North Rankin Complex Facility Operations Environment Plan Summary

Production Division

September 2019

Revision 0

Table of Contents

1. INTRODUCTION 6
1.1 Defining the Activity 6
2. LOCATION OF THE ACTIVITY 7
3. DESCRIPTION OF THE ACTIVITY 9
3.1 Overview 9
3.2 Operational Area 9
3.3 Timing of the Activities 9
3.4 Facility Layout and Description 10
3.4.1 Topsides 10
3.4.2 Wells and Reservoirs 10
3.4.3 Pipeline and Riser System 10
3.4.4 Subsea Infrastructure 11
3.5 Operational Details 11
3.5.1 Manning and Modes of Operation 11
3.5.2 Process Description 12
3.5.3 Produced Water System 13
3.5.4 Drainage Systems 14
3.5.5 Utility Systems 15
3.5.6 Operational Flaring 17
3.5.7 Lifting Operations 18
3.5.8 Diesel Bunkering 19
3.5.9 Safety Features and Emergency Systems 19
3.5.10 Vessels 19
3.5.11 Helicopter Operations 19
3.6 Hydrocarbon and Chemical Inventories and Selection 19
3.6.1 Hydrocarbons 19
3.6.2 Chemical Usage 20
3.6.3 Indicative Chemical Inventories 20
3.7 Subsea Inspection, Monitoring, Maintenance and Repair Activities 22
3.7.1 IMR Activities 22
3.7.2 Platform Well Management and Maintenance Activities 22
4. DESCRIPTION OF THE RECEIVING ENVIRONMENT 25
4.1 Species 36
4.2 Socio-Economic and Cultural 42
4.3 Values and Sensitivities 45
5. ENVIRONMENTAL IMPACTS AND RISKS 49
5.1 Risk and Impact Identification and Evaluation 49
5.1.1 Establish the Context 50
5.1.2 Impact and Risk Identification 50
5.1.3 Risk Analysis 50

5.1.4 Decision Support Framework ... 50
5.1.5 Identification of Control Measures ... 51
5.1.6 Risk Rating Process ... 51
5.2 Classification and Analysis of Major Environment Events ... 53
5.2.1 MEE Identification ... 53
5.2.2 MEE Classification ... 53
5.2.3 Safety and Environment Critical Elements (SCE) and Performance Standards ... 53
5.3 Impact and Risk Evaluation ... 54
5.3.1 Demonstration of ALARP ... 55
5.3.2 Demonstration of Acceptability ... 55
5.4 Hydrocarbon Spill Risk Assessment Methodology ... 56
5.4.1 ZoC and Hydrocarbon Contact Thresholds ... 56
5.4.2 Surface Hydrocarbon Threshold Concentrations ... 56
5.4.3 Entrained Hydrocarbon Threshold Concentrations ... 57
5.4.4 Dissolved Aromatic Hydrocarbon Threshold Concentrations ... 58
5.4.5 Accumulated Hydrocarbon Threshold Concentrations ... 60
5.5 Potential Environment Risks Not Included Within the Scope of the Environment Plan ... 60

6. ENVIRONMENTAL RISK AND IMPACTS SUMMARY ... 61

7. ONGOING MONITORING OF ENVIRONMENTAL PERFORMANCE ... 66

7.1 Environment Plan Revisions and Management of Change ... 66

8. OIL POLLUTION EMERGENCY RESPONSE ARRANGEMENTS ... 68

8.1 Oil Pollution Emergency Arrangements (Australia) ... 68
8.2 NRC Oil Pollution First Strike Plan ... 69
8.3 Oil Spill Preparedness and Response Mitigation Assessment ... 69

9. CONSULTATION ... 71

9.1 Ongoing Consultation ... 72
9.2 Non-Routine Events ... 72

10. TITLEHOLDER NOMINATED LIAISON PERSON ... 74

11. ABBREVIATIONS ... 75

12. REFERENCES ... 80

APPENDIX A: ENVIRONMENTAL IMPACTS AND RISKS ... 85

APPENDIX B: CONTROL MITIGATION MEASURES FOR POTENTIAL ENVIRONMENTAL IMPACTS ASSOCIATED WITH SPILL RESPONSE ACTIVITIES ... 172

APPENDIX C: SUMMARY OF STAKEHOLDER FEEDBACK AND WOODSIDE'S RESPONSE ... 177

List of Tables

Table 2-1: Locations of the NRC, associated infrastructure and petroleum permits 8
Table 3-1: Hydrocarbon Inventories of process and non-process equipment 20
Table 3-2: Indicative bulk inventories of chemicals 21
Table 4-1: Summary of key existing environment characteristics 26
Table 4-2 Threatened and Migratory Marine Species under the EPBC Act Potentially Occurring within the Operational Areas 36
Table 4-3: Summary of Established and Proposed Marine Protected Areas (MPAs) and Other Sensitive Locations in the Region Relating to the Operational Areas 47
Table 5-1: Woodside Risk Matrix (Environment and Social and Cultural) Consequence Descriptions 52
Table 5-2: Woodside Risk Matrix Likelihood Levels 52
Table 5-4: Summary of Woodside's Criteria for ALARP Demonstration 55
Table 5-5: Summary of Woodside's Criteria for Acceptability 55
Table 5-6: Summary of Thresholds Applied to the Quantitative Hydrocarbon Spill Modelling Results 56
Table 5-7: The Bonn Agreement Oil Appearance Code 57
Table 5-8: Characteristics of the hydrocarbon types used in the modelling of scenarios 58
Table 5-9: Summary of Total Recoverable Hydrocarbons NOECs for Key Life-histories of Different Biota Based on Toxicity Tests for WAF of fresh NWS Condensate 59
Table 6-1: Environmental Risk and Impacts Register Summary 62
Table 9-1: Relevant Stakeholder Identified for the Petroleum Activities Program 71
Table 12-1: Indicative source characteristics of continuous underwater noise associated with the Petroleum Activities Program as reported in †Jiménez-Arranz et al. (2017) and by ‡McCauley (2005) and §McCauley (2002) 91
Table 12-2: Frequency ranges of IMMR sources and marine fauna 93
Table 12-3: Impulsive thresholds at which physiological and behavioural impacts to cetaceans may occur from impulsive acoustic discharges 94
Table 12-4: Continuous Sources - Impact threshold for environmental receptors based on *Southall et al. (2007) & National Marine Fisheries Services (NMFS, 2005). 94
Table 12-5: Impulsive noise exposure thresholds for injury and behavioural response for marine turtles 95
Table 12-6: Continuous Sources – Turtle Impact threshold for environmental receptors based †Popper et al. (2014) 95
Table 12-7: Impulsive noise exposure thresholds for different types of fish (Popper et al. 2014)... 96
Table 12-8: Continuous Sources – Fish and Turtle Impact threshold for environmental receptors based †Popper et al. (2014) 96
Table 12-9: Summary of impact thresholds and R_{max} for different species 98
Table 12-10: Trigger values used during routine monitoring 105
Table 12-11: PC99 concentrations and safe dilutions 108
Table 12-12: Trigger value used during non-routine sediment monitoring 110
Table 12-13: Estimated annual emissions from fuel combustion at the NRC (excluding support vessels) (based on FY2017/18) 114
Table 12-14: Estimated annual emissions from flaring at the NRC 115
Table 12-15: Assessment of the impacts and risks of IMS introduction associated with the Petroleum Activity Program 128
Table 12-16: Summary of worst-case loss of containment hydrocarbon release scenarios 132
Table 12-17: Key receptor locations and sensitivities potentially contacted above impact thresholds by the loss of well containment scenario with summary hydrocarbon spill contact (table cell values correspond to scenario numbers) 134
Table 12-18: Summary of worst-case subsea loss of containment hydrocarbon release scenario 150

Table 12-19: Key receptor locations and sensitivities potentially contacted above impact thresholds by the loss of well containment scenario with summary hydrocarbon spill contact....................... 152
Table 12-20: Summary of worst-case topsides loss of containment hydrocarbon release scenario 158
Table 12-21: Analysis of risks and impacts.. 173

List of Figures

Figure 2-1: NRC and Trunkline Operational Areas 7
Figure 4-1: Vessel density map in the vicinity of Operational Area from 2016, derived from AMSA satellite tracking system data (vessels include cargo, LNG tanker, ore carriers passenger vessels, support vessels and other vessels).. 45
Figure 4-2: Established and proposed Commonwealth and State Marine Protected Areas in Relation to the Operational Area.. 46
Figure 5-1: Key steps in Woodside's Risk Management Process 49
Figure 5-2: Woodside Risk Matrix – Risk Level 53
Figure 12-1: Ecosystem integrity and monitoring.. 104
Figure 12-2: Routine monitoring and adaptive management framework for produced water 105
Figure 12-3: Historical average daily PW discharge volumes.. 107

1. INTRODUCTION

Woodside Energy Limited (Woodside), as Titleholder for this activity, under the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (referred to as the Environment Regulations), prepared an Environment Plan (EP) for the North Rankin Complex (NRC) and associated infrastructure, on behalf of the North West Shelf (NWS) Joint Venture Participants. The NRC offshore facility (the facility), is comprised of two platforms, the North Rankin A (NRA) platform and the North Rankin B (NRB) platform, and has been in production since 1984 and is operated by Woodside under the Petroleum Title WA-1-L and Pipeline Licences WA-1-PL, WA-10-PL, TPL/15 and TPL/16 (**Table 2-1**). The NRC Operations EP was accepted by National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) on 13 September 2019.

This EP Summary has been prepared to meet the requirements of Regulations 11(3) and 11(4) under the Environment Regulations, as administered by NOPSEMA. This document summarises the NRC Operations EP, accepted by NOPSEMA under Regulation 10A of the Environment Regulations.

1.1 Defining the Activity

The Petroleum Activities Program constitutes a petroleum activity, as defined in Regulation 4 of the Environment Regulations. As such, an EP is required.

2. LOCATION OF THE ACTIVITY

The facility is located in Commonwealth waters on the North West Shelf (NWS) of Western Australia (WA), in Production Licence Area WA-1-L. It is located approximately 135 km north-west of Dampier (**Figure 2-1**). Gas and condensate produced from the facility are exported via two 130km trunklines, to shore for processing. Product can be routed via the 40” first (1TL) trunkline or 42” second trunkline (2TL). Approximately 105 km of each trunkline’s length is in Commonwealth waters and is included in the scope of this EP, the remaining lengths are in State waters and are the subject of a separate EP. Associated subsea infrastructure includes the Persephone (PSP) pipeline, which extends 7 km north east of NRC to the PSP field with two wells.

The facility is marked on nautical maps surrounded by a 500 metre petroleum safety zone (PSZ). The PSP pipeline, 1TL and 2TL are marked on nautical charts.

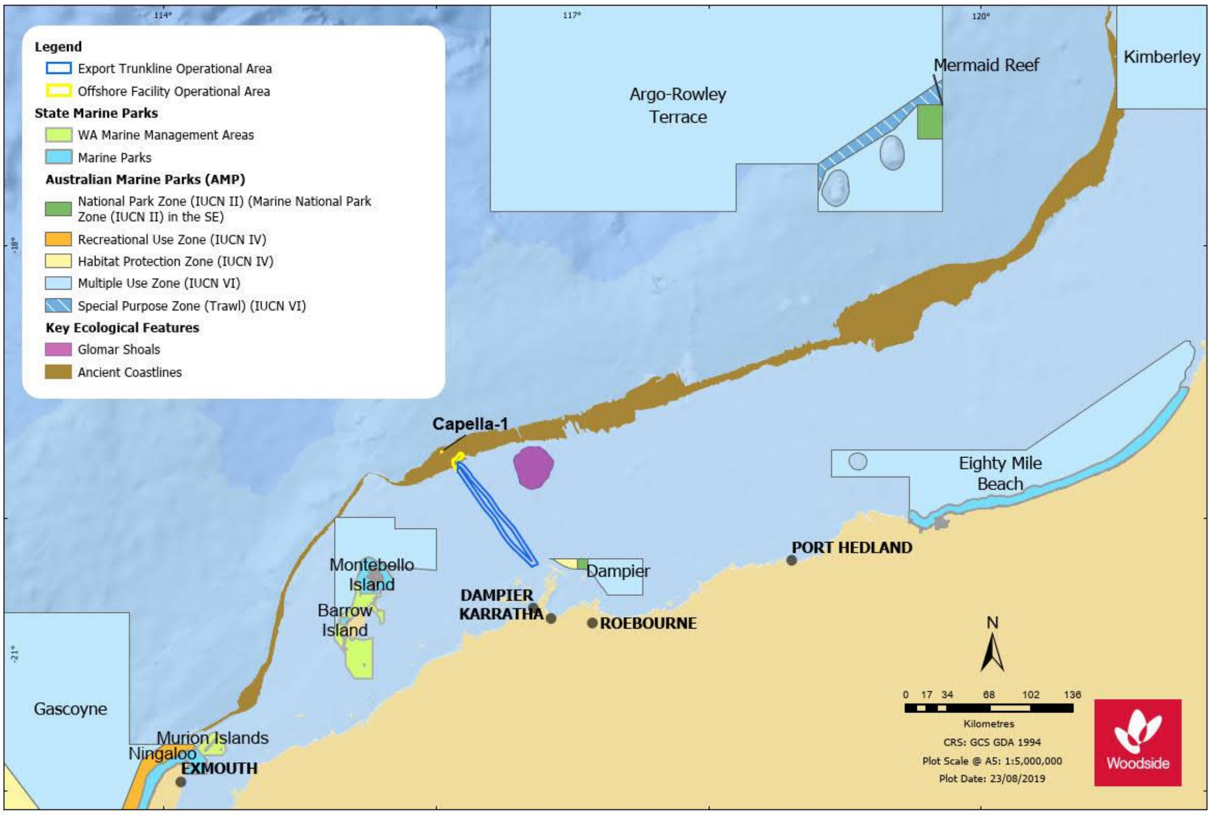

Figure 2-1: NRC and Trunkline Operational Areas

The coordinates and permit areas of the facility and associated infrastructure are presented in **Table 2-1.**

Table 2-1: Locations of the NRC, associated infrastructure and petroleum permits

Structure	Latitude	Longitude	Title
North Rankin A Platform	19° 35’ 03.23”S	116° 08’ 17.06’E	WA-1-L
North Rankin B Platform	19° 35’ 02.52”S	116° 08’ 11.32’E	WA-1-L
1TL - First Trunkline tie-in point to NRA	19° 35’ 03.12”S	116° 08’ 19.88”E	WA-1-PL
1TL – First Trunkline at outer limit of West Australian State waters boundary (3nm)	20° 20’ 49.49”S	116° 42’ 40.80”E	TPL/15
2TL - Second Trunkline tie-in point on the GWA Interfield Line (IFL)	19° 35’ 07.94”S	116° 08’ 05.06”E	WA-10-PL
2TL – Second Trunkline at outer limit of West Australian State waters boundary (3nm)	20° 20’ 20.26”S	116° 43’ 54.17”E	TPL/16
PSP Flowline	-	-	WA-1-L
PSA01 Well	19°32'25.02"S	116°10'50.88"E	WA-1-L
PSA02 Well	19°32'24.30"S	116°10'49.96"E	WA-1-L
Capella-1[1]	19°30'54.033"	116°02'19.57"E	WA-1-L

[1] Suspended exploration well.

3. DESCRIPTION OF THE ACTIVITY

3.1 Overview

Woodside, as Titleholder for this activity, is the operator of the NRC and associated infrastructure on behalf of the North West Shelf (NWS) Joint Venture Project, the title holders of which includes, BHP Billiton Petroleum (North West Shelf) Pty. Ltd., BP Developments Australia Pty Ltd, Chevron Australia Pty. Ltd, Japan Australia LNG (MIMI) Pty. Ltd, Shell Australia Pty. Ltd. and CNOOC NWS Private Ltd.

The NRC produces dry gas and condensate from a series of reservoirs and associated subsea infrastructure. Three processing trains on the facility, Train 100 (T100) Train 200 (T200) and Train 300 (T300), process the production fluids via a series of cooling, separation, compression and dehydration processes before being exported to the 1TL and the IFL/ 2TL and an onshore liquefaction facility.

The infrastructure covered by this EP includes the:

- NRC comprising NRA and NRB platforms
- wells and subsea infrastructure associated with or tied back to the NRC
- NRC trunklines located in Commonwealth waters
- other subsea infrastructure including Xmas trees, manifolds, flowlines/pipelines and umbilicals.

3.2 Operational Area

The Operational Area defines the spatial boundary of the Petroleum Activities Program. The Operational Area described in this EP has been sub-divided into two the Export Trunkline Operational Area and the Offshore Facility Operational Area. The Export Trunkline Operational Area includes (**Figure 2-1**):

- 1TL and 2TL (between the NRC and the State waters boundary) and an area within 1500 m around the infrastructure.

The Offshore Facility Operational Area includes (**Figure 2-1**):

- NRC and the area within a 500 m PSZ around the platform
- NRC subsea facilities excluding 1TL and 2TL (between the NRC and the State waters boundary) and an area within 1500 m around the infrastructure
- PSP subsea facilities, and an area within 1500 m around the infrastructure
- Capella-1 wellhead and an area within 500 m around the wellhead.

Vessel related activities within the Operational Area will comply with this EP. Vessels supporting the Petroleum Activities Program when outside the Operational Area adhere to applicable maritime regulations and other requirements.

3.3 Timing of the Activities

The NRC commenced production in 1984. The NRC is designed to operate 24 hours a day, 365 days a year. Maintenance activities are undertaken as required to support the day to day operations.

The end of life of the NRC is not predicted during the life of this EP. Any future decommissioning or drilling will be the subject to a separate EP.

3.4 Facility Layout and Description

3.4.1 Topsides

The NRA and NRB platforms are situated approximately 100 m apart and connected by two bridges. The NRA platform consists of 23 topsides modules.

The NRA production deck is 23 m above sea level and the platform extends to approximately 71 m above sea level, to the top of the flare stack. The NRB facilities primarily provide separation and compression facilities to unlock low-pressure reserves from the North Rankin, Perseus and Persephone Fields. The NRB platform deck is 30 m above sea level and the platform extends to approximately 135 m above sea level, to the top of the flare stack.

Redundant equipment may be removed from NRC using a heavy lift vessel including but not limited to drilling facilities and components of the NRA accommodation module.

The diesel powered, hydraulic driven pedestal mounted platform cranes perform lifting operations associated with supply vessels and operations, maintenance and project work scopes.

3.4.2 Wells and Reservoirs

North Rankin

There are 22 platform wells on the NRA platform that produce from the North Rankin reservoir. Surface controlled sub-surface safety valves (SCSSV) are installed on wells as the emergency down-hole safety system. These fail-closed valves are controlled from the surface via a single control line.

Perseus

There are seven platform wells that produce the Perseus reservoir from the NRA platform. SCSSV are installed on wells as the emergency down-hole safety system. These fail-closed valves are controlled from the surface via a single control line. The Perseus field is presently developed by both NRC and GWA.

Persephone

Two production wells within the Persephone reservoir are tied back to the NRC via a 7 km 12” flowline. Control and monitoring of the subsea wells is through an electrohydraulic umbilical from NRC. SCSSV are installed on wells as the emergency down-hole safety system. These valves are controlled from the surface via an electro-hydraulic umbilical from NRC to the Persephone trees.

Capella 1

There is one suspended exploration well located near the NRC platform. This well is not tied back to the platform and will be monitored using general visual inspection on a risk-based inspection basis until it is permanently plugged for abandonment (subject to separate EP). The WOMP is implemented, and well integrity notification and reporting is undertaken in accordance with the Regulations (as applicable).

3.4.3 Pipeline and Riser System

NRC receives production fluids (gas, condensate and associated produced water) from the wells at NRA and subsea wells, with the fluid then routed across the bridge for processing and compression on NRB prior to being routed back to NRA for gas dehydration and condensate dewatering. The export manifolds on NRA then send the processed gas and condensate to the Karratha Gas Plant (KGP) via the two trunklines.

3.4.4 Subsea Infrastructure

The main components of subsea infrastructure include wells, Xmas trees, manifolds, umbilicals, power cable to Angel, risers and flowlines.

The subsea system is controlled from the NRC central control room (CCR) through the following components:

- jumpers and umbilicals which provide hydraulic and electric power, communications and chemical supplies between the platform and subsea components. Umbilicals run between the platform and the Subsea Distribution Units (SDU) and Umbilical Termination Assemblies (UTA), Umbilical Termination Baskets (UTBs) and jumpers run between SDUs/UTAs/UTBs and the manifold
- valves which control subsea operations and processes
- chokes which control pressure and flow rates of hydrocarbons
- subsea Control Modules (SCM) which are sealed, and pressure compensated electro-hydraulic units (found on manifold and/or Xmas trees) and link the surface and subsea controls.

Subsea valves may also be overridden manually from either a Remote Operated Vehicle (ROV) or divers.

3.5 Operational Details

This section provides a description of the main operations associated with the facility. It includes key elements in relation to interaction between the activity and the environment.

3.5.1 Manning and Modes of Operation

The CCR is normally manned 24 hours per day. Other activities which affect manning levels, are:

- crew change
- engineering projects
- campaign maintenance
- inspections/audits
- cyclone down manning / demanning
- planned facility shutdowns.

Normal operations at NRC fall under any one of the following modes of operation:

- production and maintenance, including subsea IMMR activities
- well maintenance including workovers and interventions
- major projects involve refurbishment, modification or major maintenance on the facility
- remote operations
- subsea export.

These modes of operation may occur concurrently.

Major Projects and Brownfield modifications

Major projects involve refurbishment, modification or major maintenance on the facility.

Remote Operations

While the NRC is typically operated as a manned facility, Woodside may de-man NRC (e.g. as a precautionary safety measure during severe cyclones). Operation of the NRC may be maintained during de-manning via a Remote Operation Station (ROS) at the KGP.

Whilst remotely operated, the NRC continues to produce at stable rates, which are established prior to de-manning the facility. Operating at stable rates means production remains steady with no major process changes; this minimises the potential for process upsets. The ROS has the same critical operational controls as the CCR on the NRC.

Subsea Export

Routinely 1TL and 2TL receive export gas and condensate from production trains T100/T200 and T300, however export to either trunkline from any production train is possible. Gas arriving from the Okha FPSO via the Gas Export Line (GEL) can be exported to either 1TL or 2TL. The GEL is tied in to 1TL approximately 150 m from the NRA platform, while export from Okha to 2TL occurs via two 10-inch flexible jumpers connected to the GWA Interfield Line (IFL) tie-in spool approximately 50 m from NRA. The GEL is also used to import gas from either 1TL or 2TL to provide fuel to the Okha facility.

