk Profile Heat Map

Key

Very Low	Low	Moderate	High	Very High

Figure 6.17 - Midwest Risk Profile Relative Risk Scores



* Note use of log scale.

The cells with the highest risk levels are:

1. ID #186 *Port of Geraldton* (Glenfield Beach - Coronation Beach)
2. ID #170 (Steep Point - Quoin Head (B))
3. ID #197 (Wedge Island point – Grey)

Note: Names of the shoreline cells as numbered in the chart are as given in Table 5.1.

6.5. Sub-Zone Drill Down

Overview

The following sections contain a brief drill-down summary on each of the four sub-zones within the Midwest zone (refer Section 5.2 for definition of sub-zones).

Cell counts and heat maps are presented for each of the sub-zones. A summary table is also presented for each sub-zone. The key benefit of these tables 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.

WA07 Sub-Zone Summary

The WA07 Sub-Zone begins south of Geraldton Port and includes Dongara, Leeman, Green Head, Jurien Bay, Cervantes, and ends at Lancelin in the north.

Figure 6.18 shows the count of each cell rating within the WA07 Sub-Zone. Figure 6.19 depicts these cell ratings on a heat map.

Figure 6.18 – WA07 Sub-Zone Cell Counts

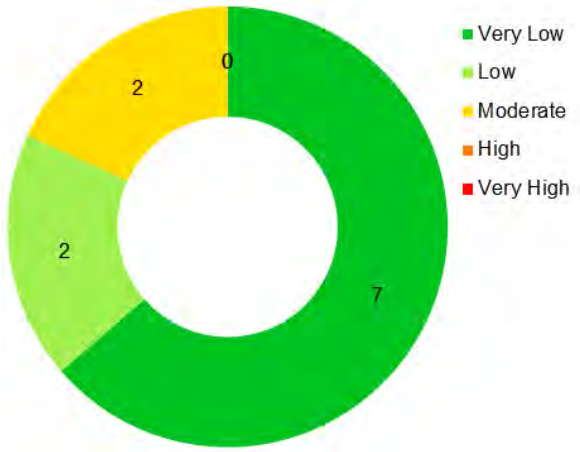
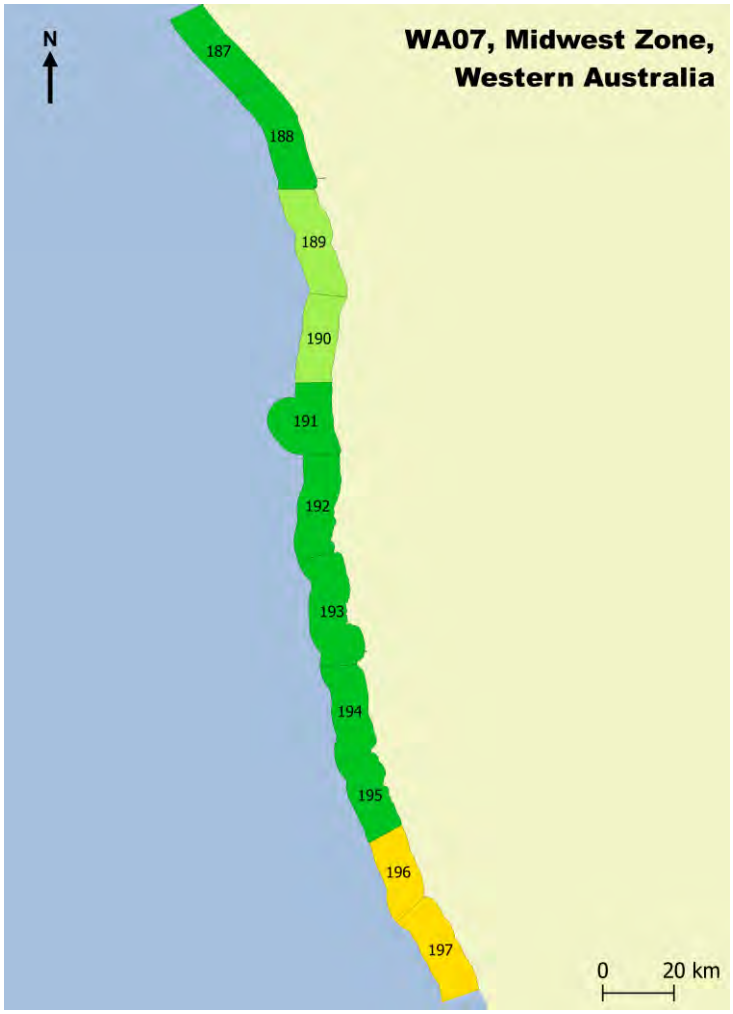


Figure 6.19 – WA07 Sub-Zone Risk Profile



Despite high levels of environmental sensitivity the overall risk in this sub-zone is low. The table on the following page summarises risk and protection priority information for this sub-zone.