3.5.2 Process Description

Production Process

The NRC receives production well fluids (gas, condensate and associated PW) for topside processing via gas dehydration and condensate dewatering. The facility then exports the processed gas and condensate onshore to the KGP.

The NRC has three processing trains (Trains 100, 200, 300) designed for a gas export capacity of 22 kT/day per train dry gas plus associated condensate.

The gas export compressor takes suction at the lower operating pressures and returns the gas to export pressure allowing it to be routed onshore via the interfield pipeline.

Flare Systems

The NRC flare system has the following functions:

- protect process equipment and piping against overpressure that can be a result of system failure or fire
- collect hydrocarbons from blowdown valves (BDV) and dedicated pressure safety valves (PSV), and to lead them to a flare knock out (KO) drum where liquid is separated and returned to the process. The vapour is burnt safely through the flare system
- enable controlled depressurisation of systems containing hydrocarbons
- collect vapours from the process, most significantly from the glycol regeneration system
- keep flare heat radiation and noise within acceptable levels.

NRA and NRB have independent flare systems without any connection between them. Each flare system has its own flare header, KO drum and flare tips, and dispose of gas derived from sources located on the respective platform. The bridge pipe work can be blown down via the NRB flare. The low pressure (LP) and high pressure (HP) flare systems dispose of gas and associated liquid vents from various systems on each platform. The flow of gas through each of the HP and LP flare networks is measured using separate ultrasonic flow meters with pressure and temperature compensation. The flares are equipped with pilots and a flame front generator and continuously purged to avoid ingress of air into the system. Both the LP and HP flare flow-rates are monitored and are alarmed to warn of purge loss.

High Pressure System

The NRA HP flare system collects vented hydrocarbons from process and utility systems, with design pressures of approximately 1,000 kPag or greater. The nominal process design pressure of topside equipment is 13,100 kPag. Two HP flare sub-headers receive the discharge from all relief and BDV from vessels and pipes in the gas and condensate processing streams (e.g. during blowdown). The HP flare system is also designed to receive the flow from the fuel gas scrubbers and well flows during well clean-up. The flare header is purged with fuel gas to maintain flare combustion and prevent air entering the system.

The NRA HP flare KO drum receives a flow of gas and associated liquid from the HP flare header. The HP flare KO drum is designed to separate entrained liquid droplets greater than 600 microns at the design capacity flowrate. Liquids collected in the drum are discharged away to the oily water settling tank (OWST) via the HP (or LP) KO drum pumps. Liquids in the HP flare KO drum can also be drained to the drain sump caisson. Vapours from the flare drum are disposed of at the flare tip.

The NRB HP flare system collects vented hydrocarbons from process and utility systems, with design pressures of greater than 1,000 kPag. The flare system provides a means of safe disposal for all normal and emergency pressure releases (e.g. during blowdown). All releases flow into one HP flare header.

The NRB HP flare KO drum is designed for the removal of liquid droplets 600 microns or larger at the design capacity flowrate. Liquids collected in the NRB KO drum are pumped via the NRB closed drains system to the NRA HP flare KO drum for further processing to the OWST. Vapours from the flare drum are disposed at the HP flare tip.

Low Pressure System

The NRA LP flare system primarily collects vapours from the glycol regeneration process and the produced water degasser, and any other LP gases from vessels with design pressures of less than approximately 1,000 kPag. The LP flare system also provides an inert atmosphere in the LP storage tanks via the tank vent header. Gas discharged from the glycol regeneration system acts as a purge and eliminates the risk of air entering the LP flare system. The water captured from the process within the glycol regeneration system is boiled off and flared.

The NRA LP flare knock-out drum separates entrained liquid from the collected gas and discharges it to the OWST or drain sump caisson. The LP KO Drum also receives liquids from the drain sump caisson. The KO drum is designed for the removal of liquid droplets 600 micron or larger at the design capacity flowrate. The LP flare tip burns the LP gas from the LP KO drum. The NRB LP flare system provides a means of safe disposal of hydrocarbon releases from LP equipment items (equipment with operating pressures less than 1,000 kPag). Flows are directed into a header which in turn runs to the LP flare knock-out drum. No liquids are normally expected in the LP Flare KO drum. Liquid drop out may accumulate over time and is routed to the closed drains drum. The LP header is continually purged to prevent air entering the header and creating a potentially explosive mixture. A standard pipe flare tip, which is mounted within the physical boundary of the HP flare tip, burns the LP flare gases.

3.5.3 Produced Water System

Produced water (PW) is water brought to the surface from the reservoir during the production of oil and gas. PW can consist of produced formation water (a water reservoir below the hydrocarbon formation), condensed water (water vapour present within gas/condensate which condenses when brought to the surface), or a combination of both. PW is separated out from hydrocarbon components during the production process and discharged to the marine environment.

PW System Description

The PW system for the NRC is located on the NRA platform and consists of the degasser, two degasser water pumps, two centrifuges and a bypass line around the pumps and centrifuge.

The PW stream is primarily made up of:

- water recovered from the condensate stream by the NRB bulk water condensate separators
- a lesser quantity of water removed downstream by the NRA primary water/condensate separators
- a lesser quantity of water removed by the NRA discharge scrubbers
- water from the OWST. This is predominantly water from the glycol reboiler overheads, which is routed from the HP and LP Flare KO Drums
- water from NRA wet condensate vessel B, originating from the condensate coalescers.

PW Treatment

The PW system directs all PW streams from the process to the PW degasser to remove dissolved gas. The degasser allows mixing and provides a hold-up volume for the control of a uniform feed to the PW centrifuge(s), thus ensuring efficiency of the centrifuge is not affected by gas breakout. The system also returns water to the degasser and sends oil to the recovered oil tank on the NRA platform for export ashore. The centrifuges are provided with a recycle loop back to the degasser for level control. When flow-rates allow, this recycle also allows additional polishing of the water before it is discharged. If there is no centrifuge online, PW bypasses the centrifuge(s) and is directed from the degasser to the drain sump caisson. Once directed to the caisson PW is not immediately discharged to the environment, and an additional level of oil/water gravity separation occurs within the caisson. The oil-gas and oil-water interfaces in the drain sump caisson are monitored by two independent level indicators. The drain sump caisson pump maintains the water-oil level within an operating band by pumping the oil layer to the recovered oil tank which can subsequently be pumped to the export pipeline. Water within the drain sump caisson is discharged to the environment at 40 m below sea level.

3.5.4 Drainage Systems

The open and closed drains system consist of both hazardous and non-hazardous drains. The open drains system is required for disposal of water and hydrocarbons, which are at atmospheric pressure (e.g. deck water). Drains from hazardous areas are totally segregated from drains from non-hazardous areas to prevent ingress of gases into a non-hazardous area via the drains system. The NRA and NRB open drains are independent systems with similar design.

NRA Hazardous and Non-Hazardous Open Drains

The hazardous open drains collect normal deck drainage, including rainfall, wash down from equipment/flooring and any spillage from all areas designated as hazardous. These drains originate from deck floor drain boxes, tundishes and equipment drip trays located in hazardous areas. This fluid flows to the hazardous open drains caisson for gravity separation. The NRA open drains caisson pump within the hazardous open drains caisson transfers any accumulated oil from the caisson to the waste oil tank then to waste iso-containers for onshore disposal.

The main non-hazardous open drains, from sources not containing hydrocarbons, diesel or lubricating oils are collected via a separate header system and discharged directly overboard. These include reject water from potable water maker and water overflow from roofs.

Any non-hazardous area drains from equipment which potentially contains diesel, lubricating or seal oils, is directed through a collection header into the hazardous open drains caisson via a seal pot. The seal pot prevents hydrocarbon vapour ingress into non-hazardous areas of the platform via the drains system. The seal provided is a 1 m liquid leg with a continual flush of service water.

NRB Hazardous and Non Hazardous Open Drains

As with NRA, hazardous open drains on NRB collect normal deck drainage from all areas designated as hazardous. On NRB the hazardous open drain fluids are first routed to the hazardous open drains tank for gravity separation. Here, the drain collection headers are submerged in the tank to prevent vapour migration between the headers. The NRB recovered oil pump within the recovered oil caisson transfers any accumulated oil from the tank to waste iso-containers. The hazardous open drains pumps transfer accumulated oil from the hazardous open drains tank to waste iso-containers for onshore disposal.

The main non-hazardous open drains, from sources not containing hydrocarbons, diesel or lubricating oils are collected via a separate header system and discharged directly overboard. Any non-hazardous area drains potentially containing diesel, lubricating or seal oils are directed via a separate header and liquid seal to the hazardous open drains tank. This liquid seal (via a seal pot) maintains a 1 m liquid seal between hazardous and non-hazardous drains systems. For further protection against gas migration from the hazardous to the non-hazardous system, the header is submerged (approximately 1 m) below the hazardous header termination depth within the caisson.

Closed Drains / Recovered Oil System

The closed drains system is used for draining volatile hydrocarbon liquids from all normally pressurized and hazardous process equipment. Liquid sources are normally positively isolated and only drained to the closed drains system after depressurisation. To avoid overflowing the NRB closed drain drum, draining operations are performed in a controlled manner. During normal operation, the closed drains drum pumps routes the liquids to the NRA HP flare KO drum for processing via the NRA recovered oil system (typical operation). If the NRA HP flare KO drum is unavailable, liquids can be directed to the NRB HP flare KO drum.

The closed drains system on NRA feeds into the NRA closed drains header, prior to transfer to the NRA flare KO drum. KO drum liquids from the NRB HP and LP flares also intermittently flow to the NRB closed drain system.

Well clean up fluids are routed to the NRB HP flare KO drum which discharges liquids to the closed drain system. On both NRA and NRB, the system consists of drain headers which are sloped to allow fluids to flow by gravity to the closed drain drum (for NRB) and the NRA flare KO drum (for NRA). The closed drain drum vent ties into the LP flare system. The vent line ensures that the drum operates at the same pressure as the LP flare (normally atmospheric) and vapour associated with the drain fluids is routed to the LP flare.

The recovered oil system is located on the NRA platform. Recovered oil is separated from water and routed to the recovered oil tank while water is discharged back to the drain sump caisson. Oil is tested for water content and if less than 700 ppm can be pumped to the export line.

3.5.5 Utility Systems

Platform Lighting

The NRC has appropriate lighting to ensure a safe working environment to support 24-hour operations. Lighting is split between emergency and normal lighting. The emergency light fittings have been located to illuminate the designated escape routes on the facility. There are also battery backed-up emergency lights on the facility.

There are navigational lights on the platform flare tower and on the booms and towers of the pedestal cranes. Helideck lighting is also provided to assist helicopter landing.

Unless required to support over the side activities (such as refuelling and lifting operations), lighting on the platform is directed to the work area, which aids in limiting light spill to sea.

Heating Ventilation and Air Conditioning (HVAC) System

There are three main HVAC systems on NRA for normal operations which provide pressurised, air conditioned, purge and exhaust air services to various modules. There are also secondary air handling units which supply supplementary cooling and are able to provide for the CCR/central equipment room (CER) thermal gain. This is an enclosed recirculation system and enables continued operational conditions in case of the primary HVAC failure, hence providing HVAC redundancy.

The HVAC system on NRB consists of ducted air conditioning systems that utilise a common chilled water system for cooling and dehumidification. Two main air-conditioned areas, the NRB accommodation area and equipment rooms, have separate air handling units. Each area also has separate ventilation systems providing recirculation and exhaust air where required. Additional HVAC systems are located on the two NRB cranes.

Ozone depleting substances are no longer used on the NRC and refrigerants are managed by a licenced Refrigerant Authority.

Water Systems

There are a number of water systems on the NRC providing water for process systems, utilities, fire protection and drilling. Under normal operation all water is drawn from the ocean via seawater lift pumps.

There are two types of water systems on the NRC:

- Once-through systems (a single pass cooling circuit) where seawater is drawn into the cooling system for end users e.g. heat exchanger cooling, feed for potable water maker and fire water ring main for deluge.
- Closed Loop systems where the cooling medium is continuously circulated through heat exchangers for heat transfer e.g. chilled and tempered water systems.

Seawater/ Service Water System

All seawater requirements on the NRC are supplied from the NRB Service System by four sea water lift pumps and two caissons.

The seawater pumps are rated to operate at approximately 5,000 m^3 per pump, per hour. Cooling water (CW) is discharged vertically through the two 1.6 m diameter caissons 3.7 m apart and approximately 15 m below the water surface. Typical discharge rates range from 12,300 to16,500 m^3/hr, with temperatures varying from 34°C to 50°C (averaging approximately 45°C). An electro-chlorinator produces sodium hypochlorite by electrolysis of sodium chloride found in seawater. Sodium hypochlorite produced from the electro-chlorinator is continually injected into the suction side of the running seawater lift pump to prevent algal growth. The NRA seawater system is out of service and has been isolated.

The service water booster pumps make up the difference in pressure from the seawater lift pumps to the pressure required for the various users. The service water booster pumps effectively act as a firewater jockey pump, maintaining the firewater ring main pressure to prevent unnecessary start-up of the diesel driven firewater pumps. These booster pumps also provide the NRB and NRA heli-deck with a suitable water pressure for instantaneous firefighting.

Service water can also be supplied by the essential services pumps, should the seawater lift and service water booster pumps be offline. The essential services pumps maintain pressure in the firewater ring main, supply water to the NRB HVAC system, seawater chlorination package, non-hazardous drains seal pot and spillback, but do not provide tempered water cooling on NRA. The essential services pump caissons are dosed with sodium hypochlorite at the pump intake to prevent microbial growth in the service water system.

Tempered Water System

The tempered water system on both platforms provides indirect cooling by re-circulating chemically treated potable water to remove heat from process and utility coolers through a closed loop system. Tempered water is circulated around the system by the tempered water circulation pumps. The tempered water pumps take suction from the tempered water expansion vessel, which is located at the system high point. From the pumps, tempered water is fed to the plate heat exchangers where it is cooled by the seawater system. From these exchangers the tempered water is distributed to all users.

To prevent general corrosion, fouling and blockage of small passages in the heat exchangers, the tempered water systems are injected as required with oxygen scavenger, pH buffer and biocide. Periodic system maintenance may require the draining of the tempered water system, resulting in the discharge of water and residual treatment chemicals to the marine environment.

Potable Water

The potable water system desalinates seawater via filtration and reverse osmosis to produce potable water for both platforms. It is located on NRA, and water is transferred to NRB via piping across the bridge. Overflow potable water from the RO unit is sent for storage in the NRA jacket leg, where it may be used for well maintenance or when additional supply to the platforms is required. The storage tanks can also be replenished from a supply boat if the potable water maker is inoperative.

The desalination unit is designed for a standard operating and discharge capacity. The unit discharges approximately 9.5 m^3/hr of wastewater with a salinity of 55-60 mg/L. Chemical additives include injection of a solution of sodium antiscalant to prevent scale formation and sodium hypochlorite solution for chlorination.

Power Generation

The main power generation system consists of four Solar Mars 100 gas turbine-driven generators located on NRB, which deliver 6.6 kV power.

The NRA Solar gas turbine generators are out of service and have been isolated. All power to the NRC and Angel is supplied from NRB. In normal operations the NRB generators are gas fired, with an automatic change-over to diesel firing in case of loss of fuel gas.

In the event of failure of main power generation and to keep essential and vital services operating, an emergency diesel generator (EDG) unit is provided on NRB. This unit can supply essential and vital loads on both NRA and NRB. It is fuelled from a diesel day tank which gives a 12-hour running reserve. During normal operation, the EDG remains on standby or may be used to supplement the main generation system. This allows for the safe shutdown of production and the restoring of normal power. The NRA EDG is used as a back-up to the NRA emergency power loads. It is fuelled via a diesel day tank which gives a 12-hour running reserve. The EDG’s can be started from the remotely from the CCR or locally.

Sewage and Putrescibles Wastes

Sewage from the ablutions are macerated and disposed of to the ocean via the sewage caisson on each platform. Putrescible waste (principally food scraps) is either ground to less than 25 mm diameter and disposed to ocean via the sewerage caisson or bagged and transported to shore for disposal as domestic waste.

Sand Management

Production of sand is minimised where possible on the NRC. The primary approach used to manage sand on the NRC is to monitor and minimise sand production, primarily by controlling wellhead pressures. Uncontrolled sand production is undesirable and can pose a risk of erosion and deposition in vessels leading to increased wear and process system trips. Sand production is monitored on each well by real-time clamp-on acoustic sand detectors, which monitor noise created by the impact of a particle on a flowline bend. Ultrasonic testing of the flowlines is carried out periodically to detect erosion. Thermographic surveys to measure the temperature difference between the hotter produced fluids and the cooler deposited sand in production vessels can be conducted as required on un-lagged vessels. Vessel entry and inspection for sand is carried out as required.

3.5.6 Operational Flaring

Flaring is expected to occur during a range of operational circumstances; key operational flaring events are explained in further detail in the following sections. Annual internal facility flare targets are set based on operational activities planned for the year. This target is used to assess facility flare performance.

Normal Operations

A relatively small quantity of gas is required to be continuously flared associated with purge and pilot of the flare system and disposal of waste streams which are not recovered to the process.

Intermittent Process Upsets and Activities

There are intermittent gas streams to the flare during process upsets, maintenance activities, and when vessels are depressurised and purged. The flow of gas through each of the HP and LP flare networks is measured using ultrasonic flow meters with pressure and temperature compensation. The flares are equipped with pilots and a flame front generator and continuously purged with fuel gas to avoid ingress of air into the system.

Emergency Blowdown

The topsides equipment and piping is divided into isolatable sections, each with a dedicated BDV. During an Emergency Shutdown (ESD), each section is separately depressurised to the HP flare. Each section contains a fail open actuated BDV which allows blowdown of the entire platform inventory. Approximately 166 t is flared during each planned ESD.

Manual Depressurisation

Manual depressurisations result in intermittent flaring of hydrocarbons, triggered by routine equipment maintenance, planned ESD testing and/or depressurisation of equipment and piping to remove the equipment from service. Equipment is depressurised prior to draining, as the closed drains system is not intended for high pressure service.

Subsea Flowline Depressurisation

The fluid in the subsea flowlines/pipelines (which carry hydrocarbons from the subsea wells to the NRC) may on occasions need to be routed to the riser platform flare to allow the pressure in the flowlines to be reduced. The flowlines may require depressurisation for the following reasons:

- production flowline maintenance and critical leak-off testing (LOT)
- to facilitate remediation in the event of an unplanned hydrate blockage in the subsea flowlines
- flowline hydrate management
- over pressurisation of flowlines above integrity limit
- suspension of redundant pipelines/flowlines.

Estimated Flare Volumes

The amount of gas that may be flared on an annual basis is a dependent on continuous and intermittent process sources, planned activities requiring flaring, and unplanned process upsets. The estimated annual amount of gas flared ranges between 20,000 and 21,000 tonnes.

3.5.7 Lifting Operations

Lifting operations on the facility include:

- lifting from platform support vessels
- lifting around the facility
- heavy lift operations.

3.5.8 Diesel Bunkering

Diesel is transferred to NRC in bulk from supply vessels via the east NRA bunkering station and stored in the jacket leg. The NRC diesel system is an integrated system across NRA and NRB. Bunkering, storage, pumping and treatment facilities are located on NRA, supplying diesel fuel at correct pressures to all NRA and NRB users. Unused diesel is recycled back to storage.

The crane pedestals of both the East and West cranes on NRB are used for diesel storage. The storage volume of the two pedestal tanks is approximately 184 m^3. The bulk diesel storage is provided by the NRA jacket leg, which has a capacity of 440 m^3. The overall diesel storage volume on NRC is 624 m^3.

3.5.9 Safety Features and Emergency Systems

A range of safety features and emergency systems have been integrated into the design and operation of the NRC to manage safety risk and associated major environment risk. The safety features and emergency measures in place of the NRC are listed in the NRC Safety Case.

3.5.10 Vessels

Platform support vessels are utilised in a support capacity for transferring material and equipment to and from the facility. The normally scheduled support vessel is the Siem Thiima. Vessels supporting the facility may vary depending on vessel schedules and availability. While in the field, the vessel also backloads materials and segregated waste for transportation back to the King Bay Supply Facility (KBSF) in Karratha, as well as carrying out standby duties including during working over the side activities while in the field.

Subsea support vessels are used for subsea inspection, maintenance and repair activities. Vessels vary depending on operational requirements, vessel schedules, capability and availability.

Typical support vessels use a Dynamic Positioning (DP) system to allow manoeuvrability and avoid anchoring when undertaking works due to the proximity of subsea infrastructure. However, vessels are equipped with anchors which may be deployed in the event of an emergency.

An Accommodation Support Vessel (ASV) may be required for short periods (typically < 1 month) to support planned maintenance campaigns, shutdown maintenance or major projects.

A Heavy Lift Vessel (HLV) may be used for the removal of redundant equipment. The HLV uses a DP system to allow manoeuvrability and avoid anchoring when undertaking works, due to the proximity of subsea infrastructure.

3.5.11 Helicopter Operations

Helicopters are the primary means of transporting passengers and/or urgent freight to/from the NRC. They are also the preferred means of evacuating personnel in the event of an emergency. Helicopter support is principally supplied from Karratha Airport. Approximately fourteen trips per fortnight are undertaken.

3.6 Hydrocarbon and Chemical Inventories and Selection

3.6.1 Hydrocarbons

Non-process inventories of hydrocarbons used on the NRC are outlined in **Table 3-1.**

Table 3-1: Hydrocarbon Inventories of process and non-process equipment

Material	Storage Means	Storage Capacity
Diesel	Diesel storage tanks (x2)	NRA: 440 m^3 total NRB: 184 m^3 total
Lube oil/seal oil/Hydraulic oil	Various size containers based on type and use	Various - general 20 L and 205 L drums
HUC Lube Oil	Transferred in 4 m^3 containers, stored in pipe work/system vessels.	75 m^3
Hot Oil System	Storage Tank	12 m^3
Drain Sump Caisson/ Recovered Oil Tank	Storage Tank	0.6 m3

3.6.2 Chemical Usage

Chemicals are used on the NRC for a variety of purposes and can be divided into two broad categories (operational and maintenance).

Operational Chemicals

Operational Process Chemicals

A process chemical is the active chemical added to a process or static system, which provides functionality when injected in produced fluid, utility system streams or for pipeline treatment. These chemicals may be present in routine or non-routine discharge streams from the NRC. Examples include corrosion inhibitors, biocides, scale inhibitors, demulsifies, glycols and hydrate inhibitors.

Operational Non-Process Chemicals

Non-process chemicals include chemicals which do not fall into the category described above, which may be required for operational reasons and, by their use, may be intermittently discharged or have the potential to be discharged (e.g. required as a result of maintenance or intervention activities). Examples include subsea control fluids, dyes and well intervention/workover chemicals.

Maintenance Chemicals

Maintenance chemicals include chemicals which are required for general maintenance or ‘housekeeping’ activities and are critical for overall maintenance of the facility and its equipment. These may include paints, degreasers, greases, lubricants and domestic cleaning products. They may also include chemicals required for specialty tasks, such as laboratory testing and analysis. Maintenance chemicals generally present negligible risk to the environment as they are not discharged because of their use (e.g. paint) or are used intermittently and discharged in low volumes (e.g. domestic cleaning products).

3.6.3 Indicative Chemical Inventories

An indicative list of bulk chemicals commonly used on the NRC, and estimated storage quantities, is summarised in **Table 3-2**. In addition to the chemicals listed, the NRC may also maintain other small volumes of various operational chemicals and facility maintenance chemicals as previously described.

Table 3-2: Indicative bulk inventories of chemicals

Material	Storage Means	Storage Capacity
Corrosion Inhibitor	Tote Tank	8 m3 (4 m3 per container)
Trieythlene Glycol (TEG)	TEG storage tank	35 m3
Monoethylene Glycol (MEG)	MEG storage vessel	8 m3 (4 m3 per container)
Biocide/ pH Buffer/ Oxygen Scavenger	NRB chemical injection skid	15 L containers
Demulsifier/ Water Clarifier	Tote Tank	4 m3 of each.
Subsea Control Fluid	Hydraulic Power Unit Tank stores 'in use' fluid. Additional fluid stored in drums.	~2 m3
Coolant	Various sized containers	1 m3
Aqueous Film Forming Foam (AFFF)	Tote Tank	1 m3

Environmental Selection Criteria

As part of Woodside's chemical approval process, operational chemicals required by the Petroleum Activities Program are selected and approved in accordance with the Woodside Chemical Selection and Assessment Environment Guideline.

The chemical assessment process follows the principles outlined in the Offshore Chemical Notification Scheme (OCNS) which manages chemical use and discharge in the United Kingdom (UK) and the Netherlands (background on the OCNS scheme provided is below), specifically:

- Where operational chemicals with an OCNS rating of Gold/Silver/E/D and no OCNS substitution or product warning are selected, or a substance is considered to pose little or no risk to the environment (PLONOR), no further control is required. (Such chemicals do not represent a significant impact on the environment under standard use scenarios and therefore, are considered ALARP and acceptable).
- If other OCNS rated or non-OCNS rated operational chemicals are selected, the chemical will be assessed further.

If no environmental data is available for a chemical or if the environmental data does not meet the acceptability criteria outlined above, potential alternatives for the chemical will be investigated, with preference for options with an HQ band of Gold or Silver or which are OCNS Group E or D with no substitution or product warnings.

If no more environmentally suitable alternatives are available, further risk reduction measures (e.g. controls related to use and discharge) will be considered for the specific context and implemented where relevant to ensure the risk is ALARP and acceptable.

Once the further assessment/ALARP justification has been completed, concurrence from the relevant manager that the environmental risk as results of chemical use is ALARP and acceptable is obtained.

Background Overview of the OCNS Scheme

The OCNS Scheme applies the requirements of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). The OSPAR Convention is widely accepted as best practice for chemical management.

All chemical substances listed on the OCNS ranked list of registered products have an assigned ranking based on toxicity and other relevant parameters such as biodegradation, and bioaccumulation, in accordance one of two schemes:

- Hazard Quotient Colour Band: Gold, Silver, White, Blue, Orange and Purple (listed in order of increasing environmental hazard), or
- OCNS Grouping: E, D, C, B or A (listed in order of increasing environmental hazard). Applied to inorganic substances, hydraulic fluids and pipeline chemicals only.

3.7 Subsea Inspection, Monitoring, Maintenance and Repair Activities

3.7.1 IMR Activities

A range of subsea inspection, monitoring, maintenance and repair activities (referred to as IMR) may be undertaken during the operations of the facility. Subsea IMR activities are typically undertaken from a diving or support vessel via one or more ROVs and/or divers. Typical support vessels use DP systems to allow manoeuvrability and avoid anchoring when undertaking works due to the proximity of subsea infrastructure. IMR activities may include:

- inspections
- monitoring
- maintenance
- repair
- pipeline pigging
- subsea chemical usage
- discharges during IMMR activities
- marine growth removal
- sediment relocation
- suspension and preservation of redundant equipment.

3.7.2 Platform Well Management and Maintenance Activities

As the NRC has platform-based wells, well management and well activities are conducted from the platform. This may include routine maintenance and inspection activities through to well interventions, workovers and well kill. Interventions of the subsea wells require a suitable vessel or drill rig to accommodate and support intervention packages and do not form part of the scope of this EP.

Well Intervention

Well interventions may be required for reservoir surveillance, enhancing productivity / injectivity, assessing wellbore condition, restoring well integrity, or other scenarios that develop during operate phase.

Well interventions may include the following activities:

- wellhead maintenance (including actuator, valve, choke and tree change outs)

- annulus fluid top-ups and Echo meter shots
- electric-line, slick-line and coiled tubing interventions
- logging or surveys
- fishing junk or lost-in-hole equipment
- setting and recovering plugs and wireline insert subsurface safety valves
- mitigating safety critical failures (e.g. failed safety valve)
- chemical squeeze operations
- perforating the wellbore.

Routine Wellhead Maintenance

Wellhead maintenance is conducted routinely on all surface wellheads/trees in accordance with the Facility Well Integrity Management Plan. Wellhead maintenance consists of greasing and functioning the wellhead/Xmas tree valves and replacement of any non-serviceable items. Integrity testing of the valves is also completed and recorded by the facility.

Well Workover

Well workovers generally involve recovery and re-installation or replacement of production / injection completion strings. On the NRC, well workovers are undertaken using a Hydraulic Workover Unit (HWU). Workovers may be required to replace or repair failed downhole well equipment including tubing, casing, liners or other completion components. In order to be worked over the well is plugged, as outlined below.

During the workover activities, well fluids are isolated by a deep well plug (and packer) and Blowout Preventer (BOP). In addition, the combination of the choke/kill manifold and brine is used as means of detecting and controlling the well fluids. If a kick is detected, appropriate controls are initiated to prevent further escalation, e.g. kill fluid pumped into the well (see below) or BOP shut.

Well Kill

This is an operation to displace reservoir fluids from the wellbore by replacing them with a weighted fluid system (kill fluid) to achieve zero and stable shut-in tubing head pressure. A well kill may be required if well integrity is compromised and provides a means of mitigation until such time that a more permanent fix can be implemented to re-instate full well integrity. A well kill may also be carried out to facilitate planned, routine well workover and intervention activities.

The kill fluid formula is selected according to the characteristics of the well and the reservoir fluids. Chemically treated and coarsely filtered seawater has been concluded to be an acceptable kill fluid for all wells.

Management of Activities

Interventions and workovers of platform wells are conducted directly from NRC. An HWU is used for working over platform wells. Well interventions, workovers and well kills in Woodside are conducted by the Drilling and Completions function, interfacing and concurring with the facility, as appropriate.

During intervention and workover activities, well control for the prevention of any release of reservoir fluids to the environment is achieved by various barriers such as plugs (including deep set), kill fluids and BOPs. Two or more confirmed barriers are maintained under normal circumstances and in cases with fluid columns being maintained, wells are constantly monitored for kicks. Should a barrier fail, or a kick is detected, appropriate actions (consistent with good oil field practice and standards) are undertaken to restore barrier integrity and / or well control. However, as the work being undertaken on the NRC relates to production wells, the reservoir pressure is known and therefore, the potential for kicks are low; especially if the fluid level is maintained.

Chemical Use and Discharges

Interventions, workovers and well kills typically involve the use and discharge of chemicals which may include, but not limited to:

- glycol
- high viscous (hi-vis) polymer pills or sweeps
- surfactant and / or solvent pills or sweeps
- fluid loss control (FLC) and / or lost circulation material (LCM) pills
- seawater, raw or inhibited with any combinations including biocide, oxygen scavenger, caustic or soda ash
- brine, KCl / NaCl, raw or inhibited with any combinations including biocide, oxygen scavenger, caustic or soda ash.

Well Unloading and Clean-up

Following subsea interventions, workovers and well kills, the well may be unloaded and flowed via the process facilities to be cleaned of any remaining chemicals and fluids in the wellbore or reservoir. During this phase, the products may be processed, as follows:

- **gas**: will be routed into the production process where possible, or flared if unsuitable
- **fluids**: will be routed to the HP flare knock-out drum which discharges liquids to the closed drain system
- **wastes (may include fluids and sand/solids):** will be managed as appropriate based on composition. Solids will be separated for onshore disposal as required following Woodside's Waste Management Plan for Offshore Facilities. An additional strainer may be placed in the flowlines prior to the main separators to remove any large debris that may be in the wellbore.

4. DESCRIPTION OF THE RECEIVING ENVIRONMENT

The existing environment characteristics are described in terms of the Operational Area and Zone of Consequence (ZoC). The Operational Area is located within offshore waters approximately 135 km north-west of Dampier and includes the Capella-1 suspended exploration well located near the NRC platform and the export trunklines Operational Area includes the section of the trunklines within Commonwealth Waters only. The wider ZoC has been identified by hydrocarbon spill modelling of the credible worst-case scenario (loss of well integrity described in **Appendix A**: Environmental Impacts and Risks).

Table 4-1: Summary of key existing environment characteristics

	Sensitive Receptor	Description
Physical Environment	***Climate and Meteorology***	<u>Operational Areas and Wider ZoC</u> • tropical monsoon climate with hot summers and mild winters. • most rainfall occurs during late summer and autumn. • seasonal wind patterns with south-westerly winds characterising summer months and easterly winds characterising winter. Winds during transition period between seasons typically more variable. • tropical cyclones have occurred in region during summer period.
	Oceanography	<u>Operational Areas</u> • locally generated wind surface currents are superimposed on geostrophic and tidal currents. • geostrophic flow characterised by the southward flowing leeuwin current, which strengthens in late summer and winter. • water quality is expected to reflect the offshore oceanic conditions of the North West Shelf Province (NWS Province) and wider region. • surface water temperatures are relatively warm, ranging seasonally from approximately 24.3 to 28.5 °C. • offshore waters are expected to be of high quality given the distance from shore and lack of terrigenous inputs. <u>Wider ZoC</u> • water quality is regulated by the Indonesian Throughflow (ITF), which plays a key role in initiating the Leeuwin Current and brings warm, low-nutrient, low-salinity water to the North West Marine Region (NWMR). It is the primary driver of the oceanographic and ecological processes in the NWS Province. • variation in surface salinity throughout the year is minimal (35.2 and 35.7 practical salinity units (PSU)). • during summer, the Leeuwin Current typically weakens and the Ningaloo Current develops, facilitating upwelling of cold, nutrient-rich waters up onto the continental shelf. • other areas of localised upwelling in the NWMR include the Exmouth Plateau, where seabed topographical features force the surrounding deeper, cooler, nutrient rich waters up into the photic zone. • turbidity is primarily influenced by sediment transport by oceanic swells and primary productivity.
	Bathymetry	<u>Operational Areas</u> • located in waters approximately 30 to 120 m deep (Export Trunklines) and 110 to 162 m deep (Offshore Facility) along the continental shelf

	Sensitive Receptor	Description
		• generally flat with gentle gradient. Wider ZoC • relatively complex bathymetric features are found at Rankin Bank to the east and Glomar Shoals to the west of the Operational Areas. • numerous Key Ecological Features (KEFs) associated with bathymetric features in the wider ZoC.
	Marine Sediment	Operational Areas • consist of fine sediments (from muds to sands) of high quality (low levels of contaminants). • sediments along the export trunklines are predominantly fine sand with variable proportions of coarser sand fractions, silt, shells and shell fragments, coral cemented materials. Wider ZoC • sediment characteristics change with depth and distance from shore, with sediments becoming progressively finer with increasing depth and distance, particularly beyond continental shelf break.
	Air Quality	There is limited air quality data for the NWS Province. However, ambient air quality in the Operational Areas and wider ZoC is expected to be of high quality.
Habitats	***Critical Habitat – EPBC Listed***	No Critical Habitats or Threatened Ecological Communities, as listed under the EPBC Act, are known to occur within the Operational Areas. Refer to the relevant section for each protected species for a description of the critical habitats that may occur within the wider ZoC.
	Marine Primary Producers	Given the water depth, benthic primary producers will not occur within the Operational Areas: Coral Reefs *Wider ZoC:* • nearest coral habitat to the Operational Areas is Rankin Bank. • coral reef habitats include Glomar Shoals, the Montebello/Barrow/Lowendal Islands Group, Barrow Island and Ningaloo Coast. Seagrass Beds / Macroalgae *Wider ZoC:* • nearest seagrass/macroalgae habitat is widely distributed in coastal waters that receive sufficient light to support seagrass and macroalgae. Mangroves

Sensitive Receptor	Description
	Wider ZoC: • broadly distributed in protected coastlines throughout the wider ZoC.
Lifecycle Stages 'Critical' Habitats	Refer to Biologically Important Areas (BIAs) and species descriptions
Other Communities/Habitats	<u>Plankton</u> *Operational Areas:* • plankton communities in the Operational Areas are likely to reflect the broader NWS Province. *Wider ZoC* • offshore phytoplankton communities in the NWS Province are characterised by smaller taxa (e.g. bacteria), while shelf waters are dominated by larger taxa (e.g. diatoms). • peak primary productivity along the shelf edge of the Ningaloo Reef occurs in late summer/early autumn. <u>Pelagic and Demersal Fish Populations</u> *Operational Areas:* • fish communities in the Operational Areas comprise small and large species pelagic fish, as well as demersal species associated with subsea infrastructure. • Ancient Coastline at 125 m KEF may support demersal fish assemblages. *Wider ZoC* • key demersal fish biodiversity areas are likely to occur in other complex habitats, e.g. coral reefs. • relatively complex habitats (e.g. reefs, Rankin Bank and Glomar Shoals) support high demersal fish richness and abundance. <u>Filter Feeders</u> *Operational Areas:* • filter feeders are generally located in areas with strong currents and hard substratum, and have developed on subsea infrastructure in the Operational Areas. • low to moderate density filter feeders widely distributed in surveyed portions of Operational Areas. *Wider ZoC:* • the NWMR has been identified as a sponge diversity hotspot with a high variety of biodiverse areas, particularly in the Ningaloo Marine Park.

	Sensitive Receptor	Description
		<u>Benthic Communities</u> *Operational Areas:* • sparse assemblage of epifauna and infauna in the Operational Areas, which included polychaetes and crustaceans. *Wider ZoC:* • areas of hard substrate expected to host relatively diverse benthic communities.
Protected Species	***Biologically Important Areas (BIAs)***	<u>Operational Areas</u> • flatback, loggerhead, green and hawksbill turtle internesting buffer during summer nesting periods • humpback whale migration corridor (north and south) • roseate tern breeding area (mid-March to July) • Australia fairy tern breeding area (July to late September) • foraging area for the wedge-tailed shearwater during its breeding season (August to April) • whale shark foraging area off Ningaloo coast with seasonally high use (April to June). <u>Wider ZoC</u> • large number of BIAs within wider ZoC.
	Marine Mammals	<u>Operational Areas</u> • sei whale – there are no known key aggregation areas (resting, breeding or feeding) located within the Operational Areas. • Bryde's whale – tropical and temperate waters, with inshore and offshore morphologies / populations. May be seasonally present between December and June. • blue whale - there are no known key aggregation areas (resting, breeding or feeding) located within the Operational Areas. • fin whale – there are no known key aggregation areas (resting, breeding or feeding) located within the Operational Areas. • dugong – known to occur in tropical coastal environments where seagrasses occur, including Ningaloo Marine Park. Likely to rarely transit the export trunklines within the Operational Area. • humpback whale – migration corridor BIA overlaps the export trunklines section of the Operational Area, = likely to be seasonally present between June and September (including northbound and southbound migration). • sperm whale – unlikely to occur in Operational Areas due to preference for oceanic waters. • spotted bottlenose dolphin – likely to occur in the export trunklines section of the Operational Area.

Sensitive Receptor	Description
	• Indo-Pacific humpback dolphin – likely to transit only the inner section of the export trunklines within the Operational Area • Antarctic minke whale – migrates up to 20 °S for feed and possible breed. Unlikely to occur within Operational Areas but may occur in wider ZoC. • southern right whale – unlikely to occur in Operational Area, may occur in southern extent of ZoC. • killer whale, orca – no recognised key localities, expected to rarely occur. Wider ZoC • a range of migratory cetacean species occur, including several dolphin species. • resident coastal populations of small cetacean species. • Antarctic minke whale – migrates up to 20 °S for feed and possible breed. Unlikely to occur within Operational Area but may occur in wider ZoC. • southern right whale – unlikely to occur in Operational Area, may occur in southern extent of ZoC.
Marine Turtles	Operational Areas • the Operational Areas do not contain any known critical habitat for any species of marine turtle (flatback turtle, green turtle, hawksbill turtle and loggerhead turtles have internesting buffers overlapping the Export Trunklines Operational Area). • presence of the five species of Threatened marine turtles (loggerhead, green, leatherback, hawksbill and flatback) within the Offshore Facility Operational Area is likely to be infrequent and limited to individuals or small numbers transiting however, they are expected to commonly transit the export trunklines section, particularly near significant nesting beaches adjacent to the Operational Area during their breeding seasons (e.g. Dampier Archipelago). • Foraging leatherback turtles which feed predominantly on gelatinous pelagic fauna such as jellyfish may occur within the Operational Areas. Wider ZoC • green, loggerhead, flatback and hawksbill turtles have significant nesting rookeries on beaches along the Montebello/Barrow/Lowendal Islands Group, Ningaloo coast and the Muiron Islands. Leatherback turtles may occur within the wider ZoC but there are no known nesting beaches in Western Australia. • marine turtles may forage in shallow waters on the continental shelf, including Rankin Bank.
Sea snakes	Operational Areas • given the offshore location and deeper water depths of the Operational Areas, sea snake sightings will likely be infrequent and comprise a few individuals but may be more prevalent within the export trunklines section of the Operational Area.

Sensitive Receptor	Description
	Wider ZoC • sea snakes frequent the waters of the continental shelf and around offshore islands.
Fishes and Elasmobranchs	Operational Areas • the EPBC Act Protected Matters Search Tool identified ten species of Threatened and/or Migratory sharks (narrow sawfish, grey nurse shark, white shark, shortfin mako, longfin mako, reef manta ray, giant manta ray, dwarf sawfish, green sawfish and whale shark) that may occur in the Operational Areas. • the Operational Areas overlap whale shark foraging area (although may constitute migration corridor for animals moving to and from annual aggregation off Ningaloo Coast). • two Conservation Dependent species under the EPBC Act were also identified (southern bluefin tuna and scalloped hammerhead) likely to occur in the Operational Area or ZoC. Wider ZoC • whale sharks are known to aggregate annually, from March to July, in areas off Ningaloo and North West Cape. After the aggregation period, the distribution of the whale sharks is largely unknown, but surveys suggest that the group disperses widely and up to 1800 km away to areas in Indonesia, Christmas Island and Coral Sea. • Ningaloo Reef is an important area for giant and reef manta rays in autumn and winter, and they are known to occur in tropical waters throughout the wider ZoC. • grey nurse sharks are likely to be found in shallow waters of the wider ZoC. • sawfish may occur in shallow coastal habitats. • great white sharks, shortfin makos and longfin makos are all known to occur within the wider ZoC. • blind gudgeon may be found in the wider ZoC
Birds	Operational Areas: • fifteen species of Threatened and/or Migratory bird species (common sandpiper, common noddy, fork-tailed swift, sharp-tailed sandpiper, red knot, curlew sandpiper, pectoral sandpiper, streaked shearwater, lesser frigate bird, great frigatebird, southern giant petrel, eastern curlew, osprey, roseate tern and Australian fairy tern) were identified as potentially occurring within the Operational Areas. No critical habitat associated with these species has been identified within the Operational Area. • BIAs for the wedge-tailed shearwater, roseate tern and Australian fairy tern, during their breeding seasons, overlap the Export Trunklines Operational Area. Wider ZoC:

	Sensitive Receptor	Description
		• there are several BIAs (key breeding/nesting, roosting, foraging and resting areas) for seabirds and migratory shorebirds in the wider ZoC, including areas on the islands of the Montebello/Barrow/Lowendal Islands group, Pilbara Islands, Ningaloo Coast and Muiron Islands. • no Ramsar wetlands in the wider ZoC.
Socio-economic	***Cultural Heritage***	Operational Areas • there are no known sites of Indigenous or European cultural or heritage significance within or in the vicinity of the Operational Areas. Wider ZoC • Barrow Island, Montebello Islands, Ningaloo Reef and the adjacent foreshore contain numerous registered Indigenous heritage sites. • the closest recorded shipwreck to the Operational Areas is *Zelma*, approximately 15 km south of the Operational Areas. • World Heritage Areas include the Ningaloo Coast World Heritage Area. • National Heritage listed and proposed places include Barrow Island, Montebello Islands and Ningaloo Coast. • Commonwealth Heritage listed places include the Ningaloo Marine Area – Commonwealth Waters.
	Ramsar Wetlands	No Ramsar wetlands in Operational Areas or wider ZoC.
	Fisheries - Commercial	Operational Areas There are a number of Commonwealth and State fisheries designated management areas, however, only the State Pilbara Line Fishery (Pilbara Demersal Scalefish Fisheries) is expected to be active within the Operational Areas: *Commonwealth fisheries:* • Southern Bluefin Tuna Fishery • Western Skipjack Tuna Fishery • Western Tuna and Billfish Fishery *State fisheries:* • Pilbara Demersal Scalefish Fishery • West Coast Deep Sea Crustacean Managed Fishery • Specimen Shell Fishery • Onslow Prawn Managed Fishery

Sensitive Receptor	Description
	• Pearl Oyster Managed Fishery • Marine Aquarium Fish Managed Fishery • Western Australian Abalone Fishery • Mackerel Managed Fishery • South West Coast Salmon Managed Fishery • There are no aquaculture activities within or adjacent to the Operational Areas. Wider ZoC A number of State and Commonwealth fisheries overlap the ZoC.
Fisheries - Traditional	There are no traditional, or customary fisheries within or adjacent to the Operational Areas. Traditional fisheries are typically restricted to shallow coastal waters and/or areas with structure such as reef. Ningaloo Coast, Barrow Island and Montebello Islands and the adjacent foreshores have a known history of fishing, when areas were occupied (as identified from historical records).
Tourism and Recreation	Operational Areas: • tourism activities in the Offshore Facility Operational Area is not known due to water depths and distance offshore. • Within the export trunklines section of the Operational Area (36 km to the Dampier boat ramp at its closest point) recreational fishing is likely to occur, however, it is likely to be restricted to few relatively large vessels transiting mainly between offshore islands and shoals. Wider ZoC: • recreational fishing is expected to occur throughout wider ZoC, primarily in continental shelf waters including Rankin Bank. • the Ningaloo Marine Park and Montebello Islands are popular for marine nature-based tourist activities.
Shipping	Operational Areas: • several shipping fairways overlap the Export Trunklines Operational Area. Wider ZoC: • the coastal and offshore waters of the region support significant commercial shipping activity, the majority of which is associated with the mining and oil and gas industries. • major shipping routes are associated with entry to the ports of Barrow Island, Dampier, Onslow and Port Hedland.
Oil and Gas Infrastructure	Operational Areas: • GWA and Angel are nearby to the Operational Areas (18 km west and 40 km east respectively).