WA07 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
187	9 Mile Beach - Head Butts (A)	Very Low		Moderate					N/A	*Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding likely to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding likely to occur within area Mammals: Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*
188	9 Mile Beach - Head Butts (B)	Very Low		High					N/A	*Birds: Anous tenuirostris melanops (Australian lesser noddy) (EN) Known to occur*	*Petroleum Facilities, Oil Tankers, Bulk Carriers*
189	White Point - Leander Point	Low		High						*Nature Reserve (Beekeepers) (IUCN IA)*	*Petroleum Facilities*
190	Cliff Head - White Point	Low		High					N/A	*Nature Reserve (Beekeepers) (IUCN IA), Seagrass*	*Petroleum Facilities*
191	Illawong - Cliff Head	Very Low		High					N/A	*Nature Reserve (Beagle Islands) (IUCN IA), Seagrass*	*Petroleum Facilities, Oil Tankers, Bulk Carriers*
192	Leeman - Coolimba	Very Low		High						*Nature Reserve (Beekeepers) (IUCN IA), Seagrass*	*Oil Tankers, Bulk Carriers, Petroleum Facilities, General Cargo*
193	Green Head - Leeman	Very Low		High						*Fish: Carcharias taurus (grey nurse shark) (VU) Known to occur Mammal: Parantechinus apicalis (Dibbler) (EN) Known to occur, certain*	*Oil Tankers, General Cargo, Bulk Carriers, Container*
194	Booker Valley - Island Point	Very Low		High						*Fish: Carcharias taurus (grey nurse shark) (VU) Known to occur Mammal: Parantechinus apicalis (Dibbler) (EN) Known to occur, certain*	*Oil Tankers, General Cargo, Bulk Carriers, Container*
195	Thirsty Point - Booker Valley	Very Low		High						*Marine Park (Jurien Bay)(IUCN IA), Nature Reserve (Boullanger, Whitlock, Favourite, Tern And Osprey Islands) (IUCN IA)*	*Oil Tankers, General Cargo, Container, Bulk Carriers*
196	Grey - Thirsty Point	Moderate		High						*Marine Park (Jurien Bay)(IUCN IA), Nature Reserve (Boullanger, Whitlock, Favourite, Tern And Osprey Islands) (IUCN IA)*	*Oil Tankers, Container, General Cargo*
197	Wedge Island point - Grey	Moderate		High						*Birds: Calyptorhynchus latirostris (Carnaby's cockatoo) (EN) Known to occur (Certain)*	*Oil Tankers, Container*

Key for Risk and Protection Priorities

Very Low	Low	Moderate	High	Very High

Key for Exposure

Lowest — Highest

WA08 Sub-Zone Summary

The WA08 Sub-Zone begins at Geraldton Port to the south and extends to Kalbarri National Park to the north.

Figure 6.20 shows the count of each cell rating within the WA10 sub-zone. Figure 6.21 depicts these cell ratings on a heat map.