	Sensitive Receptor	Description
		Wider ZoC: • numerous Petroleum Titles surrounding the Operational Areas. • several fixed platforms near the Operational Areas, including Goodwyn, Okha, Pluto, Angel and Reindeer.
	Defence	There are designated defence practice areas in the offshore marine waters off Ningaloo and the North West Cape, beyond the Operational Area.
Values and Sensitivities	***Montebello / Barrow / Lowendal Islands***	Protected areas in this locality include: • Montebello Australian Marine Park • Montebello Islands Marine Park, Barrow Island Marine Park, Barrow Island Marine Management Area • Barrow Island Nature Reserve • Lowendal Islands Nature Reserve
	Ningaloo Coast and Gascoyne	Protected areas in this locality include: • Ningaloo Coast World Heritage Area and National Heritage Area • Ningaloo Australian Marine Park • Ningaloo Marine Park and Muiron Islands Marine Management Area • Gascoyne Australian Marine Park.
	Pilbara Coast and Islands	Sensitive areas in this locality include: • Dampier Australian Marine Park • Dampier Archipelago National Heritage Place • Pilbara Islands (north group) • Pilbara Islands (middle group) • Pilbara Islands (south group).
	Kimberley Coast and Islands	Protected areas in this locality include: • Eighty Mile Beach Australian Marine Park
	Rowley Shoals	Protected areas in this locality include: • Argo-Rowley Terrance Australian Marine Park

Sensitive Receptor	Description
Shark Bay	Protected areas in this locality include: • Shark Bay Marine Park
Key Ecological Features	<u>Operational Areas</u> • Ancient Coastline at 125 m Depth Contour. <u>Wider ZoC:</u> A number of KEFs occur within the wider ZoC.
Other Sensitive Areas	Rankin Bank lies approximately 54 km west of the Operational Areas at the closest point

4.1 Species

A total of 95 EPBC Act listed marine species were identified as potentially occurring within the Operational Areas and wider ZoC. Of the species identified by the Protected Matters Search Tool (PMST) report, 40 are listed as threatened and 58 are migratory under the EPBC Act, of which a subset of 32 and 43 species were identified as potentially occurring within the export pipeline and the facility sections of the Operational Areas, respectively. (**Table 4-2**).

Table 4-2 Threatened and Migratory Marine Species under the EPBC Act Potentially Occurring within the Operational Areas

Species Name	Common Name	Threatened Status	Migratory Status	Operational Area		ZoC
				Offshore Facility	Export Trunklines	
Mammals						
Balaenoptera borealis	Sei whale	Vulnerable	Migratory	Y	Y	Y
Balaenoptera edeni	Bryde's whale	N/A	Migratory	Y	Y	Y
Balaenoptera musculus	Blue whale	Endangered	Migratory	Y	Y	Y
Balaenoptera physalus	Fin whale	Vulnerable	Migratory	Y	Y	Y
Dugong dugon	Dugong	N/A	Migratory	N/A	Y	Y
Megaptera novaeangliae	Humpback whale	Vulnerable	Migratory	Y	Y	Y
Orcinus orca	Killer whale, Orca	N/A	Migratory	Y	Y	Y
Physeter macrocephalus	Sperm whale	N/A	Migratory	Y	Y	Y
Tursiops aduncus (Arafura/ Timor Sea populations)	Spotted bottlenose dolphin (Arafura/Timor Sea populations)	N/A	Migratory	Y	Y	Y
Sousa chinensis	Indo-Pacific humpback dolphin	N/A	Migratory	N/A	Y	Y
Balaenoptera bonaerensis	Antarctic minke whale, dark-shoulder minke whale	N/A	Migratory	N/A	N/A	Y
Eubalaena australis	Southern right whale	Endangered	Migratory	N/A	N/A	Y
Reptiles						
Aipysurus apraefrontalis	Short-nosed sea snake	Critically Endangered	N/A	N/A	Y	Y
Caretta caretta	Loggerhead turtle	Endangered	Migratory	Y	Y	Y
Chelonia mydas	Green turtle	Vulnerable	Migratory	Y	Y	Y

Species Name	Common Name	Threatened Status	Migratory Status	Operational Area		ZoC
				Offshore Facility	Export Trunklines	
Dermochelys coriacea	Leatherback turtle, Leathery turtle	Endangered	Migratory	Y	Y	Y
Eretmochelys imbricata	Hawksbill turtle	Vulnerable	Migratory	Y	Y	Y
Natator depressus	Flatback turtle	Vulnerable	Migratory	Y	Y	Y
Fishes and Elasmobranchs						
Anoxypristis cuspidata	Narrow sawfish, Knifetooth sawfish	N/A	Migratory	Y	Y	Y
Carcharias taurus (west coast population)	Grey nurse shark	Vulnerable	N/A	N/A	Y	Y
Carcharodon carcharias	White shark, great white shark	Vulnerable	Migratory	Y	Y	Y
Isurus oxyrinchus	Shortfin mako, Mako shark	N/A	Migratory	Y	Y	Y
Isurus paucus	Longfin mako	N/A	Migratory	Y	Y	Y
Manta alfredi	Reef manta ray, coastal manta ray, inshore manta ray, Prince Alfred's ray, resident manta ray	N/A	Migratory	Y	Y	Y
Manta birostris	Giant manta ray, chevron manta ray, Pacific manta ray, pelagic manta ray, oceanic manta ray	N/A	Migratory	Y	Y	Y
Pristis clavata	Dwarf sawfish, Queensland Sawfish	Vulnerable	Migratory	N/A	Y	Y
Pristis zijsron	Green sawfish, Dindagubba, narrowsnout sawfish	Vulnerable	Migratory	Y	Y	Y
Rhincodon typus	Whale shark	Vulnerable	Migratory	Y	Y	Y

Species Name	Common Name	Threatened Status	Migratory Status	Operational Area		ZoC
				Offshore Facility	Export Trunklines	
Sphyrna lewini[1]	Scalloped hammerhead	N/A	N/A	Y	Y	Y
Thunnus maccoyii[2]	Southern bluefin tuna	N/A	N/A	Y	Y	Y
Lamna nasus	Portbeagle, Mackeral shark	N/A	Migratory	N/A	N/A	Y
Birds						
Actitis hypoleucos	Common sandpiper	N/A	Migratory	Y	Y	Y
Anous stolidus	Common noddy	N/A	Migratory	Y	Y	Y
Apus pacificus	Fork-tailed swift	N/A	Migratory	N/A	Y	Y
Calidris acuminata	Sharp-tailed sandpiper	N/A	Migratory	Y	Y	Y
Calidris canutus	Red knot	Endangered	Migratory	Y	Y	Y
Calidris ferruginea	Curlew sandpiper	Critically Endangered	N/A	N/A	Y	Y
Calidris melanotos	Pectoral sandpiper	N/A	Migratory	Y	Y	Y
Calonectris leucomelas	Streaked shearwater	N/A	Migratory	Y	Y	
Fregata ariel	Lesser frigatebird, least frigatebird	N/A	Migratory	Y	Y	Y
Fregata minor	Great frigatebird, greater frigatebird	N/A	Migratory	Y	Y	Y
Hydroprogne caspia	Caspian tern	N/A	Migratory	N/A	N/A	Y
Macronectes giganteus	Southern giant petrel	Endangered	Migratory	N/A	Y	Y
Numenius madagascarien sis	Eastern curlew, far eastern curlew	Critically Endangered	Migratory	Y	Y	Y
Pandion haliaetus	Osprey	N/A	Migratory	N/A	Y	Y
Sterna dougalli	Roseate tern	N/A	Migratory	N/A	Y	Y
Sternula nereis nereis	Australian fairy tern	Vulnerable	N/A	N/A	Y	Y

[1] Conservation Dependent listed species under the EPBC Act

[2] Conservation Dependent listed species under the EPBC Act

Species Name	Common Name	Threatened Status	Migratory Status	Operational Area		ZoC
				Offshore Facility	Export Trunklines	
Ardenna carneipes	Flesh-footed shearwater, fleshy-footed shearwater	N/A	Migratory	N/A	N/A	Y
Ardenna pacifica	Wedge-tailed shearwater	N/A	Migratory	N/A	N/A	Y
Charadrius veredus	Oriental plover, oriental dotterel	N/A	Migratory	N/A	N/A	Y
Glareola maldivarum	Oriental pratincole	N/A	Migratory	N/A	N/A	Y
Limosa lapponica	Bar-tailed godwit	N/A	Migratory	N/A	N/A	Y
Limosa lapponica baueri	Bar-tailed godwit (baueri), Western Alaskan bar-tailed godwit	Vulnerable	N/A	N/A	N/A	Y
Limosa lapponica menzbieri	Northern Siberian bar-tailed godwit, bar-tailed godwit (menzbieri)	Critically Endangered	N/A	N/A	N/A	Y
Malurus leucopterus edouardi	White-winged fairy-wren (Barrow Island), Barrow Island black and white fairy-wren	Vulnerable	N/A	N/A	N/A	Y
Onychoprion anaethetus	Bridled tern	N/A	Migratory	N/A	N/A	Y
Papasula abbotti	Abbott's booby	Endangered	N/A	N/A	N/A	Y
Phaethon lepturus	White-tailed tropicbird	N/A	Migratory	N/A	N/A	Y
Pterodroma mollis	Soft-plumaged petrel	Vulnerable	N/A	N/A	N/A	Y
Thalasseus bergii	Crested tern	N/A	Migratory	N/A	N/A	Y
Tringa nebularia	Common greenshank, greenshank	N/A	Migratory	N/A	N/A	Y
Sternula albifrons	Little tern	N/A	Migratory	N/A	N/A	Y
Thalassarche cauta cauta	Shy Albatross	Vulnerable	N/A	N/A	N/A	Y
Thalassarche cauta steadi	White-capped Albatross	Vulnerable	N/A	N/A	N/A	Y

Species Name	Common Name	Threatened Status	Migratory Status	Operational Area		ZoC
				Offshore Facility	Export Trunklines	
Thalassarche impavida	Campbell Albatross	Vulnerable	N/A	N/A	N/A	Y
Thalassarche melanophris	Black-browed Albatross	Vulnerable	N/A	N/A	N/A	Y

Seabirds

The Operational Areas may be occasionally visited by migratory and oceanic birds but does not contain any emergent land that could be used as roosting or nesting habitat (and contains no known critical habitats (including feeding) for any species. Fifteen species of birds considered to be MNES were identified as potentially occurring within the Operational Areas (13 within the export pipeline and 11 within the facility) including the Australian fairy tern, common sandpiper, common noddy, sharp-tailed sandpiper, red knot, roseate tern, pectoral sandpiper, lesser frigatebird, great frigatebird, curlew sandpiper, eastern curlew, forked-tail swift, southern great petrel, streaked shearwater and osprey.

A Biologically Important Area (BIA) for the migratory wedge-tailed shearwater overlaps the Operational Areas. The NWMR lies within the East Asian-Australasian flyway for migratory birds; species undertaking migrations between East Asia and Australia may be present between late spring and early autumn.

Based on the results of two survey cruises and other unpublished records, Dunlop et al. (1988) recorded the occurrence of 18 species of seabirds over the NWS Province. These included a number of species of petrel, shearwater, tropicbird, frigatebird, booby and tern, as well as the silver gull. Of these, eight species occur year-round, and the remaining ten are seasonal visitors. From these surveys, it was noted that seabird distributions in tropical waters were generally patchy, except near islands.

Migratory shorebirds may be present in or fly through the region between July and December and again between March and April as they complete migrations between Australia and offshore locations (Bamford et al. 2008, Commonwealth of Australia 2015c). Note that no Ramsar wetlands were identified within the Operational Areas or wider ZoC.

Marine Mammals

Blue whales were identified as potentially occurring within the Operational Areas and wider ZoC. There is a pygmy blue whale migration BIA off the coast of Western Australia that lies approximately 41 km north-west of the Operational Area at the closest point and lies within the wider ZoC. Based on pygmy blue whale migration timing, the species may occur in the wider ZoC between April and August (north-bound migration) and October to January (south-bound migration). A foraging BIA lies off the Ningaloo Reef/North West Cape region (approximately 327 km south-west of the Operational Areas at the closet point, but within the wider ZoC), within which pygmy blue whales may feed (Double et al. 2014).

Humpback whales were identified as occurring within the Operational Areas and wider ZoC. The species regularly migrates seasonally between feeding grounds in the Southern Ocean and breeding and calving grounds off northern WA, particularly Camden Sound (Jenner et al. 2001). Calving typically occurs at the northern extent of the migration corridor (beyond the wider ZoC). The humpback whale migration BIA overlaps the export trunklines sections of the Operational Area and is approximately 36 km from the Offshore Facility Operational Area. The Exmouth Gulf and Shark Bay humpback whale resting/aggregation BIAs are located outside the ZoC. Noise loggers deployed near Woodside's GWA facility 21 km from the Operational Area) detected humpback whales present at the end of September, likely migrating south, and from June to mid-August in deeper water, nearer to the continental shelf, likely migrating north (RPS Environment and Planning 2012). The southward migration of cow/calf pairs is slightly later during October (extending into November and December). During the southbound migration, it is likely that most individuals, particularly cow/calf pairs, stay closer to the coast than the northern migratory path. Humpback whales may occur within the Export Trunklines Operational Area and wider ZoC during these migration periods.

There is the potential for seven species of cetaceans, including, Sei whale, Bryde's whale, Fin whale, Sperm whale, Antarctic Minke whale, Southern Right Whale, Killer whale, Spotted Bottlenose dolphin and Indo-pacific humpback dolphin to infrequently transit the Operational Areas.

The dugong was identified as potentially occurring in the Export Trunklines Operational Area and the wider ZoC. Dugong distribution is correlated with seagrass habitats in which dugong feed, although water temperature has also been correlated with dugong movements and distribution (Preen et al. 1997, Preen 2004). Dugongs are known to migrate between seagrass habitats (hundreds of kilometres) (Sheppard et al. 2006). However, given the Export Trunklines Operational Area is located offshore in deep water which does not support seagrass habitat and does not contain any critical dugong habitat, the occurrence of dugongs in the area is considered very unlikely. Dugongs may occur along the Ningaloo Coast and around islands of the Pilbara Coast, within the wider ZoC, and may rarely transit the Export Trunklines Operational Area.

Marine Reptiles

Five of the six marine turtle species recorded for the NWMR have the potential to occur within the Operational Areas; the loggerhead turtle, green turtle, leatherback turtle, hawksbill turtle and the flatback turtle. Four of the turtle species (green, loggerhead, flatback and hawksbill) have significant nesting rookeries on beaches along the mainland coast and islands in the wider ZoC.

There is no emergent habitat within the Operational Areas; therefore, nesting aggregations are unlikely to occur in the vicinity of the Operational Areas (both the Offshore Facility and Export Trunklines). Given the water depth and lack of suitable benthic prey, foraging adult turtles are not expected to occur within the facility section of the Offshore Facility Operational Area, with the exception of the leatherback turtle which feed predominantly on gelatinous pelagic fauna such as jellyfish. There is potential for marine turtles to use the Glomar Shoals KEF as foraging habitat at times; however, it is not a known foraging location and turtles will likely only be present within the shallower areas of the KEF (i.e. outside the Operational Areas).

The BIAs that overlap the Export Trunklines Operational Area include:

- Flatback turtle internesting buffers around the Dampier Archipelago, Cape Lambert, Dixon Island, Intercourse Island, Legendre Island, Huay Island and Delambre Island during their summer nesting period (a nesting habitat critical to the survival of flatback turtles with a 40 km internesting buffer also overlaps this BIA).
- Green turtle year-round internesting buffer over the Dampier Archipelago (a nesting habitat critical to the survival of green turtles with a 20 km internesting buffer also overlaps and slightly expands this BIA).
- Hawksbill turtle internesting BIA over the Dampier Archipelago (peak season in spring and early summer) (a nesting habitat critical to the survival of hawksbill turtles with a 20 km internesting buffer also overlaps and very slightly expands this BIA).
- Loggerhead internesting buffers around Rosemary Island and Cohen Island.

Sixteen species of sea snakes were identified as potentially occurring within the wider ZoC. One of these species, the short-nosed sea snake, is listed as Critically Endangered and identified as potentially occurring within the Export Trunklines Operational Area. This species has primarily been recorded on the Sahul Shelf at Ashmore Reef and Cartier Island. Given the water depth of the Offshore Facility Operational Area, sea snake sightings will be infrequent and likely comprise few individuals within the Operational Areas.

Sharks, Rays and Fishes

The whale shark was identified as potentially occurring within the Operational Areas. Whale sharks aggregate annually to feed in the waters of the Ningaloo Coast (this feeding BIA lies approximately 316 km south-west of the Operational Areas, within the wider ZoC) from March to July, with the largest numbers recorded in April and May (Sleeman et al. 2010). However, seasonal aggregation can be variable, with individual whale sharks recorded at other times of the year. The population (comprised of individuals that visit the reef at some point during their lifetime) has been estimated to range between 300 and 500 individuals; the number visiting Ningaloo Reef in any given year is expected to be somewhat smaller (Meekan et al. 2006). Timing of the whale shark migration to and from Ningaloo coincides with the coral mass spawning period, when there is an abundance of food (krill, planktonic larvae and schools of small fish) in the waters adjacent to Ningaloo Reef. At Ningaloo Reef, whale sharks stay within a few kilometres of the shore and in waters approximately 30–50 m deep (Wilson et al. 2006).

Several shark/ray species including the great white shark, shortfin mako, longfin mako, giant manta ray, grey nurse shark, green sawfish, dwarf sawfish, largetooth or freshwater sawfish, scalloped hammerhead, reef manta ray and narrow sawfish may be present within the Operational Area, for short durations when individuals transit the area.

Of the fish species identified as potentially occurring within the Operational Area, 35 are species of pipefish and seahorse. However, bycatch data indicates they are uncommon in deeper continental shelf waters (50–200 m) and therefore, are unlikely to occur within the Operational Area. This family (Syngnathidae) are commonly found in seagrass and sandy habitats around coastal islands and shallow reef areas along the NWSP and is more likely to be found in coastal areas including the Ningaloo Coast. Southern Bluefin Tuna area also likely to occur within the Operational Areas and wider ZoC, particularly during summer when juveniles migrate southwards.

4.2 Socio-Economic and Cultural

There are no known sites of Indigenous or European cultural heritage significance within the vicinity of the Operational Areas.

Within the wider ZoC, Ningaloo Reef, Exmouth, Barrow Island, Montebello Islands and the Kimberley coast and adjacent foreshores have a long history of occupancy by Aboriginal communities. Indigenous heritage places are protected under the *Aboriginal Heritage Act* 1972 (WA) or EPBC Act.

In 2018 the Australian Parliament passed the Underwater Cultural Heritage Act 2018 (Underwater Heritage Act). The Act came into effect on 1 July 2019, replacing the Historic Shipwrecks Act 1976. This new Underwater Heritage Act continues the protection of Australia’s shipwrecks, but has also broadened to include protection to sunken aircraft and other types of underwater cultural heritage.

A search of the National Shipwreck Database indicated that there are no known shipwrecks recorded within the Operational Areas. There are six shipwrecks within 50 km of the Export Trunklines Operational Area and their approximate distances are as follows:

- Zelma (15 km from the Operational Areas)
- Alice (34 km from the Operational Areas)
- Unknown (K. Lambert Report) (40 km from the Operational Areas)
- McCormack and McDermott Derrick Barge No 20 both 47 km from the Operational Areas
- Dampier (48 km from the Operational Areas.

There are no heritage listed sites within the Operational Areas; however, there are a number of gazetted and proposed National and Commonwealth heritage places in the wider ZoC, including the Ningaloo Coast World Heritage Area, Barrow Island and the Montebello-Barrow Islands Marine Conservation Reserves Nominated Heritage Place, the Ningaloo Coast Natural Heritage Place and Ningaloo Marine Area (Commonwealth Waters) Commonwealth Heritage Place.

No Ramsar wetlands overlap the Operational Areas or wider ZoC.

A number of Commonwealth and State fisheries are located within the Operational Areas and/or wider ZoC including the following:

- Mackerel Managed Fishery
- Marine Aquarium Fish managed Fishery
- Onslow Prawn managed Fishery
- Pearl Oyster Managed Fishery
- Pilbara Demersal Scalefish Fishery
- North West Slope Trawl Fishery
- Western Deepwater Trawl Fishery
- Southern Bluefin Tuna Fishery
- South West Coast Salmon Managed Fishery
- Specimen Shell Fishery
- West Coast Deep Sea Crustacean Managed Fishery
- Western Abalone Fishery
- Western Skipjack Tuna Fishery
- Western Tuna and Billfish Fishery.

State fisheries designated management areas within the Operational Areas or ZoC include the following:

- Exmouth Gulf Prawn Managed Fishery
- Nickol Bay Prawn Managed Fishery
- West Coast Rock Lobster Fishery.

There are no aquaculture operations within or adjacent to the Operational Areas as these operations are typically restricted to shallow coastal waters.

There are no traditional or customary fisheries within the Operational Areas, as these are typically restricted to shallow coastal waters and/or areas with structure such as reef. However, it is recognised that Barrow Island, Montebello Islands and Ningaloo Reef, all within the wider ZoC, have a known history of fishing when areas were occupied (as from historical records) (Department of Conservation and Land Management, 2005c; Department of Environment and Conservation, 2007).