Figure 6.20 – WA08 Sub-Zone Cell Counts

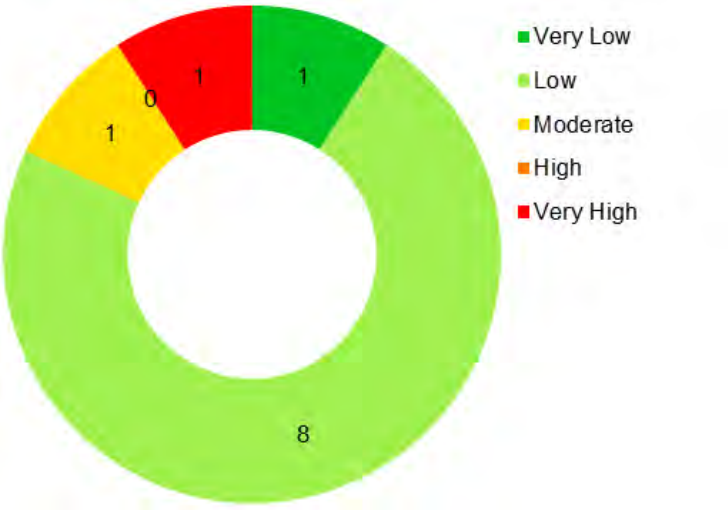
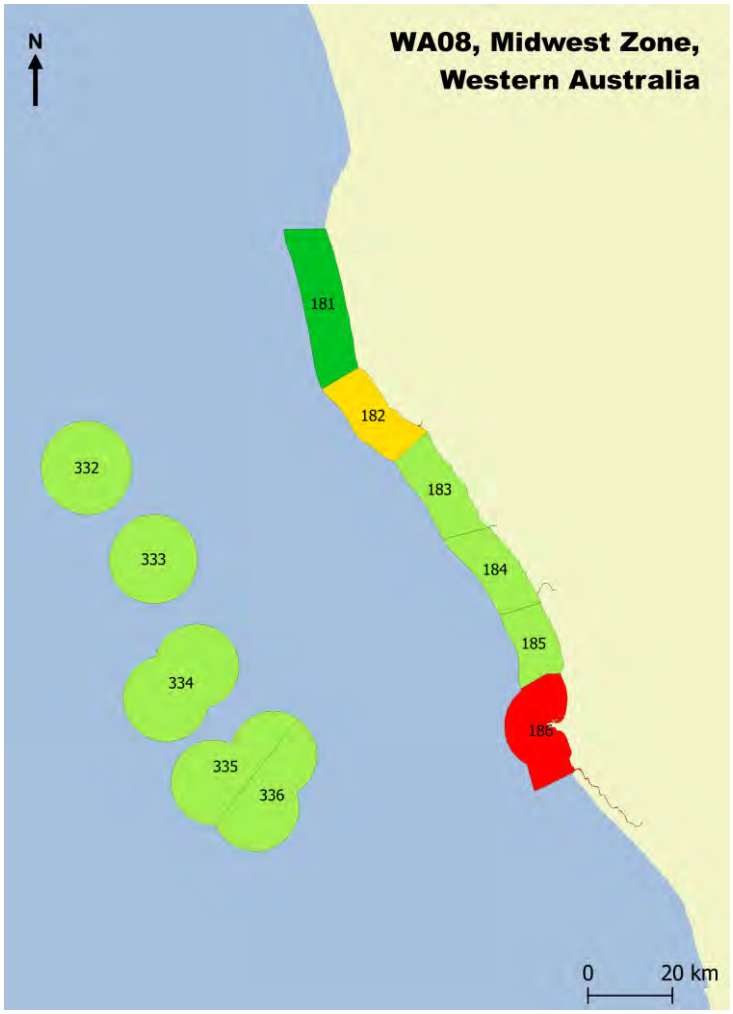


Figure 6.21 – WA08.West Sub-Zone Risk Profile



The risk in this sub-zone is driven by activity and high protection priorities at the Port of Geraldton (ID 186). The table on the following page summarises the risk and protection priority information for this sub-zone.

WA08 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
181	Broken Anchor Bay - Shoal Point (A)	**Very Low**		**Moderate**					*N/A*	*Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding, known to occur within area, Mammals: Bettongia penicillata ogilbyi (woylie, brush-tailed bettong) (CR) Specimen certain (WAM Vouchered), Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Bulk Carriers, Oil Tankers, General Cargo*
182	Broken Anchor Bay - Shoal Point (B)	**Moderate**		**High**					*N/A*	*Birds: Calidris ferruginea (Curlew Sandpiper) (CR) Species or species habitat known to occur within area, Numenius madagascariensis (Eastern Curlew) (CR) Species or species habitat known to occur within area*	*Bulk Carriers, Oil Tankers*
183	Broken Anchor Bay - Shoal Point (C)	**Low**		**Moderate**					*N/A*	*Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding, known to occur within area, Mammals: Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Bulk Carriers, Oil Tankers*
184	Bowes River - Little Bay	**Low**		**Moderate**					*N/A*	*Birds: Calyptorhynchus baudinii (Baudin's cockatoo) (EN) Observed to be likely to occur within area, Thalassarche melanophris (black browed albatross) (EN) Likely to be observed within the area Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding, known to occur within area, Mammals: Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Oil Tankers, Bulk Carriers*
185	Coronation Beach - Bowes River	**Low**		**Moderate**					*N/A*	*Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding, known to occur within area, Mammals: Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Oil Tankers, Bulk Carriers*