Tourism and Recreation

No tourist activities take place specifically within the Operational Areas; however, it is acknowledged that there are growing tourism and recreational sectors in WA which have expanded over the last couple of decades. Growth and the potential for further expansion in tourism and recreational activities is recognised for the Pilbara and Gascoyne regions, with the development of regional centres and a workforce associated with the resources sector (SGS Economics & Planning 2012).

Tourism is one of the major industries of the Gascoyne region and contributes significantly to the local economy in terms of both income and employment. The main marine nature-based tourist activities are concentrated around and within the Ningaloo World Heritage Area (approximately 268 km south-west of the Operational Areas) including recreational fishing, snorkelling and scuba diving, whale shark (April to August) and manta ray (year round) encounters, whale watching (July to October), whale encounters (August and November) and turtle watching (all year round) (Schianetz et al. 2009). The Dampier Archipelago and Montebello Islands (7 km and 39 km from the Operational Areas respectively), are the closest locations for tourism with some charter boat operators taking visitors to these islands (Department of Environment and Conservation, 2007).

Given the distance to the nearest access nodes from the Offshore Facility Operational Area (135 km to the Dampier boat ramp on the Burrup Peninsula and 204 km to Port Headland), recreational fishing effort is expected to be restricted to relatively large vessels and hence is considered to be low. Within the Export Trunklines section of the Operational Area (36 km to the Dampier boat ramp at its closest point) recreational fishing is likely to occur, however, will be restricted to few relatively large vessels transiting mainly between offshore islands and shoals.

Shipping

The NWMR supports significant commercial shipping activity, the majority of which is associated with the mining and oil and gas industries. The Australian Maritime Safety Authority (AMSA) has introduced a network of marine fairways across the NWMR of WA to reduce the risk of vessel collisions with offshore infrastructure. The fairways are not mandatory but AMSA strongly recommends commercial vessels remain within the fairway when transiting the region. It is noted that none of these fairways intersect with the Offshore Facility Operational Area with one overlapping the Export Trunklines section of the Operational Area (**Figure 4-1**).

Ports in the region are nodes of increased vessel activities; active ports in the vicinity of the Operational Area include:

- Dampier (approximately 135 km south)
- Barrow Island (approximately 123 km south)
- Port Hedland (approximately 204 km south).

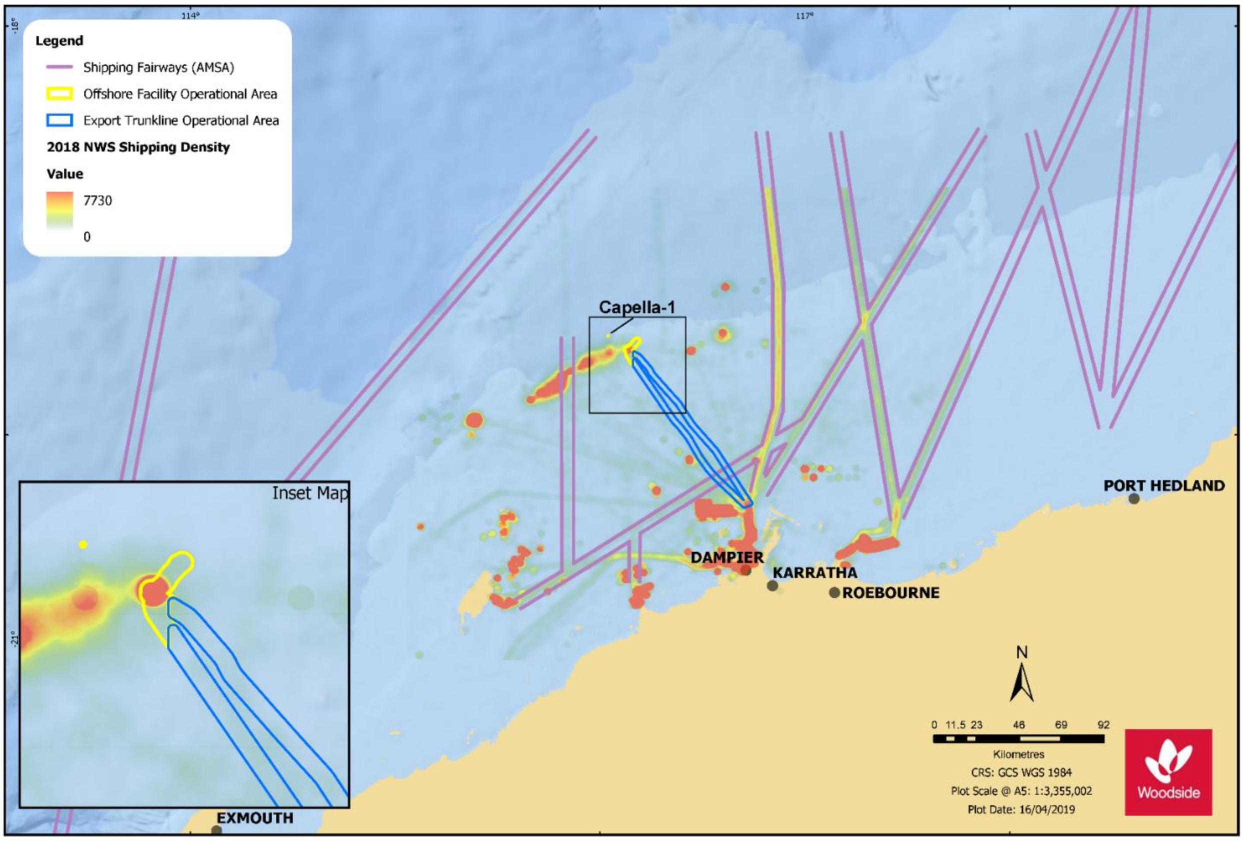

Figure 4-1: Vessel density map in the vicinity of Operational Area from 2016, derived from AMSA satellite tracking system data (vessels include cargo, LNG tanker, ore carriers passenger vessels, support vessels and other vessels)

Oil and Gas Infrastructure

The Offshore Facility Operational Area is located within an area of established oil and gas operations in the broader NWMR. Several facilities are located in proximity to the Operational Areas. Several FPSOs and platforms are currently in operation in the vicinity of the Offshore Facility Operational Area.

Defence

There are designated Department of Defence practice areas in the offshore marine waters off Ningaloo and the North West Cape, beyond the Operational Areas. A Royal Australian Air Force base located at Learmonth, on North West Cape, lies approximately 288 km south-west of the Operational Area.

4.3 Values and Sensitivities

The offshore environment of the NWMR contains environmental assets (such as habitat and species) of high value or sensitivity including Commonwealth offshore waters, as well as the wider regional context including coastal waters and habitats such as the Montebello/Barrow/Lowendal Island Group and the Ningaloo World Heritage Area, and the associated resident, temporary or migratory marine life including species such as marine mammals, turtles and birds.

Many sensitive receptor locations are protected as part of Commonwealth and State managed areas and have been allocated conservation objectives (International Union for Conservation of Nature (IUCN)

Protected Area Category) based on the Australian IUCN reserve management principles in Schedule 8 of the EPBC Regulations 2000. These principles determine what activities are acceptable within a protected area under the EPBC Act. All planned petroleum activities will take place within the Operational Areas, which overlaps a Key Ecological Feature (described below), The planned activities associated with the Petroleum Activities Program will be conducted in a manner consistent with the Australian IUCN reserve management principles for the IUCN categories which have been identified in **Table 4-3** and shown in **Figure 4-2**.

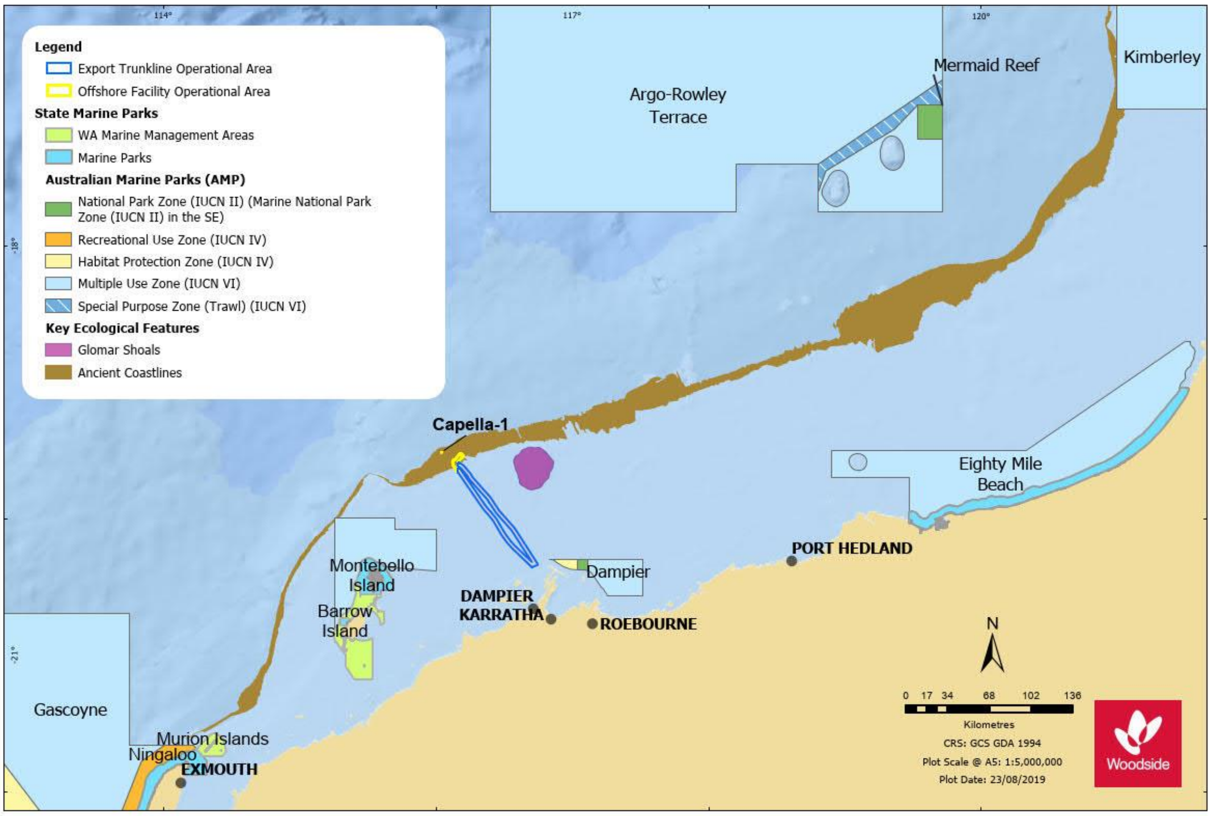

Figure 4-2: Established and proposed Commonwealth and State Marine Protected Areas in Relation to the Operational Area

Table 4-3: Summary of Established and Proposed Marine Protected Areas (MPAs) and Other Sensitive Locations in the Region Relating to the Operational Areas

	Distance from Operational Areas to Values/Sensitivity boundaries (km)	IUCN Protected Area Category*
Australian Marine Parks (AMP) (formerly Commonwealth Marine Reserves)		
Dampier†	9	II, IV, VI
Montebello†	40	VI
Argo-Rowley Terrace†	197	II, VI
Eighty Mile Beach†	237	VI
Gascoyne†	273	II, IV, VI
Mermaid Reef	436	IA
Ningaloo†	289	IV
Shark Bay	590	IV
State Marine Parks and Nature Reserves		
Marine Parks		
Montebello Islands	84	IA, II, IV, VI
Barrow Island	134	IA, IV, VI
Ningaloo	289	IA, II, IV
Rowley Shoals	348	II
Marine Management Areas		
Barrow Island	104	IA, IV, VI
Muiron Islands	268	IA, VI
Fish Habitat Protection Areas		
None identified in the Operational Areas or ZoC		
Nature Reserves		
Lowendal Islands Nature Reserve†	39	IA
Barrow Island Nature Reserve†	134	IA
Heritage		
World Heritage Areas		
The Ningaloo Coast	268	Not applicable
National Heritage Areas		
Dampier Archipelago (including Burrup Peninsula)	7	Not applicable
The Ningaloo Coast	268	Not applicable
Commonwealth Heritage Areas		
Ningaloo Marine Area - Commonwealth Waters	268	Not applicable
Key Ecological Features		
Glomar Shoals	25	Not applicable

	Distance from Operational Areas to Values/Sensitivity boundaries (km)	IUCN Protected Area Category*
Ancient coastline at 125 m depth contour	Overlapping Operational Areas	Not applicable
Continental Slope Demersal Fish Communities	67	Not applicable
Exmouth Plateau	180	Not applicable
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	244	Not applicable
Commonwealth Waters adjacent to Ningaloo Reef	291	Not applicable

Ancient Coastline at 125 m Depth Contour

Several steps and terraces as a result of Holocene sea level changes occur in the region, with the most prominent of these features occurring as an escarpment along the NWS Province and Sahul Shelf at a water depth of 125 m, which forms the Ancient Coastline at 125 m Depth Contour KEF (the Ancient Coastline). The Ancient Coastline KEF overlaps the Operational Areas, extending along a line approximated by the 125 m isobath. The Ancient Coastline is not continuous throughout the NWS Province, and coincides with a well-documented eustatic still stand at approximately 130 m worldwide (Falkner et al. 2009).

Where the Ancient Coastline provides areas of hard substrate, it may contribute to higher diversity and enhanced species richness relative to soft sediment habitat (DSEWPaC 2012a). Parts of the Ancient Coastline, represented as rocky escarpment, are considered to provide biologically important habitat in an area predominantly made up of soft sediment.

The escarpment type features may also potentially facilitate mixing within the water column due to upwelling, providing a nutrient-rich environment. Although the Ancient Coastline adds more habitat types to a representative system, the habitat types are not unique to the coastline as they are widespread on the upper shelf (Falkner et al. 2009).

5. ENVIRONMENTAL IMPACTS AND RISKS

5.1 Risk and Impact Identification and Evaluation

Woodside undertook an environmental risk assessment (with outputs applicable to the EP provided in (**Appendix A**: Environmental Impacts and Risks) to identify the potential environmental impacts and risks associated with the operation of the facility and the control measures to manage the identified environmental impacts and risks to as low as reasonably practicable (ALARP) and an acceptable level. This risk assessment and evaluation was undertaken using Woodside's Risk Management Framework.

Environmental impacts and risks include those directly and indirectly associated with the Petroleum Activities Program and includes potential emergency and accidental events. Planned activities have the potential for inherent environmental impacts. An environmental risk is an unplanned event with the potential for impact (termed risk 'consequence').

Herein, potential impact from planned activities are termed 'impacts', and 'risks' are associated with unplanned events with the potential for impact (should the risk be realised), with such impact termed potential 'consequence'.

The key steps of Woodside's Risk Management Processes are shown in **Figure 5-1**. A summary of each step and how it is applied to the proposed Program is provided below.

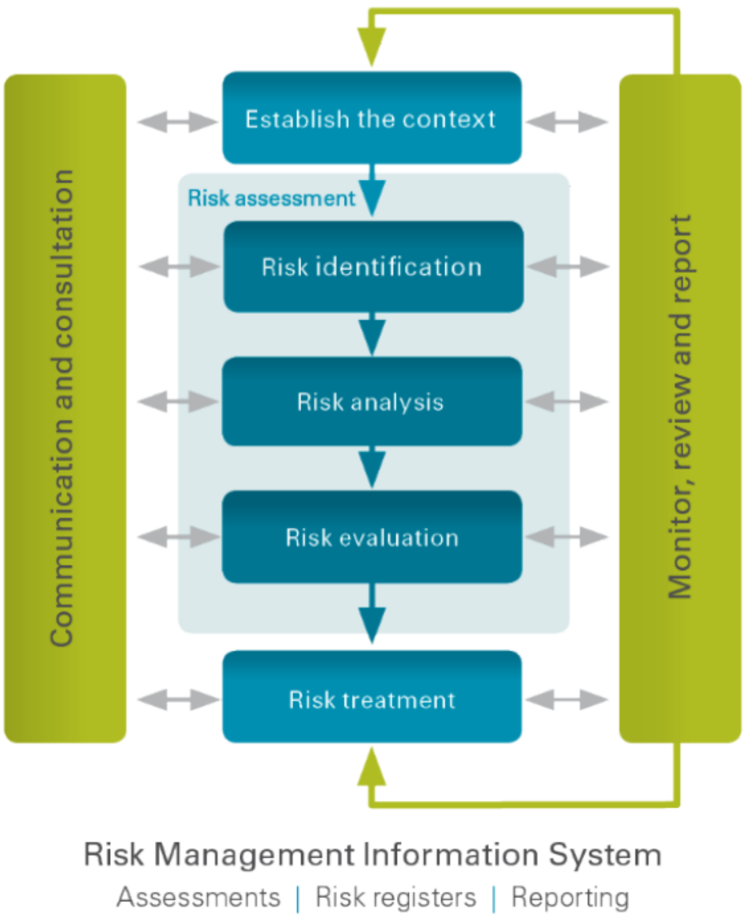

Figure 5-1: Key steps in Woodside's Risk Management Process

5.1.1 Establish the Context

The objective of a risk assessment is to assess identified risks and apply appropriate control measures to eliminate, control or mitigate the risk to ALARP and to determine if the risk is acceptable.

Hazard identification workshops aligned with NOPSEMA's Hazard Identification Guidance Note were undertaken by multidisciplinary teams made up of relevant personnel with sufficient breadth of knowledge, training and experience to reasonably assure that risks and associated impacts were identified and assessed.

5.1.2 Impact and Risk Identification

An Environmental Hazard Identification (ENVID) was undertaken by multidisciplinary teams consisting of relevant engineering and environmental personnel with sufficient breadth of knowledge, training and experience to reasonably assure that risks were identified, and their potential environmental impacts assessed.

Impacts and risks were identified during the ENVID for both planned (routine and non-routine) activities and unplanned (accidents/incidents/emergency conditions) events.

5.1.3 Risk Analysis

Risk analysis further develops the understanding of a risk by defining the impacts and assessing appropriate controls. Risk analysis considered previous risk assessments for similar activities, review of relevant studies, review of past performance, external stakeholder consultation feedback and review of the existing environment.

The following key steps were undertaken for each identified risk during the risk assessment

- identification of decision type in accordance with the decision support framework
- identification of appropriate control measures (preventative and mitigation) aligned with the decision type
- assessment of the risk rating.

5.1.4 Decision Support Framework

To support the risk assessment process and Woodside's determination of acceptability, Woodside's HSE risk management procedures include the use of decision support framework based on principles set out in the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This concept has been applied during the ENVID or equivalent preceding processes during historical design decisions to determine the level of supporting evidence that may be required to draw sound conclusions regarding risk level and whether the risk or impacts is acceptable and ALARP. This is to confirm:

- activities do not pose an unacceptable environmental risk
- appropriate focus is placed on activities where the impact or risk is anticipated to be acceptable and demonstrated to be ALARP
- appropriate effort is applied to the management of risks and impacts based on the uncertainty of the risk, the complexity and risk rating (i.e. potential higher order environmental impacts are subject to further evaluation assessment).

The framework provides appropriate tools, commensurate to the level of uncertainty or novelty (referred to as the decision type A, B or C). The decision type is selected based on an informed discussion around the uncertainty and documented in ENVID worksheets.

This framework enables Woodside to appropriately understand a risk, determine if the risk or impact is acceptable and can be demonstrated to be ALARP.

Decision Type A

Decision Type A are well understood and established practice, they generally consider recognised good industry practice which is often embodied in legislation, codes and standards and use professional judgment.

Decision Type B

Decision Type B typically involves greater uncertainty and complexity (and can include potential higher order impacts/risks). These risks may deviate from established practice or have some lifecycle implications and therefore require further engineering risk assessment in order to support the decision and ensure that the risk is ALARP. Engineering risk assessment tools may include:

- risk-based tools such as cost based analysis or modelling
- consequence modelling
- reliability analysis
- company values.

Decision Type C

Decision Type C typically has significant risks related to environmental performance. Such risks typically involve greater complexity and uncertainty, therefore requiring adoption of the precautionary approach. The risks may result in significant environmental impact; significant project risk/exposure or may elicit negative stakeholder concerns. For these risks or impacts, in addition to Decision Type A and B tools, company and societal values need to be considered by undertaking broader internal and external stakeholder consultation as part of the risk assessment process.

5.1.5 Identification of Control Measures

Woodside applies a hierarchy of control measures when considering Good Practice and Professional Judgement. The hierarchy of control is applied in order of importance as follows; elimination, substitution, engineering control measures, administrative control measures and mitigation of consequences/impacts.

5.1.6 Risk Rating Process

The current risk rating process is undertaken to assign a level of risk to each impact measured in terms of consequence and likelihood. The assigned risk level is the current risk (i.e. risk with controls in place) and is therefore determined following the identification of the decision type and appropriate control measures.

The risk rating process considers the environmental impacts and where applicable, the social and cultural impacts of the risk. The risk ratings are assigned using the Woodside Risk Matrix (refer to **Figure 5-2**).

The risk rating process is performed using the following steps:

Select the Consequence Level

Determine the most credible impacts associated with the selected event assuming all controls (prevention and mitigation) are absent or have failed (refer to **Table 5-1**). Where more than one potential consequence applies, the highest severity consequence is selected.

Table 5-1: Woodside Risk Matrix (Environment and Social and Cultural) Consequence Descriptions

Environment	Social & Cultural	Consequence Level
Catastrophic, long-term impact (> 50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	Catastrophic, long-term impact (>20 years) to a community, social infrastructure or highly valued areas/items of international cultural significance	A
Major, long term impact (10-50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	Major, long-term impact (5-20 years) to a community, social infrastructure or highly valued areas/items of national cultural significance	B
Moderate, medium-term impact (2-10 years) on ecosystems, species, habitat or physical or biological attributes	Moderate, medium term Impact (2-5 years) to a community, social infrastructure or highly valued areas/items of national cultural significance	C
Minor, short-term impact (1-2 years) on species, habitat (but not affecting ecosystems function), physical or biological attributes	Minor, short-term impact (1-2 years) to a community or highly valued areas/items of cultural significance	D
Slight, short-term impact (<1 year) on species, habitat (but not affecting ecosystems function), physical or biological attributes	Slight, short-term impact (<1 year) to a community or areas/items of cultural significance	E
No lasting effect (<1 month). Localised impact not significant to environmental receptors	No lasting effect (<1 month). Localised impact not significant to areas/items of cultural significance	F

Select the Likelihood Level

Select the likelihood level from the description that best fits the chance of the selected consequence occurring, assuming reasonable effectiveness of the prevention and mitigation controls (refer to **Table 5-2**).

Table 5-2: Woodside Risk Matrix Likelihood Levels

Likelihood Description						
Frequency	1 in 100,000 – 1,000,000 years	1 in 10,000 – 100,000 years	1 in 1,000 – 10,000 years	1 in 100 – 1,000 years	1 in 10-100 years	>1 in 10 years
Experience	**Remote**: Unheard of in the industry	**Highly Unlikely**: Has occurred once or twice in the industry	**Unlikely**: Has occurred many times in the industry but not at Woodside	**Possible**: Has occurred once or twice in Woodside or may possibly occur	**Likely**: Has occurred frequently at Woodside or is likely to occur	**Highly Likely**: Has occurred frequently at the location or is expected to occur
Likelihood Level	0	1	2	3	4	5

Calculate the Risk Rating

A likelihood and risk rating is only applied to environmental risks using the Woodside Risk Matrix. This risk level is used as an input into the risk evaluation process and ultimately for the prioritisation of further risk reduction measures. Once each risk is treated to ALARP, the risk rating articulates the ALARP baseline risk as an output of the ENVID studies.

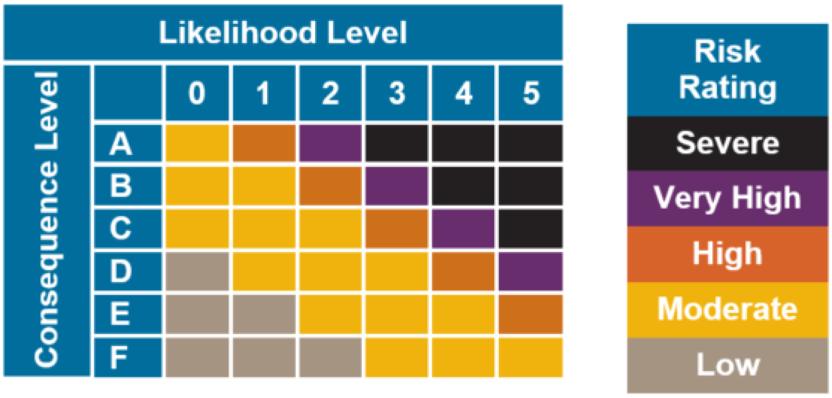

Figure 5-2: Woodside Risk Matrix – Risk Level

The risk analysis and evaluation for the Petroleum Activities Program indicate that all of the current environmental risks and impacts associated with the activity are reduced to ALARP and are of an acceptable level (refer to **Figure 5-2**).

5.2 Classification and Analysis of Major Environment Events

For Woodside's offshore production facilities, a further level of analysis is undertaken to identify, classify and analyse Major Environment Events (MEEs). This extra level of rigour is applied to ensure sufficient controls are in place for risks with potential Major and above consequences. In the health and safety area Major Accident Events (MAE) are identified using a similar process which supports consistency in management of key risks within Woodside in accordance with Process Safety Risk Management Procedures.

MEEs are defined by Woodside as:

- An event with potential environment, reputation (pertaining to environment events), social or cultural consequences of category B or higher as per Woodside Risk Matrix (**Figure 5-2**), which are evaluated against credible worst case scenarios which may occur when all controls are absent or have failed.

5.2.1 MEE Identification

The ENVID and risk rating process results in the generation of numerous sources of risk with differing consequence levels. Not all of these risks meet the MEE definition and are therefore screened out at this stage of the MEE process.

Although these risks are screened out, all risks identified in this EP (including MEEs), are evaluated for ALARP and acceptability using the methodology described in **Section 5.3**.

5.2.2 MEE Classification

A standard naming convention has been established for MEEs; this is based around ensuring the MEE titles reflect the cause of the event e.g. 'subsea system loss of containment', rather than the event itself e.g. significant hydrocarbon spill to the marine environment. The MEEs are assigned a unique identification code e.g. MEE-01, MEE-02 etc.

5.2.3 Safety and Environment Critical Elements (SCE) and Performance Standards

Woodside identifies and manages Safety Critical Elements (SCE) technical performance standards and management system performance standards (MSPS) in accordance with Process Safety Management Procedures, Risk Management Procedure, and Change Management Procedures. SCEs are identified for MAE and MEEs. An SCE is a hardware control, the failure of which could cause or contribute substantially to, or the purpose of which is to prevent or limit the effect of a MAE, MEE or Process Safety Event. In addition, Woodside defines Safety and Environment Critical Equipment (SCE) as an item of equipment or structure forming part of a hardware SCE that supports the SCE in achieving the safety function[3].

Once each SCE is selected, technical performance requirements are developed in accordance with Safety and Environment Critical Element (SCE) Management Procedure which form the SCE technical Performance Standards. These standards are a statement of the performance required of a SCE (e.g. functionality, availability, reliability, survivability), which is used as the basis for establishing agreed assurance tasks for each SCE and therefore support the management of operations within acceptable safety and/or environment risks levels and ensure continuous management of risk to ALARP. An assurance task is an activity carried out by the operator to confirm that the SCE meets or will meet its SCE Performance Standard. Examples of assurance tasks include inspection routines, test routines, instrumentation calibration and reliability monitoring.

SCE technical Performance Standards are not inherently aligned directly to Environment Performance Standards (EPS) and are used in conjunction with Woodside's management system to identify and treat potential step-outs from expected controls performance or integrity envelopes and ensure SCE performance can be optimised. Woodside's HSE Event Reporting Guideline describes the identification of 'Damage to SCEs' which is an SCE failure presenting a risk level which requires that Immediate Control Actions must be put in place to manage increased current risk. For applicable SCEs, 'Damage to SCE' failures represent scenarios which may fail to achieve an EPS presented in this EP.

Safety Critical Management System Barriers

For each MEE, Safety Critical Management System specific measures are also identified. These are management system components (generally Woodside Management System (WMS) processes) that are key barriers in the management of MEEs.

5.3 Impact and Risk Evaluation

Environmental impacts and risks, as opposed to safety risks, cover a wider range of issues, differing species, persistence, reversibility, resilience, cumulative effects and variability in severity. Determining the degree of environmental risk and the corresponding threshold for whether a risk/impact has been reduced to ALARP and is acceptable is evaluated to a level appropriate to the nature and scale of each impact or risk. Evaluation includes consideration of the following evaluation criteria:

- the Decision Type
- principles of Ecologically Sustainable Development as defined under the EPBC Act
- internal context - the proposed controls and risk level are consistent with Woodside policies, procedures and standards
- external context – consideration of the environment consequence and stakeholder acceptability
- other requirements – the proposed controls and risk level are consistent with national and international industry standards, laws and policies.

In accordance with Regulation 10A(a), 10A(b) and 10A(c), and 13(5)(b) of the Environmental Regulations, Woodside applies the following process to demonstrate ALARP and acceptability for environmental impacts and risks appropriate to the nature and scale of each impact or risk.

[3] *Note: not all individual equipment items which make up SCE are safety critical.*

5.3.1 Demonstration of ALARP

Descriptions have been provided below (**Table 5-3**) to articulate how Woodside demonstrates different risks, impacts and Decision Types identified within the EP are ALARP.

Table 5-3: Summary of Woodside's Criteria for ALARP Demonstration

<table>
<tr><th>Risk</th><th>Impact</th><th>Decision Type</th></tr>
<tr><td>Low and Moderate</td><td>Negligible, Slight or Minor (D, E or F)</td><td>A</td></tr>
<tr><td colspan="3">Woodside demonstrates these Risks, Impacts and Decision Types are reduced to ALARP:
• if controls identified meet legislative requirements, industry codes and standards, applicable company requirements and industry guidelines
• further effort towards impact/risk reduction (beyond employing opportunistic measures) is not reasonably practicable without sacrifices grossly disproportionate to the benefit gained.</td></tr>
<tr><td>High, Very High or Severe</td><td>Moderate and above (A, B, or C)</td><td>B and C</td></tr>
<tr><td colspan="3">Woodside demonstrates these higher order Risks, Impacts and Decision Types are reduced to ALARP (where it can be demonstrated using good industry practice and risk based analysis) that;
• legislative requirements, applicable company requirements and industry codes and standards are met
• societal concerns are accounted for
• the alternative control measures are grossly disproportionate to the benefit gained.</td></tr>
</table>

5.3.2 Demonstration of Acceptability

Descriptions have been provided below (**Table 5-4**) to articulate how Woodside demonstrates how different risks, impacts and Decision Types identified within the EP are Acceptable.

Table 5-4: Summary of Woodside's Criteria for Acceptability

<table>
<tr><th>Risk</th><th>Impact</th><th>Decision Type</th></tr>
<tr><td>Low and Moderate (below C level consequence)</td><td>Negligible, Slight or Minor</td><td>A</td></tr>
<tr><td colspan="3">Woodside demonstrates these Risks, Impacts and Decision Types are 'Broadly Acceptable', if they meet legislative requirements, industry codes and standards, applicable company requirements and industry guidelines. Further effort towards risk reduction (beyond employing opportunistic measures) is not reasonably practicable without sacrifices grossly disproportionate to the benefit gained.</td></tr>
<tr><td>High, Very High or Severe (C+ consequence risks)</td><td>Moderate and above</td><td>B and C</td></tr>
<tr><td colspan="3">Woodside demonstrates these higher order Risks, Impacts and Decision are 'Acceptable if ALARP' can be demonstrated using good industry practice and risk based analysis, if legislative requirements are met and societal concerns are accounted for and the alternative control measures are grossly disproportionate to the benefit gained.
In undertaking this process for moderate and high current risks, Woodside evaluates the following criteria:
• principles of Ecological Sustainable Development as defined under the EPBC Act
• internal context - the proposed controls and consequence/ risk level are consistent with Woodside policies, procedures and standards</td></tr>
</table>

- external context – consideration of the environment consequence and stakeholder acceptability
- other requirements – the proposed controls and consequence/ risk level are consistent with national and international industry standards, laws and policies.

Additionally, Very High and Severe risks require 'Escalated Investigation' and mitigation to reduce the risk to a lower and more acceptable level. If after further investigation the risk remains in the Very High or Severe category, the risk requires appropriate business engagement in accordance with Woodside's Risk Management Procedure to accept the risk. This includes due consideration of regulatory requirements.

5.4 Hydrocarbon Spill Risk Assessment Methodology

Quantitative hydrocarbon spill modelling was undertaken using a three-dimensional hydrocarbon spill trajectory and weathering model which is designed to simulate the transport, spreading and weathering of specific hydrocarbon types under the influence of changing meteorological and oceanographic forces.

5.4.1 ZoC and Hydrocarbon Contact Thresholds

The outputs of the quantitative hydrocarbon spill modelling are used to assess the environmental risk, if a credible hydrocarbon spill scenario occurred, solely in terms of delineating which areas of the marine environment could be exposed to hydrocarbon levels exceeding hydrocarbon threshold concentrations.

The summary of all the locations where hydrocarbon thresholds could be exceeded by any of the simulations modelled is defined as the ZoC. A stochastic modelling approach was applied to the quantitative hydrocarbon spill modelling. Stochastic modelling is the combination of a number of individual spill trajectory simulations, modelled under a range of historical metocean data considered seasonally and geographically representative for the scenario modelled. The stochastic results indicate the probability of where hydrocarbon might travel, and the time taken by the hydrocarbon to reach a given sensitive receptor for all modelled simulations. When considering the ZoC, it is important to understand that the ZoC does not represent the extent of any single spill event, which would be significantly smaller in spatial extent than a ZoC presenting stochastic modelling probabilities.

As the weathering of different fates of hydrocarbons (surface, entrained and dissolved) differs due to the influence of the metocean mechanism of transportation, a different ZoC is presented for each fate.

The spill modelling outputs are presented as threshold concentrations for surface, entrained and dissolved hydrocarbons for the modelled scenarios. Surface spill concentrations are expressed as grams per square metre (g/m^2), with entrained and dissolved aromatic hydrocarbon concentrations expressed as parts per billion (ppb). A conservative approach, adopting accepted contact thresholds that are documented to impact the marine environment, is used to define the ZoC. Hydrocarbon thresholds are presented in the table below (**Table 5-5**) and described in the following subsections.

Table 5-5: Summary of Thresholds Applied to the Quantitative Hydrocarbon Spill Modelling Results

Surface Hydrocarbon (g/m^2)	Entrained hydrocarbon (ppb)	Dissolved aromatic hydrocarbon (ppb)	Accumulated hydrocarbon (g/m^2)
10	94	94	100

5.4.2 Surface Hydrocarbon Threshold Concentrations

The spill modelling outputs defined the ZoC for surface hydrocarbon spills (contact on surface waters) using the ≥10 g/m^2 based on the relationship between film thickness and appearance (Bonn Agreement, 2015) (**Table 5-6**). This threshold concentration expressed in terms of g/m^2 is geared towards informing potential oiling impacts for wildlife groups and habitats that may break through the surface slick from the water or the air (for example: emergent reefs, vegetation in the littoral zone and air-breathing marine reptiles, cetaceans, seabirds and migratory shorebirds).

Thresholds for registering biological impacts resulting from contact of surface slicks have been estimated by different researchers at approximately 10–25 g/m^2 (French et al., 1999; Koops et al., 2004; NOAA, 1996). Potential impacts of surface slick concentrations in this range for floating hydrocarbons may include harm to seabirds through ingestion from preening of contaminated feathers or the loss of the thermal protection of their feathers. The 10 g/m^2 threshold is the reported level of oiling to instigate impacts to seabirds and is also applied to other wildlife though it is recognised that 'unfurred' animals where hydrocarbon adherence is less, may be less vulnerable. 'Oiling' at this threshold is taken to be of a magnitude that can cause a response to the most vulnerable wildlife such as seabirds. Due to weathering processes, surface hydrocarbons will have a lower toxicity due to change in their composition over time. Potential impacts to shoreline sensitive receptors may be markedly reduced in instances where there is extended duration until contact.

Table 5-6: The Bonn Agreement Oil Appearance Code

Appearance (following Bonn visibility descriptors)	Mass per area (g/m^2)	Thickness (μm)	Volume per area (L/Km^2)
Discontinuous true oil colours	50 to 200	50 to 200	50,000 to 200,000
Dull metallic colours	5 to 50	5 to 50	5,000 to 50,000
Rainbow sheen	0.30 to 5.00	0.30 to 5.00	300 to 5,000
Silver sheen	0.04 to 0.30	0.04 to 0.30	40 to 300

5.4.3 Entrained Hydrocarbon Threshold Concentrations

The spill modelling outputs are used to define the ZoC by defining the spatial variability of entrained hydrocarbons above a set concentration threshold contacting sensitive receptors (expressed in ppb).

Entrained hydrocarbons present a number of possible mechanisms for harmful exposure to marine organisms. The entrained hydrocarbon droplets may contain soluble compounds, hence have the potential for generating elevated concentrations of dissolved aromatic hydrocarbons (e.g. if mixed by breaking waves against a shoreline). Physical and chemical effects of the entrained hydrocarbon droplets have also been demonstrated through direct contact with organisms, for example through physical coating of gills and body surfaces, and accidental ingestion (National Research Council 2005).

The threshold concentration of entrained hydrocarbons that could result in a biological impact cannot be determined directly using available ecotoxicity data for water accommodated fraction (WAF) of oil hydrocarbons. However, it is likely this data specific to dissolved oil hydrocarbon represents a worst-case scenario. This is owing to the fact that entrained oil hydrocarbons are less biologically available to organisms through absorption into their tissues than dissolved oil hydrocarbons. It is therefore expected that the entrained threshold concentration of 94 ppb will represent a potential impact substantially lower than the 'no observed effect' concentrations (NOEC) presented in

Table 5-8. A contact threshold of 500 ppb for entrained/dissolved hydrocarbons was considered to be highly conservative threshold for diesel for a range of species including crustaceans, molluscs, echinoderms and fish (NERA 2018).

5.4.4 Dissolved Aromatic Hydrocarbon Threshold Concentrations

To confirm the appropriate threshold for dissolved hydrocarbon impacts associated with the Petroleum Activities Program Woodside examined various ecotoxicology data available. NWS condensate is the closest hydrocarbon Woodside has ecotoxological testing data for, based on the similarity of the percentage of volatile and aromatic components to the hydrocarbons that may credibly be released during the Petroleum Activities Program. Note that all condensates considered in the modelling studies have a low asphaltene (< 0.1%) and wax (~ 0.2–0.9%) content. Based on this comparison, NWS condensate is considered to be a reasonable analogue for Angel and Perseus condensate for the basis of ecotoxological testing, confirming a dissolved hydrocarbon threshold.

The ecotoxicity testing focusses on the total petroleum hydrocarbons (TPH) concentration of the WAF of the hydrocarbon and includes the carbon chains C6 to C36. Typically, C4 to C10 compounds are volatile (BP < 180 °C), C11 to C15 compounds are semi-volatile (BP 180–265 °C), C16 to C20 compounds have low volatility (265–380 °C) and C21 compounds and above are residual (BP > 380 °C). A summary of the characteristics of the hydrocarbons used as a basis for the modelling studies used to inform the assessment of MEEs is provided in **Table 5-7.**

Table 5-7: Characteristics of the hydrocarbon types used in the modelling of scenarios

Hydrocarbon Type	Density (g/cm^3 at 15 °C)	Viscosity (cP @ 20 °C)	Component	Volatile (%)	Semi-volatile (%)	Low volatility (%)	Residual (%)	Aromatics (%)
			Boiling Point (°C)	<180 C4 to C10	180 – 265 C11 to C15	265 – 380 C16 to C20	>380 >C20	Of whole oil <380 boiling point (BP)
Angel condensate	0.752	0.655	% total	70.6	22.4	6.8	0.3	13.4
			% aromatics	9.5	3.0	0.9	-	-
NWS condensate	0.739	0.577	% of total	74.6	19.1	6.2	0.0	12.3
			% aromatics	5.1	2.1	5.1	-	-
Perseus condensate	0.790	0.560	% of total	52.1	42.1	5.6	0.2	10.32
Marine diesel	0.829	4.0		6	34.6	54.4	5	-

Table 5-8: Summary of Total Recoverable Hydrocarbons NOECs for Key Life-histories of Different Biota Based on Toxicity Tests for WAF of fresh NWS Condensate

Biota and Life Stage	Exposure duration (hrs)	NOEC – WAF concentration of unweathered NWS condensate showing no direct biological effect (ppb)
Sea urchin fertilisation	1	94*
Sea urchin larval development	72	719
Milky oyster larval development	48	719
Micro-algal growth test	72	633
Rock oyster spat survival test	48	3784
Amphipod acute toxicity test	96	633
Larval fish imbalance test	96	633

** Value estimated due to TPH concentration measurement method limitations.*

Source: ESA 2012

The ecotoxological testing focusses on the total petroleum hydrocarbons (TPH) concentration of the water accommodated fraction (WAF) of the hydrocarbon. It includes the carbon chains C6 to C36. Typically, C4 to C10 compounds are volatile (BP <180°C), C11 to C15 compounds are semi-volatile (BP 180–265°C), C16 to C20 compounds have low volatility (265–380°C), and C21 compounds and above are residual (BP >380°C).

The purpose of the threshold is to inform the assessment of the potential for toxicity impacts on sensitive marine biota. The ecotoxicity tests were undertaken on a broad range of taxa of ecological relevance, for which accepted standard test protocols are well established. These ecotoxicology tests are focussed on the early life stages of test organisms, when organisms are typically at their most sensitive. The ecotoxicology tests were conducted on six mainly tropical–subtropical species representatives from six major taxonomic groups.

The laboratory-based ecotoxicology tests used a range of WAF concentrations to expose the different test organisms. For each ecotoxicity test, samples of the WAF were analysed to determine the TPH concentration of the solution.

Table 5-8 presents the results of NOEC for NWS condensate. The NOECs for the organisms tested ranged from 94 ppb to 3784 ppb. Based on these ecotoxicology tests, a dissolved aromatic hydrocarbon threshold of 94 ppb has been adopted.

500 ppb has been selected a conservative impact threshold for diesel, noting that there is no impact threshold for dissolved diesel components in the National Energy Resources Australia (NERA) reference case as the toxic components are in such small concentrations in refined hydrocarbons that their effect in the marine environment is considered negligible. (NERA 2018).

5.4.5 Accumulated Hydrocarbon Threshold Concentrations

Owens et al. (1994) define accumulated hydrocarbon < 100 g/m^2 to have an appearance of a stain on shorelines. French-McKay (2009) defines accumulated hydrocarbons ≥ 100 g/m^2 to be the threshold that could impact the survival and reproductive capacity of benthic epifaunal invertebrates living in intertidal habitat; therefore, ≥ 100 g/m^2 has been adopted as the threshold for shoreline accumulation.

5.5 Potential Environment Risks Not Included Within the Scope of the Environment Plan

The ENVID identified a number of sources of environmental risk/impact as a result of the Petroleum Activities Program, that were assessed as not being applicable (not credible) within or outside the Operational Areas and therefore, were determined to not form part of this EP. This is described in the following section for information only.

Shallow/Near-shore Activities

The Petroleum Activities Program is located in water depths of approximately between 30 and 162 m and at a distance approximately 46 km from nearest landfall (Montebello Islands), consequently risks/impacts associated with shallow/near-shore activities such as anchoring and vessel grounding were assessed as not credible.

6. ENVIRONMENTAL RISK AND IMPACTS SUMMARY

Table 6-1 presents a summary of the sources of impact/risk, analysis and evaluation for the Petroleum Activities Program.

The risks identified during the ENVID (including decision type, current risk level, acceptability of risk and tools used in the demonstration of acceptability and ALARP) have been divided into two broad categories:

- planned (routine and non-routine) activities
- unplanned events (accidents, incidents or emergency situations).

Within these categories, impact assessment groupings are based on stressor type e.g. emissions, physical presence etc. In all cases the worst credible consequence was assumed.

The analysis and evaluation for the Petroleum Activities Program indicate that all of the current environmental risks and impacts associated with the activity are reduced to ALARP and are of an acceptable level (see **Appendix A**: Environmental Impacts and Risks).