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
186	Glenfield Beach - Coronation Beach	Very High		High						*Nature Reserve (Unnamed WA33799) (IUCN IA)*	*Oil Tankers, Bulk Carriers*
332	Bowes River - Broken Anchor Bay (A)	Low		High						*Birds: Anous tenuirostris melanops (Australian lesser noddy) (EN) Known to occur in the area, Turnix varius scintillans (Abrolhos painted button-quail) (EN) Known to occur in the area*	*Oil Tankers, Bulk Carriers*
333	Bowes River - Broken Anchor Bay (B)	Low		High						*Birds: Turnix varius scintillans (Abrolhos painted button-quail) (EN) Known to occur in the area*	*Oil Tankers, Bulk Carriers, Petroleum Facilities*
334	Glenfield Beach - Bowes River (A)	Low		High						*Birds: Anous tenuirostris melanops (Australian lesser noddy) (EN) Known to occur in the area, Turnix varius scintillans (Abrolhos painted button-quail) (EN) Known to occur in the area*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*
335	Glenfield Beach - Bowes River (B)	Low		High						*A-Class Fish Reserve*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*
336	Glenfield Beach - Bowes River (C)	Low		High						*Birds: Anous tenuirostris melanops (Australian lesser noddy) (EN) Known to occur in the area*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

WA09 Sub-Zone Summary

The WA09 Sub-Zone begins at Kalbarri in the south and stretches to Carnarvon in the north.

Figure 6.22 shows the count of each cell rating within the WA09 sub-zone and Figure 6.23 depicts these cell ratings on a heat map.

Figure 6.22 – WA09 Sub-Zone Cell Counts

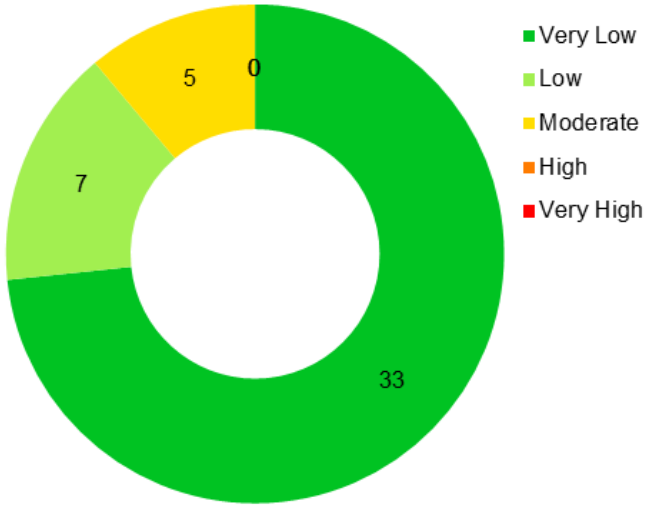


Figure 6.23 – WA09.East Sub-Zone Risk Profile

Despite very high protection priorities in this sub-zone, exposure is relatively low, resulting in low-moderate risk levels. The table on the following page summarises the risk and protection priority information for this sub-zone.

WA09 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
138	South Bejaling Hill - Point Quobba	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers*
139	West Side Creek - South Bejaling Hill	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers*
140	Grey Point - West Side Creek	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers*
141	Wooramel coast - Grey Point (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers*
142	Wooramel coast - Grey Point (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers*
143	Kopke Point S - Wooramel coast	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
144	Yaringa Point - Kopke Point S (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
145	Yaringa Point - Kopke Point S (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
146	Booldah well - Nilemah coast E	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
147	Petit Point - Booldah well (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
148	Petit Point - Booldah well (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
149	Taillefer Spit - Petit Point	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
150	Monkey Mia - Taillefer Spit (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
151	Monkey Mia - Taillefer Spit (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
152	Monkey Mia - Taillefer Spit (C)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
153	Monkey Mia - Taillefer Spit (D)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
154	Middle Bluff - Cape Peron North (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
155	Middle Bluff - Cape Peron North (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
156	Goulet Bluff - Middle Bluff (A)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
157	Goulet Bluff - Middle Bluff (B)	**Very Low**		**Very High**						*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*