Table 6-1: Environmental Risk and Impacts Register Summary

Aspect	Source of Impact	Key Potential Environmental Impacts (Refer to relevant EP section for details)	Controlled Impact Classification	Residual Impact Level (ALARP controls in place)	Acceptability of Impact
Planned Activities (Routine and Non-routine)					
Physical presence: disturbance to marine users	Presence of NRC and subsea infrastructure excluding and/or displacing other users from Petroleum Safety Zone and Operational Areas respectively.	Potential isolated social impact resulting from interference with other sea users (e.g. commercial and recreational fishing, and shipping).	F	Social and Cultural – Slight, short-term impact (<1 year) to a community or areas/items of cultural significance	Broadly Acceptable
Physical presence: Disturbance to Seabed	Presence of NRC and subsea infrastructure modifying marine habitats.	Localised modification of seabed habitat (formation of artificial reef) within Operational Area with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Subsea operations, inspection, maintenance and repair activities resulting in disturbance to seabed.	Localised modification of seabed habitat within Operational Area.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	Broadly Acceptable
Routine acoustic emissions: Generation of noise during routine operations	Noise generated within the Operational Area from: • facility and associated infrastructure • vessel and subsea IMMR activities • helicopters.	Localised behavioural impacts to marine fauna around and within the Operational Area with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
Routine and non-routine discharges: Discharge of hydrocarbons and chemicals during subsea operations and activities	Discharge of subsea control fluids.	Localised decrease in water quality around subsea system within Operational Area with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Discharge of hydrocarbons remaining in subsea pipework and equipment as a result of subsea intervention works.	Potential localised decrease in water quality at release location during IMMR activities with no lasting effect.	E	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Discharge of chemicals remaining in subsea pipework and equipment or the use of chemicals for subsea IMMR activities.	Localised decrease in water quality at release location during IMMR activities with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Discharge of minor fugitive hydrocarbon/chemicals from subsea equipment.	Potential localised decrease in water quality around subsea system within Operational Area with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
Routine discharges: Produced water	Discharge of produced water from riser platform.	Slight short-term, localised decrease in water quality, marine sediments and marine biota.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	Broadly Acceptable
Routine and non-routine discharges: Discharges from utility systems and drains	Discharge of sewage, grey water and putrescible waste from vessels and NRC to the marine environment.	Localised decrease in water quality (increased nutrients and biological oxygen demand) with no lasting effect.	F Cumulative E	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Discharge of deck, bilge and drain water from vessels and NRC to the marine environment.	Localised decrease in water quality at the discharge location with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Discharge of reverse osmosis brine from vessels and NRC to the marine environment.	Localised decrease in water quality at the discharge location with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable

Aspect	Source of Impact	Key Potential Environmental Impacts (Refer to relevant EP section for details)	Controlled Impact Classification	Residual Impact Level (ALARP controls in place)	Acceptability of Impact
Planned Activities (Routine and Non-routine)					
	Discharge of cooling water from vessels and NRC to the marine environment.	Localised increase in salinity at the discharge location with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
Routine and non-routine atmospheric emissions: Fuel combustion, flaring and fugitives	NRC internal combustion engines, operational flaring and fugitive emissions, and vessel emissions (including incinerators)	Potential localised decrease in air quality, limited to the airshed local to the facility with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
Routine light emissions: Light emissions from riser platform and vessels	Light emissions from NRC and vessels.	Localised potential for behavioural disturbance of species in close proximity to riser platform and vessels with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable
	Light emissions from NRC during flaring.	Localised potential for behavioural disturbance of species in close proximity to riser platform with no lasting effect.	F	Environment – No lasting effect (< 1 month). Localised impact not significant to environmental receptors.	Broadly Acceptable

Aspect	Source of Risk	Key Potential Environmental Impacts (Refer to relevant EP section for details)	Risk Rating				Acceptability of Risk
			Consequence Classification	Potential Consequence/Level of Impact	Likelihood	Residual Risk Rating	
Unplanned Events (Accidents/Incidents)							
Unplanned release of hydrocarbons or chemicals: Hydrocarbon release during bunkering and chemical release during transfer, storage and use	Accidental spill of hydrocarbons to the marine environment during bunkering.	Potential minor short-term disruption to marine fauna, including protected species and/or localised impacts to water quality.	D	Environment – Minor short-term impact (1-2 years) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	1	M	Broadly Acceptable
	Accidental discharge of chemicals to the marine environment during transfer, storage or use.	Potential slight short-term impacts to the marine fauna, and localised temporary impacts to water quality and marine sediments.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	2	M	Broadly Acceptable
Unplanned discharges: hazardous and non-hazardous waste management	Incorrect disposal or accidental discharge of non-hazardous and hazardous waste to the marine environment.	Potential slight short-term impacts to the marine fauna, and localised temporary impacts to water quality and marine sediments.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	2	M	Acceptable if ALARP
Physical presence: Interactions with marine fauna	Physical presence of vessels resulting in collision with marine fauna.	Potential injury or death of marine fauna (single animal), including protected species.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	1	L	Broadly Acceptable
Physical presence: Introduction of invasive marine species	Invasive species in vessel ballast tanks or on vessels/submersible equipment.	Potential introduction of invasive marine species possibly resulting in an alteration of the localised environment.	E	Environment – Slight, short-term impact (< 1 year) on species, habitat (but not	1	L	Broadly Acceptable

Aspect	Source of Risk	Key Potential Environmental Impacts (Refer to relevant EP section for details)	Risk Rating: Consequence Classification	Risk Rating: Potential Consequence/Level of Impact	Risk Rating: Likelihood	Risk Rating: Residual Risk Rating	Acceptability of Risk
				affecting ecosystem function), physical or biological attributes.			
Unplanned Events (Accidents/Incidents) - MEEs							
Unplanned hydrocarbon release: Loss of well containment (MEE-01)	Release of hydrocarbons resulting from loss of platform well containment.	Potential significant impacts to the marine environment: • long-term impacts to sensitive nearshore areas of offshore islands and coastal shorelines • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Release of hydrocarbons resulting from loss of subsea well containment.		A	Environment – Catastrophic, long-term impact (> 50 years) on highly valued ecosystems, species, habitats or physical or biological attributes.	0	M	Acceptable if ALARP
Unplanned hydrocarbon release: Subsea equipment loss of containment (MEE-02)	Release of hydrocarbons resulting from subsea equipment loss of containment within the NRC exclusion zone.	Potential significant impacts to the marine environment: • long-term impacts to sensitive offshore and nearshore areas • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Release of hydrocarbons resulting from subsea equipment loss of containment outside the NRC exclusion zone.		B		0	M	Acceptable if ALARP
Unplanned hydrocarbon release: Topside loss of containment (MEE-03)	Hydrocarbon release from topside process equipment to the marine environment and atmosphere.	Potential significant impacts to the marine environment: • medium-term impacts to sensitive offshore and nearshore areas • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	C	Environment – Moderate, medium-term impact (2–10 years) on ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from topsides non-process equipment to the marine environment.		D	Environment – Minor short-term impact (1–2 years) on species, habitat (but not affecting ecosystem function), physical or biological attributes.	1	M	Broadly Acceptable
Unplanned hydrocarbon release: Loss of structural integrity (MEE-04)	Hydrocarbon release from platform well to the marine environment and atmosphere	Potential significant impacts to the marine environment: • long-term impacts to sensitive offshore and nearshore areas • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from subsea equipment to the marine environment and atmosphere		B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from topsides equipment to the marine environment and atmosphere		C	Environment – Moderate, medium-term impact (2–10 years) on ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP

Aspect	Source of Risk	Key Potential Environmental Impacts (Refer to relevant EP section for details)	Risk Rating				Acceptability of Risk
			Consequence Classification	Potential Consequence/Level of Impact	Likelihood	Residual Risk Rating	
	Marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC		B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Broadly Acceptable
Unplanned hydrocarbon release: Loss of marine vessel separation (MEE-05)	Hydrocarbon release from platform well to the marine environment and atmosphere	Potential significant impacts to the marine environment: • long-term impacts to sensitive offshore and nearshore areas • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from subsea equipment to the marine environment and atmosphere		B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from topsides equipment to the marine environment and atmosphere		C	Environment – Moderate, medium-term impact (2–10 years) on ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC.		B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Broadly Acceptable
Unplanned hydrocarbon release: Loss of control of suspended load from platform (MEE-05)	Hydrocarbon release from subsea equipment to the marine environment and atmosphere.	Potential significant impacts to the marine environment: • long-term impacts to sensitive offshore and nearshore areas • disruption to marine fauna, including protected species • potential short-term interference with or displacement of other sea users.	B	Environment – Major, long-term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes.	1	M	Acceptable if ALARP
	Hydrocarbon release from topsides equipment to the marine environment and atmosphere.		C	Environment – Moderate, medium-term impact (2–10 years) on ecosystems, species, habitat or physical or biological attributes.	1	M	Broadly Acceptable

7. ONGOING MONITORING OF ENVIRONMENTAL PERFORMANCE

The Petroleum Activities Program will be managed in compliance with the NRC Operations EP accepted by NOPSEMA under the Environment Regulations, other relevant environmental legislation and Woodside's Management System (e.g. Woodside Environment Policy).

The objective of the EP is to identify, mitigate and manage potentially adverse environmental impacts associated with the Petroleum Activities Program, during both planned and unplanned operations, to ALARP and an acceptable level.

For each environmental aspect (risk) and associated environmental impact (identified and assessed in the Environmental Risk Assessment of the EP) a specific environmental performance outcome, environmental performance standards and measurement criteria have been developed. The performance standards and control measures (available in **Appendix A**) that will be implemented (consistent with the performance standards) to achieve the environmental performance outcomes. The specific measurement criteria provide the evidence base to demonstrate that the performance standards (control measures) and outcomes are achieved.

The implementation strategy detailed in the NRC Operations EP identifies the roles/responsibilities and training/competency requirements for personnel (Woodside and its contractors) in relation to implementing controls, managing non-conformance, emergency response and meeting monitoring, auditing, and reporting requirements during the activity.

Woodside and its Contractors will undertake a program of periodic monitoring during the Petroleum Activities Program using a number of tools and systems. The tools and systems collect, as a minimum, the data (evidence) referred to in the measurement criteria. The collection of this data (and assessment against the measurement criteria) forms part of the permanent record of compliance maintained by Woodside and the basis for demonstrating that the environmental performance outcomes and standards are met.

Monitoring of environmental performance is undertaken as part of the following:

- external annual performance reporting to NOPSEMA verify compliance with the environmental performance objectives, standards and measurement criteria outlined in the EP
- internal inspection and assurance activities
- environmental emissions/discharge recording systems.

Woodside employees and Contractors are required to report all environmental incidents and non-conformances with environmental performance outcomes and standards in the EP. Incidents will be reported using an Incident and Hazard Report Form, which includes details of the event, immediate action taken to control the situation, and corrective actions to prevent reoccurrence. An internal computerised database is used for the recording and reporting of these incidents.

7.1 Environment Plan Revisions and Management of Change

Revision of the NRC Operations EP will be undertaken in accordance with the requirements outlined in Regulations 17, Regulation 18 and Regulation 19 of the Environment Regulations. Woodside will submit a proposed revision of the NRC Operations EP to NOPSEMA including as a result of the following:

- when any significant modification or new stage of the activity that is not provided for in the EP is proposed
- before, or as soon as practicable after, the occurrence of any significant new or significant increase in environmental risk or impact not provided for in the EP
- at least 14 days before the end of each period of five years commencing on the day in which the original and subsequent revisions of the EP is accepted under Regulation 11 of the Environment Regulations

- as requested by NOPSEMA.

Management of changes relevant to the NRC Operations EP, concerning the scope of the activity description, changes in understanding of the environment, including advice on species protected under EPBC Act and potential new advice from external stakeholders, will be managed in accordance with internal procedures for management of change. These provide guidance on the Environment Regulations that may trigger a revision and resubmission of the NRC Operations EP to NOPSEMA. They also provide guidance on what constitutes a significant new risk or increase in risk. A risk assessment will be conducted in accordance with Woodside's Environmental Risk Management Methodology to determine the significance of any potential new environmental impacts or risks not provided for in the NRC Operations EP. Risk assessment outcomes are reviewed in compliance with Regulation 17 of the Environment Regulations.

Minor changes where a review of the activity and the environmental risks and impacts of the activity do not trigger a requirement for a revision, under Regulation 17 of the Environment Regulations, will be considered a 'minor revision'. Minor administrative changes to the NRC Operations EP, where an assessment of the environmental risks and impacts is not required (e.g. document references, phone numbers, etc.), will also be considered a 'minor revision'. Minor revisions and administrative changes as defined above will be made to the NRC Operations EP using Woodside's document control process. Minor revisions will be tracked and incorporated during scheduled internal reviews.

8. OIL POLLUTION EMERGENCY RESPONSE ARRANGEMENTS

The documents listed below, meet the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations) relating to hydrocarbon spill response arrangements.

- Oil Pollution Emergency Arrangements (OPEA) (Australia)
- The NRC Offshore Facility Oil Pollution First Strike Plan
- Oil Spill Preparedness and Response Strategy Selection and Evaluation
- Operational Plans
- Tactical Response Plans.

8.1 Oil Pollution Emergency Arrangements (Australia)

This document outlines the emergency and crisis management incident command structure (ICS) and Woodside's response arrangements to competently respond to and escalate a hydrocarbon spill event. The document interfaces externally with Commonwealth, State and industry response plans and internally with Woodside's ICS.

Woodside's Oil Pollution Emergency Arrangements (Australia) details the following support arrangements:

- access to MODU to drill intervention well via Memorandum of Understanding (MoU) with other industry participants
- master services agreement with Australian Marine Oil Spill Centre (AMOSC) for the supply of experienced personnel and equipment
- other support services such as 24/7 hydrocarbon spill trajectory modelling and satellite monitoring services as well as aerial, marine, logistics and waste management support
- Mutual Aid Agreements with other oil and gas operators in the region for the provision of assistance in a hydrocarbon spill response.

All operations personnel involved in crisis and emergency management are required to commit to ongoing training, process improvement and participation in emergency and crisis response (both real and simulated), including emergency drills specific to potential incidents at the NRC Facility. Training includes task specific training and role-based training and 'on the job' experience (i.e. participation in crisis or emergency management exercises).

The Corporate Incident Communication Centre (CICC) based in Woodside's head office in Perth, is the onshore coordination point for an offshore emergency. The CICC is staffed by an appropriately skilled team available on call 24 hours a day. The purpose of the team is to coordinate rescues, minimise damage to the environment and facilities and to liaise with external agencies.

There are a number of arrangements which in the event of a spill will underpin Woodside's ability to implement a response across its petroleum activities. To ensure each of these arrangements are adequately tested tests are conducted in alignment with the Hydrocarbon Spill Arrangements Testing Schedule which aligns with international good practice for spill preparedness and response management. The schedule identifies the type of test which will be conducted annually for each arrangement, and how this type will vary over a five-year rolling schedule. Testing methods may include (but are not limited to): audits, drills, field exercises, functional workshops, assurance reporting, assurance monitoring and reviews of key external dependencies.

8.2 NRC Oil Pollution First Strike Plan

The NRC Oil Pollution First Strike Plan is an activity-specific document which provides details on the tasks required to mobilise a first strike response for the first 24 hours of a hydrocarbon spill event. These tasks include key response actions and regulatory notifications. The intent of the document is to provide immediate oil spill response guidance to the Incident Management Team until a full Incident Action Plan specific to the oil spill event is developed.

The facility and subsea support vessels will have Ship Oil Pollution Emergency Plans (SOPEPs) in accordance with the requirements of International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78 Annex I. These plans outline responsibilities, specify procedures and identify resources available in the event of a hydrocarbon or chemical spill from vessel activities. The NRC Oil Pollution First Strike Plan is intended to work in conjunction with the SOPEPs.

Woodside's oil spill arrangements are tested by conducting periodic exercises. These exercises are conducted to test the response arrangements outlined in the NRC Oil Pollution First Strike Plan and Oil Spill Preparedness and Response Mitigation Assessment to ensure that personnel are familiar with spill response procedures, in particular, individual roles and responsibilities and reporting requirements.

8.3 Oil Spill Preparedness and Response Mitigation Assessment

Woodside has developed an oil spill preparedness and response position in order to demonstrate that risks and impacts associated with loss of hydrocarbons from the Petroleum Activities Program would be mitigated and managed to ALARP and would be of an acceptable level.

The following oil spill response strategies were evaluated and subsequently pre-selected for a significant oil spill event (level 2 or 3 under the National Plan) from the Petroleum Activities Program:

- Monitor and Evaluate (Operational Monitoring) – Operational Monitoring commences immediately following a spill and includes the gathering and evaluation of data to inform the oil spill response planning and operations. It includes fate and trajectory modelling, spill tracking, weather updates and field observations. The following operational monitoring programs are available for implementation:
  - predictive modelling of hydrocarbons to assess resources at risk
  - surveillance and reconnaissance to detect hydrocarbons and resources at risk
  - monitoring of hydrocarbon presence, properties, behaviour and weathering in water
  - pre-emptive assessment of sensitive receptors at risk
  - monitoring of contaminated resources and the effectiveness of response and clean-up operations.

The following response strategies may be applied based on the outcomes of the implemented Operational Monitoring Programs:

- source control - a loss of well control is the identified worst-case spill scenario. Woodside's primary mitigation strategy is to minimise the volume of hydrocarbons released. Woodside pre-operational NEBA evaluation has identified relief well drilling as the primary source control strategy
- containment and recovery- the aim of this response strategy is to reduced damage to sensitive receptors by the physical removal of hydrocarbons from the marine environment
- wildlife response - an oiled wildlife response would be undertaken in accordance with Woodside's Health, Safety, Environment and Quality Policy and values and recognition of societal expectations. The response would involve reconnaissance from vessels, aircraft and shoreline surveys, the capture, transport, rehabilitation and release of oiled wildlife.
- shoreline protection and deflection- the placement of containment, protection and deflection booms on or near a shoreline is a response strategy to reduce the potential volume of hydrocarbons

contacting or spreading along shorelines, which may reduce the scale of shoreline clean-up. Hydrocarbons contained by booms would be collected where applicable.

- shoreline clean-up is undertaken when residual hydrocarbon not collected through previously described response strategies contacts shorelines. The timing, location and extent of shoreline clean-up can vary from one scenario to another, depending on the hydrocarbon type, shoreline type and access, degree of oiling and area oiled. Shoreline clean-up can limit injury to wildlife, prevent or reduce remobilisation of hydrocarbons in tidal zone, facilitate hydrocarbon recovery and meet societal expectations.
- scientific monitoring - a scientific monitoring program (SMP) would be activated following a Level 2 or 3 hydrocarbon release, or any release event with the potential to contact sensitive environmental receptors. This would consider receptors at risk (ecological and socio-economic) for the entire predicted ZoC and in particular, the identified Pre-emptive Baseline Areas (PBAs) in the event of a loss of well control from the PAP drilling activities (refer to response planning assumptions). The SMP would be informed by the operational monitoring programs but differs from the operational monitoring program in being a long-term program independent of, and not directing, the operational oil spill response. Key objectives of the Woodside oil spill scientific monitoring program are:
  - assess the extent, severity and persistence of the environmental impacts from the spill event
  - monitor subsequent recovery of impacted key species, habitats and ecosystems.
- waste management - waste management is considered a support strategy to the response strategies examined above.

9. CONSULTATION

In support of the NRC Operations EP, Woodside conducted a stakeholder assessment and engaged with relevant stakeholders (**Appendix C**: Summary of Stakeholder Feedback and Woodside's response) to inform decision-making and planning for this petroleum activity in accordance with the requirements of Regulation 11A and 14(9) of the Environment Regulations.

Woodside conducted an assessment to identify relevant stakeholders, based on the location of the NRC Operations and potential environmental and social impacts. A consultation information sheet was sent to all stakeholders identified through the stakeholder assessment process prior to lodgement of the NRC Operations EP with NOPSEMA for assessment and acceptance. Woodside provided information about the Petroleum Activities Program to the relevant stakeholders listed in **Table 9-1**. Woodside considers relevant stakeholders for routine operations as those that undertake normal business or lifestyle activities in the vicinity of the existing Petroleum Activities Program (or their nominated representative) or have a State or Commonwealth regulatory role.

Table 9-1: Relevant Stakeholder Identified for the Petroleum Activities Program

Organisation	Relevance
Department of Industry, Innovation and Science	Department of relevant Commonwealth Minister
Department of Mines, Industry Regulation and Safety	Department of relevant State Minister
Australian Maritime Safety Authority	Maritime safety
Australian Hydrographic Office	Maritime safety
Department of Primary Industries and Regional Development	Fisheries management
Commonwealth Fisheries Association	Commercial fisheries – Commonwealth
Western Australian Fishing Industry Council	Commercial fisheries – State
Department of Transport	Hydrocarbon spill preparedness (Western Australian waters)
Director of National Parks	Management of Commonwealth reserves and conservation zones
Vermilion Oil and Gas Australia	Adjacent titleholder
Carnarvon Petroleum	Adjacent titleholder
Quadrant North West	Adjacent titleholder
Western Australian Fisheries • Mackerel Fishery • Pearl Oyster • Specimen Shell • Marine Aquarium Fish • Onslow Prawn • Pilbara Fish Trawl • Pilbara Fish Trap • Pilbara Line fishery	Commercial fisheries – State

Commonwealth Fisheries • Western Skipjack Fishery • Western Tuna and Billfish Fishery • Southern Bluefin Tuna Fishery.	Commercial fisheries – Commonwealth

9.1 Ongoing Consultation

Woodside will continue to engage and consult with relevant stakeholders throughout the Petroleum Activities Program by implementing its established approach to stakeholder engagement that includes:

- direct stakeholder and community engagement providing advice to community stakeholders on progress in execution of activities.
- provision of updated activity factsheets prior to the commencement of activities.
- toll free number provided on activity factsheets.

Identified relevant stakeholders were emailed a Consultation Information Sheet, which is also published on Woodside's website. Communication with specific stakeholders has been tailored to individual requirements. For example, fishing and other marine stakeholders were provided with activity maps that overlay relevant State and Commonwealth fishing zones.

Feedback gathered during consultation informs Woodside's engagement requirements for ongoing consultation during the activity. Ongoing consultation is used to inform stakeholders on specific activity timing, duration, location and other information relevant to the activity and stakeholder needs.

Woodside uses email notifications to keep relevant stakeholders informed of intermittent activities. Woodside maintains an email database of fishery licence holders contacts to provide details about specific activity timing, duration, location and other relevant information such as vessels and exclusion zones. Woodside also provides the same advice via email to the Australian Hydrographic Services, AMSA and industry bodies, such as Western Australian Fishing Industry Council (WAFIC); who then can cascade advice to other marine users. Consideration of whether stakeholder engagement is required for an intermittent activity, such as maintenance or project activities, will be given prior to the commencement of that activity. If engagement is required, it will be undertaken in a format that is relevant given stakeholder needs.