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
158	Goulet Bluff - Middle Bluff (C)	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
159	Goulet Bluff - Middle Bluff (D)	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
160	Fording Point - Goulet Bluff	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
161	Cararang Peninsular N point - Giraud Point	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
162	Cape Heirisson - Cararang Peninsular N point	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
163	Goulet Bluff - Middle Bluff (E)	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
164	Goulet Bluff - Middle Bluff (F)	Very Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
165	Steep Point - Quoin Head (A)	Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
166	Herald Bay N - Tumbledown Point (A)	Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
167	Herald Bay N - Tumbledown Point (B)	Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
168	Cape Inscription - Herald Bay N (A)	Moderate		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
169	Cape Inscription - Herald Bay N (B)	Moderate		Very High						*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
170	Steep Point - Quoin Head (B)	Moderate		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
171	Steep Point - Quoin Head (C)	Moderate		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
172	Steep Point - Quoin Head (D)	Moderate		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
173	Steep Point - Quoin Head (E)	Low		Very High						*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
174	Kakura Dunes coast - Zuytdorp Point (A)	Low		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
175	Kakura Dunes coast - Zuytdorp Point (B)	Very Low		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Bulk Carriers, Oil Tankers, General Cargo*
176	Kakura Dunes coast - Zuytdorp Point (C)	Very Low		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
177	Kakura Dunes coast - Zuytdorp Point (D)	Very Low		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
178	Nunginjay Spring coast N - Kakura Dunes coast (A)	Very Low		Very High					*N/A*	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*

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
179	Nunginjay Spring coast N - Kakura Dunes coast (B)	Very Low		Moderate			N/A		N/A	*Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding, known to occur within area, Mammals: Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area*	*Oil Tankers, Bulk Carriers*
180	Nunginjay Spring coast N - Kakura Dunes coast (C)	Very Low		High						*Important Wetland (Murchison River (Lower Reaches))*	*Oil Tankers, Bulk Carriers*
330	Dorre Island and Bernier Island (A)	Low		Very High					N/A	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*
331	Dorre Island and Bernier Island (B)	Low		Very High					N/A	*World Heritage (Shark Bay, Western Australia)*	*Oil Tankers, Bulk Carriers, General Cargo*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

WA10 Sub-Zone Summary

The WA10 Sub-Zone begins in the south at the bottom of Lake Macleod and ends near the top of Lake Macleod.

Figure 6.24 shows the cell counts for each risk rating in this sub-zone and Figure 6.25 depicts these cell ratings on a heat map.

Figure 6.24 - WA10 Sub-Zone Cell Counts

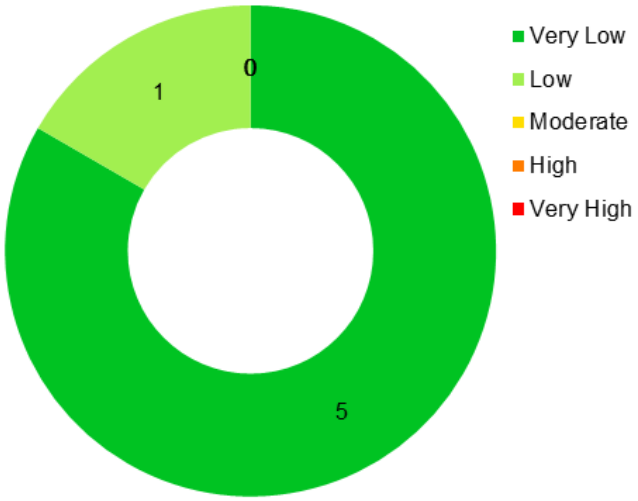


Figure 6.25 – WA10 Sub-Zone Risk Profile

The table on the following page summarises the risk and protection priority information for this sub-zone.

WA10 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
132	Gnarraloo Bay - Alison Point (B)	**Very Low**		**Very High**						*World Heritage (The Ningaloo Coast)*	*Oil Tankers, Petroleum Facilities, Bulk Carriers*
133	Red Bluff - Gnarraloo Bay (A)	**Very Low**		**Very High**						*World Heritage (The Ningaloo Coast)*	*Oil Tankers, Bulk Carriers, Petroleum Facilities*
134	Red Bluff - Gnarraloo Bay (B)	**Low**		**Very High**						*World Heritage (The Ningaloo Coast)*	*Bulk Carriers, Oil Tankers*
135	Red Bluff - Gnarraloo Bay (C)	**Very Low**		**Moderate**						*Reptiles: Aipysurus apraefrontalis (Short-nosed Seasnake) (CR) Species or species habitat likely to occur within area, Caretta caretta (Loggerhead Turtle) (EN) Breeding likely to occur within area, Chelonia mydas (Green Turtle) (VU) Breeding, congregation, aggregation known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding likely to occur within area, Natator depressus (Flatback Turtle) (VU) Breeding known to occur within area Mammals: Megaptera novaeangliae (Humpback Whale) (VU) Congregation or aggregation known to occur within area, Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Pristis zijsron (Narrowsnout Sawfish) (VU) Breeding likely to occur within area, Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area, Carcharias taurus (Grey Nurse Shark) (VU) Species or species habitat known to occur within area,*	*Bulk Carriers, Oil Tankers*

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
136	Point Quobba - Cape Cuvier (A)	Very Low		Moderate			N/A		N/A	*Birds: Sternula nereis nereis (Australian Fairy Tern) (VU) Breeding known to occur within area, Puffinus huttoni (Hutton's shearwater) (EN) Observed (Moderately certain) Charadrius mongolus (lesser sand plover) (EN) Observed (Moderately certain) Reptiles: Aipysurus apraefrontalis (Short-nosed Seasnake) (CR) Species or species habitat likely to occur within area, Caretta caretta (Loggerhead Turtle) (EN) Breeding likely to occur within area, Chelonia mydas (Green Turtle) (VU) Breeding, congregation, aggregation known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding likely to occur within area, Natator depressus (Flatback Turtle) (VU) Breeding known to occur within area Mammals: Megaptera novaeangliae (Humpback Whale) (VU) Congregation or aggregation known to occur within area, Balaenoptera musculus brevicauda (Pygmy Blue Whale) (EN) Known to occur. Fish: Pristis zijsron (Narrowsnout Sawfish) (VU) Breeding likely to occur within area, Carcharodon carcharias (Great White Shark) (VU) Species or species habitat known to occur within area, Carcharias taurus (Grey Nurse Shark) (VU) Species or species habitat known to occur within area,*	*Oil Tankers, Bulk Carriers*
137	Point Quobba - Cape Cuvier (B)	Very Low		Moderate			N/A		N/A	*Birds: Sternula nereis nereis (Australian Fairy Tern) (VU) Breeding known to occur within area, Charadrius mongolus (lesser sand plover) (EN) Observed (Moderately certain) Reptiles: Caretta caretta (Loggerhead Turtle) (EN) Breeding likely to occur within area, Chelonia mydas (Green Turtle) (VU) Breeding, congregation, aggregation known to occur within area, Dermochelys coriacea (Leatherback Turtle) (EN) Breeding likely to occur within area, Natator depressus (Flatback Turtle) (VU) Breeding known to occur within area Mammals: Megaptera novaeangliae (Humpback Whale) (VU) Congregation or aggregation known to occur within area*	*Oil Tankers, Bulk Carriers*

Key

Very Low	Low	Moderate	High	Very High

Key for Exposure

Lowest — Highest

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 Midwest zone. This report summarises the context, methodology and results for the Midwest 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 Midwest zone include: scale and exceptional ecological values especially in the Shark Bay World Heritage site. The region also has medium scale export facilities, and shipping activity from mineral sector activities. However, overall the level of risk-generating activity in the Midwest region is relatively low.

The highest risk area is around the Port of Geraldton, where there is a moderate level of shipping traffic combined with high protection priorities. In particular, the number of bulk carriers visiting the port is a key driver of risk in this area. The port doesn't pose exceptional navigational challenges, other than the inherent complexity of any port operation.

Oil tankers transit off the coast of the Midwest zone generating a relatively low but constant level of exposure along most of the Midwest shoreline. Although this exposure is neither particularly high, nor concentrated in a given area, it cumulatively results in the oil tankers being the primary overall driver of shoreline exposure in the Midwest region.

There is a low level of petroleum production and exploration activity meaning that the effect of petroleum facilities on shoreline risk is small in the Midwest region.

This companion report summarises the WAMOPRA results for the Midwest 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

Advisian, 2017. DOT307215 Provision of Western Australian Marine Oil Pollution Risk Assessment - Protection Priorities, prepared for Department of Transport.

AMSA & WA DoT, 2011. Project Safe Horizons.

Australian Hydrographic Service & United Kingdom Hydrographic Office, 2014. Admiralty Sailing Directions Australian Pilot Volume 1.

DMP, 2017. Petroleum in Western Australia.

Geraldton Port Authority, 2009. Capability Statement.

Mid West Ports, 2016. Annual Report 2015/16.

Navigatus, 2015. National Marine Oil Spill Risk Assessment 2015, prepared for Maritime NZ.

Navigatus, 2016. WAMOPRA Preliminary State-Wide Assessment, prepared for Department of Transport.

WA DoT, 2016. Ports Handbook - Western Australia 2016.