If a change requiring further engagement occurs, Woodside undertakes an assessment to identify new relevant stakeholders or a potential change to level of relevance for previously identified stakeholders. Previously identified and new relevant stakeholders will be notified of the updated scope.

Woodside will continue to accept feedback from all stakeholders throughout the duration of the accepted NRC Operations EP. Stakeholder feedback should be made to the nominated liaison person.

Feedback received through community engagement and consultation will be captured in Woodside's stakeholder database and actioned where appropriate through the Petroleum Activities Program Project Manager. Implementation of ongoing engagement and consultation activities for the Petroleum Activities Program will be undertaken by Woodside Corporate Affairs consistent with Woodside's External Stakeholder Engagement Operating Standard.

9.2 Non-Routine Events

Woodside recognises that the relevance of stakeholders identified in the EP to the activity may change in the occurrence of a non-routine event or emergency. Woodside also acknowledges that other stakeholders not identified in the EP may be affected.

Stakeholder groups include:

- government ministers

- government agencies
- local governments, including representation local communities (Exmouth and Coral bay)
- emergency response organisations
- border protection and defence
- fisheries
- charter boat operators
- marine and terrestrial tourism operators
- other petroleum operators
- other industry
- development commissions and industry associations
- aboriginal claimant groups
- community representative organisations
- non-government organisations.

10. TITLEHOLDER NOMINATED LIAISON PERSON

For further information about this activity, please contact:

Andrew Winter
Corporate Affairs Adviser
Australia Operating Unit
Woodside Energy Ltd
11 Mount Street
Perth WA 6000
Australia
T: 08 9348 4000
E: Feedback@woodside.com.au

11. ABBREVIATIONS

Acronym	Description
AFMA	Australian Fisheries Management Authority
AIMS	Australian Institute of Marine Science
ALARP	As low as reasonably practicable
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority
APPEA	Australian Petroleum Production and Exploration Association
BDV	Blowdown valve
BIA	Biologically Important Area
BoM	Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene and xylenes
CCP	Cyclone contingency plan
CCR	Central Control Room
CEFAS	Centre for environment, fisheries and aquaculture science
CEO	Chief Executive Officer
CI	Continuous improvement
CICC	Corporate Incident Communication Centre
CMMS	Computerised Maintenance management system
CMT	Crisis management Team
COO	Chief Operations Officer
CP	Cathodic protection
CS	Company Values
CVI	Close Visual Inspections
D & C	Drilling and Completions
DC	Direct current
DCS	NRC control system
DEHP	di (2-ethylhexyl) phthalate
DEWHA	Department of Environment
DoEE	Department of the Environment and Energy
DMIRS	Department of Mining, Industry Regulation and Safety
DoT	Department of Transport
DP	Dynamic positioning
DSWEPaC	Department of Sustainability, Environment, Water, Population and Communities
DWT	Dead weight tonnage
EEZ	Exclusive Economic Zone

Acronym	Description
EP	Environment Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999
EPOs	Environmental performance outcomes
EPS	Environment Performance Standards
ERP	Emergency Response Plan
FFS	Fit for Services
GP	Good Practice
GWA	Goodwyn Alpha
HAZID/EVID	Hazard identification studies
HP	High Pressure
HQ	Hazard Quotient
HSE	Health, Safety and Environment
HSEQ	Health, Safety, Environment and Quality
HVAC	Heating, ventilation and air conditioning
IUCN	International Union for the Conservation of Nature
IMCA	International Maritime Contractors Association
IMMR	Inspection, monitoring, maintenance and repair
ISO	International Organisation of Standardisation
ISQG	Interim sediment quality guideline
ITF	Indonesian Throughflow
KBSF	King Bay Supply Facility
KGP	Karratha Gas Plan
KEF	Key Ecological Feature
kHz	kilohertz
km	Kilometre
KO	Knock-out
KPI	Key performance Indicator
L	Litres
LAT	Lowest Astronomical Tide
LCS	Legislation, Codes and Standards
LNG	Liquefied natural gas
LOA	Length Overall
LOPC	Los of Primary Containment
LP	Low Pressure
LTO	Licence to Operate
MACs	Manual alarm calla points

Acronym	Description
MAEs	Major Accident Events
MEEs	Major Environmental Events
MEG	Monoethylene glycol
MC	Measurement Criteria
MCS	Master Control Station
MNES	Matters of Environmental Significance
MOPO	Manual of Permitted Operation
MPA	Marine Protected Area
MSPS	Management System Performance Standards
NCDSF	North Coast Demersal Scalefish Fisheries
NEPM	National Environmental Protection Measure
NGERS	National Greenhouse and Energy Reporting
NNM	Not Manually Manned
NOEC	No observed effect concentrations
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NORM	Naturally occurring radioactive material
NRC	North Rankin Complex
NT	Northern Territory
NWMR	North West Marine Region
NWS	North West Shelf
NWSTF	North West Slope Trawl Fishery
OCIMF	Oil Companies International Marine Forum
OCNS	Offshore Chemical Notification Scheme
OIM	Offshore Installation Manager
OIW	Oil in water
OPEP	Oil Pollution Emergency Plan
OPEX	Operational expenditure
OPGGS Act	*Offshore Petroleum and Greenhouse Gas Storage* Act
OVID	Offshore Vessel Inspection Database
PAH	Polycyclic aromatic hydrocarbon
PAR	Photosynthetically active radiation
PCS	Process Control System
PEARL	People, Environment, Asset, Reputation and livelihood
PFW	Produced formation water
PHD	Process historian database
PJ	Professional Judgement

Acronym	Description
PLONOR	Pose little or no risk
PLR	Pig launcher receiver
PMST	Protected Matters Search Tool
POB	Personnel on board
PSM	Process Safety Management
PSRA	Process Safety Risk Assessment
PSU	Practical salinity units
PSV	Pressure safety Valves
PTS	Permanent threshold shift
PW	Produced Water
RBA	Risk Based Analysis
RBI	Risk Based Inspection
RCM	Reliability Centred maintenance
ROV	Remotely operated vehicle
SCE	Safety and Environmental Critical Element
SCEW	Standing Council on Environment and Water
SCM	Subsea Control Module
SCQ	Safety and Environmental Critical Equipment
SCSSV	Surface controlled sub-surface safety valves
SIMAP	Spill Impact Mapping and Analysis program
SKM	Sinclair Knight Mertz
SOPEP	Ship Oil Pollution Emergency Plan
SPL	Sound pressure level
SSF	Specimen Shell Fishery
SSS	Side Scan Sonar
SV	Societal Values
SVOC	Semi-volatile organic chemicals
TL	Transmission loss
TPH	Total petroleum hydrocarbon
TRH	Total recoverable hydrocarbon
TTS	Temporary threshold shift
UK	United Kingdom
UPS	Battery power system
USEPA	U.S. Environmental Protection Agency
UV	Ultra violet
VOC	Volatile organic compound

Acronym	Description
VP	Vice President
WA	Western Australia
WAFIC	Western Australian Fishing Industry council
WCDGDLF	West Coast Demersal Gillnet and Demersal Longline Managed Fishery
WEL	Woodside Energy Limited
WET	Whole effluent Toxicity
WHA	World Heritage Area
WMS	Woodside Management System
WOMP	Well Operations Management Plan
ZoC	Zone of Consequence

12. REFERENCES

Australian Institute of Marine Science (AIMS), 2014b. AIMS 2013 biodiversity survey of Glomar Shoal and Rankin Bank (Report prepared by the Australian Institute of Marine Science for Woodside Energy Ltd.). Australian Institute of Marine Science, Townsville.

Bamford, M., Watkins, D., Bancroft, W., Tischler, G., Wahl, J., 2008. Migratory shorebirds of the East Asian-Australasian flyway: population estimates and internationally important sites. Wetlands International - Oceania, Canberra.

Batten, S., Allen, R., Wotton, C., 1998. The effects of the Sea Empress oil spill on the plankton of the southern Irish Sea. Marine Pollution Bulletin 36: 764–774.

BMT Oceanica, 2015a. Offshore water quality monitoring verification and sediment quality study - Goodwyn A survey report (No. 1178_003/1 Rev 0). BMT Oceanica Pty Ltd, Perth.

Cohen, A., Gagnon, M.M., Nugegoda, D., 2005. Alterations of metabolic enzymes in Australian bass, Macquaria novemaculeata, after exposure to petroleum hydrocarbons. Archives of Environmental Contamination and Toxicology 49: 200–205. doi:10.1007/s00244-004-0174-1.

Commonwealth of Australia, 2015c. Wildlife conservation plan for migratory shorebirds. Department of the Environment, Canberra.

Commonwealth of Australia, 2017. Recovery plan for marine turtles in Australia 2017-2027. Department of the Environment and Energy, Canberra.

Dall, W., Hill, B., Rothlisberg, P., Sharples, D., 1990. The biology of the Penaeidae., in: Blaxter, J., Southward, A. (Eds.), Advances in Marine Biology. Academic Press, London, p. 504.

Dean, T.A., Stekoll, M.S., Jewett, S.C., Smith, R.O., Hose, J.E., 1998. Eelgrass (Zostera marina L.) in Prince William Sound, Alaska: Effects of the Exxon Valdez oil spill. Marine Pollution Bulletin 36: 201–210.

Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016. Deepwater Horizon oil spill: final programmatic damage assessment and restoration plan and final programmatic environmental impact statement. National Oceanic and Atmospheric Administration, Silver Spring.

Department of Environment and Conservation, 2007. Management plan for the Montebello/Barrow Islands Marine Conservation Reserves. Marine Parks and Reserves Authority, Perth.

Department of Sustainability, Environment, Water, Population and Communities, 2012a. Marine bioregional plan for the North-west Marine Region: prepared under the Environment Protection and Biodiversity Conservation Act 1999. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Department of the Environment and Energy, 2015. Balaenoptera edeni — Bryde's Whale [WWW Document]. Species Profile and Threats Database. URL http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=35 (accessed 7.01.19).

Department of the Environment, 2015. Balaenoptera edeni — Bryde's Whale [WWW Document]. Species Profile and Threats Database. URL http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=35 (accessed 3.6.15).

Department of the Environment, Water, Heritage and the Arts (DEWHA), 2008. The north-west marine bioregional plan: bioregional profile. Department of the Environment, Water, Heritage and the Arts, Canberra.

Double, M.C., Andrews-Goff, V., Jenner, K.C.S., Jenner, M.-N., Laverick, S.M., Branch, T.A., Gales, N.J., 2014. Migratory movements of pygmy blue whales (Balaenoptera musculus brevicauda) between Australia and Indonesia as revealed by satellite telemetry. PloS one 9: e93578.

Dunlop, J., Wooller, R., Cheshire, N., 1988. Distribution and abundance of marine birds in the Eastern Indian Ocean. Marine and Freshwater Research 39: 661–669.

Falkner, I., Whiteway, T., Przeslawski, R., Heap, A.D., 2009. Review of Ten Key Ecological Features (KEFs) in the Northwest Marine Region: a report to the Department of the Environment, Water, Heritage and the Arts by Geoscience Australia, Geoscience Australia Record. Geoscience Australia, Canberra.

Fodrie, F.J., Heck, K.L., 2011. Response of coastal fishes to the Gulf of Mexico oil disaster. PLoS ONE 6: e21609. doi:10.1371/journal.pone.0021609.

French, D.P., Schuttenberg, H.Z., Isaji, T., 1999. Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light. Presented at the Arctic and Marine Oilspill Program Technical Seminar, Ministry of Supply and Services, Ottawa, pp. 243–270.

French-McCay, D., 2009. State-of-the-art and research needs for oil spill impact assessment modeling, in: Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response. Presented at the 32nd AMOP Technical Seminar on Environmental Contamination and Response, Environment Canada, Ottawa, pp. 601–653.

Furnas, M., Mitchell, A., 1999. Wintertime carbon and nitrogen fluxes on Australia's Northwest Shelf. Estuarine, Coastal and Shelf Science 49: 165–175.

Gagnon, M.M., Rawson, C., 2010. Montara well release: Report on necropsies from a Timor Sea green turtle. Curtin University, Perth.

Geraci, J., 1988. Physiologic and toxicologic effects of cetaceans, in: Geraci, J., St Aubin, D. (Eds.), Synthesis of Effects of Oil on Marine Mammals, OCS Study. Department of Interior, Ventura, pp. 168–202.

Gilmour, J., Smith, L., Pincock, S., Cook, K., 2013. Discovering Scott Reef: 20 years of exploration and research. Australian Institute of Marine Science, Townsville.

Hassan, A., Javed, H., 2011. Effects of Tasman Spirit oil spill on coastal birds at Clifton, Karachi coast, Pakistan. Journal of Animal and Plant Sciences 21: 333–339.

Hazel, J., Lawler, I.R., Marsh, H., Robson, S., 2007. Vessel speed increases collision risk for the green turtle Chelonia mydas. Endangered Species Research 3: 105–113.

Heatwole, H., Cogger, H.G., 1993. Chapter 36: Family Hydrophiidae, in: Fauna of Australia. Australian Government Publishing Service, Canberra.

Heintz, R.A., Rice, S.D., Wertheimer, A.C., Bradshaw, R.F., Thrower, F.P., Joyce, J.E., Short, J.W., 2000. Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development. Marine Ecology Progress Series 208: 205–216.

Helm, R.C., Costa, D.P., DeBruyn, T.D., O'Shea, T.J., Wells, R.S., Williams, T.M., 2015. Overview of effects of oil spills on marine mammals, in: Fingas, M. (Ed.), Handbook of Oil Spill Science and Technology. Wiley, pp. 455–475.

Hjermann, D.Ø., Melsom, A., Dingsør, G.E., Durant, J.M., Eikeset, A.M., Røed, L.P., Ottersen, G., Storvik, G., Stenseth, N.C., 2007. Fish and oil in the Lofoten–Barents Sea system: synoptic review of the effect of oil spills on fish populations. Marine Ecology Progress Series 339: 283–299.

International Petroleum Industry Environmental Conservation Association, 2000. Biological impacts of oil pollution: Sedimentary shores (IPIECA Report Series No. 9). International Petroleum Industry Environmental Conservation Association, London.

International Petroleum Industry Environmental Conservation Association, 2004. A guide to oiled wildlife response planning (IPIECA Report Series No. 13). International Petroleum Industry Environmental Conservation Association, London.

International Tanker Owners Pollution Federation, 2011a. Effects of oil pollution on the marine environment (Technical Information Paper No. 13). International Tanker Owners Pollution Federation Limited, London.

International Tanker Owners Pollution Federation, 2011b. Effects of oil pollution on fisheries and mariculture (Technical Information Paper No. 11). International Tanker Owners Pollution Federation Limited, London.

Jarman, S., Wilson, S., 2004. DNA-based species identification of krill consumed by whale sharks. Journal of Fish Biology 65: 586–591.

Jenner, K., Jenner, M., McCabe, K., 2001. Geographical and temporal movements of humpback whales in Western Australian waters. APPEA Journal 41: 692–707.

Jensen, A., Silber, G., 2004. Large whale ship strike database (NOAA Technical Memorandum No. NMFS-OPR). National Marine Fisheries Service, Silver Spring.

Johansen, J.L., Allan, B.J., Rummer, J.L., Esbaugh, A.J., 2017. Oil exposure disrupts early life-history stages of coral reef fishes via behavioural impairments. Nature Ecology & Evolution 1: 1146–1152. doi:10.1038/s41559-017-0232-5.

Koops, W., Jak, R., van der Veen, D., 2004. Use of dispersants in oil spill response to minimize environmental damage to birds and aquatic organisms. Interspill 2004.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S., Podesta, M., 2001. Collisions between ships and whales. Marine Mammal Science 17: 35–75.

Masel, J., Smallwood, D., 2000. Habitat usage by postlarval and juvenile prawns in Moreton Bay, Queensland, Australia. The Proceedings of the Royal Society of Queensland 109: 107–117.

McCauley, R., Duncan, A., 2011. Sea noise logger deployment, Wheatstone and Onslow, April 2009 to November 2010 (Technical Report No. R2011-23). Centre for Marine Science and Technology, Curtin University of Technology, Perth.

McCauley, R., Jenner, C., 2010. Migratory patterns and estimated population size of pygmy blue whales (Balaenoptera musculus brevicauda) traversing the Western Australian coast based on passive acoustics (International Whaling Commission Report No. SC/62/SH26). International Whaling Commission.

McCauley, R.D., 2011. Woodside Kimberley sea noise logger program, Septemer 2006 to June 2009: whales, fish and man-made noise (Report No. R2010–50_3). Curtin University, Perth.

McLean, D.L., Partridge, J.C., Bond, T., Birt, M.J., Bornt, K.R., Langlois, T.J., 2017. Using industry ROV videos to assess fish associations with subsea pipelines. Continental Shelf Research 141: 76–97. doi:10.1016/j.csr.2017.05.006.

Meekan, M.G., Bradshaw, C.J., Press, M., McLean, C., Richards, A., Quasnichka, S., Taylor, J.G., 2006. Population size and structure of whale sharks Rhincodon typus at Ningaloo Reef, Western Australia. Marine Ecology Progress Series 319: 275–285.

Milton, S.L., Lutz, P.L., 2003. Physiological and genetic responses to environmental stress, in: Lutz, P.L., Musick, J.A., Wyneken, J. (Eds.), The Biology of Sea Turtles. CRC Press, Boca Raton, pp. 164–198.

National Energy Resources Australia (NERA), 2018. Consequence Analysis of an Accidental Release of Diesel.

National Oceanic and Atmospheric Administration, 2010. Oil and sea turtles: Biology, planning and response. National Oceanic and Atmospheric Administration, Washington.

National Research Council, 2005. Oil spill dispersants: efficacy and effects. The National Academies Press, Washington, D.C.

Negri, A.P., Heyward, A.J., 2000. Inhibition of fertilization and larval metamorphosis of the coral Acropora millepora (Ehrenberg, 1834) by petroleum products. Marine Pollution Bulletin 41: 420–427.

Oil and Gas UK, 2014. Guidance on risk related decision making (Issue No. 2). United Kingdom Offshore Operators Association, London.

Owens, E.H., Humphrey, B., Sergy, G.A., 1994. Natural cleaning of oiled coarse sediment shorelines in Arctic and Atlantic Canada. Spill Science & Technology Bulletin 1: 37–52.

Oxford Economics, 2010. Potential impact of the Gulf oil spill on tourism. Oxford Economics, Oxford.

Preen, A., 2004. Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. Biological Conservation 118: 205–218.

Preen, A., Marsh, H., Lawler, I., Prince, R., Shepherd, R., 1997. Distribution and abundance of dugongs, turtles, dolphins and other megafauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, Western Australia. Wildlife Research 24: 185–208.

Romero, I.C., Schwing, P.T., Brooks, G.R., Larson, R.A., Hastings, D.W., Ellis, G., Goddard, E.A., Hollander, D.J., 2015. Hydrocarbons in deep-sea sediments following the 2010 Deepwater Horizon blowout in the northeast Gulf of Mexico. PLOS ONE 10: e0128371. doi:10.1371/journal.pone.0128371.

RPS Environment and Planning, 2012. Analysis of sea noise in the Greater Western Flank survey area, September 2010 to August 2011. RPS Environment and Planning Pty Ltd, Perth.

RPS Environment and Planning, 2012b. Sediment quality surveys March-April 2011, Greater Western Flank Marine Environmental Baseline Studies. RPS Environment and Planning Pty Ltd, Perth.

RPS, 2010. Satellite telemetry of nesting flatback turtles from Ashburton Island - Wheatstone Project EIS/ERMP (No. M10604). RPS Environment and Planning Pty Ltd, Perth.

RPS, 2012. Sediment Quality Surveys March-April 2011. Greater Western Flank Marine Environmental Baseline Studies. RPS Environment and Planning Pty Ltd, Perth.

Runcie, J., Macinnis-Ng, C., Ralph, P., 2010. The toxic effects of petrochemicals on seagrassess - literature review. Institute for Water and Environmental Resource Management, University of Technology Sydney, Sydney.

Schianetz, K., Jones, T., Kavanagh, L., Walker, P.A., Lockington, D., Wood, D., 2009. The practicalities of a Learning Tourism Destination: a case study of the Ningaloo Coast. International Journal of Tourism Research 11: 567–581. doi:10.1002/jtr.729.

SGS Economics & Planning, 2012. Economic development opportunities for the Gascoyne region associated with resource sector investment and expansion. Gascoyne Development Commission, Fortitude Valley.

Sheppard, J.K., Preen, A.R., Marsh, H., Lawler, I.R., Whiting, S.D., Jones, R.E., 2006. Movement heterogeneity of dugongs, Dugong dugon (Müller), over large spatial scales. Journal of Experimental Marine Biology and Ecology 334: 64–83.

Shigenaka, G., 2001. Toxicity of oil to reef building corals: a spill response perspective (NOAA Technical Memorandum No. NOS OR&R 8). National Oceanic and Atmospheric Administration, Seattle.

Sleeman, J.C., Meekan, M.G., Wilson, S.G., Polovina, J.J., Stevens, J.D., Boggs, G.S., Bradshaw, C.J.A., 2010. To go or not to go with the flow: Environmental influences on whale shark movement patterns. Journal of Experimental Marine Biology and Ecology 390: 84–98. doi:10.1016/j.jembe.2010.05.009

Smallwood, C.B., Beckley, L.E., Moore, S.A., Kobryn, H.T., 2011. Assessing patterns of recreational use in large marine parks: A case study from Ningaloo Marine Park, Australia. Ocean & Coastal Management 54: 330–340. doi:10.1016/j.ocecoaman.2010.11.007.

Taylor, J.G., 2007. Ram filter-feeding and nocturnal feeding of whale sharks (Rhincodon typus) at Ningaloo Reef, Western Australia. Fisheries Research 84: 65–70.

Tomajka, J., 1985. The influence of petroleum hydrocarbons on the primary production of the Danube River plankton. Acta Hydrochimica et Hydrobiologica 13: 615–618.

Underwood, J.N., 2009. Genetic diversity and divergence among coastal and offshore reefs in a hard coral depend on geographic discontinuity and oceanic currents. Evolutionary Applications 2: 222–233. doi:10.1111/j.1752-4571.2008.00065.x.

URS, 2010. Wheatstone Project: Deepwater habitat survey. URS Australia Pty Ltd, Perth.

Vanderlaan, A.S.M., Taggart, C.T., 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Marine Mammal Science 23: 144–156. doi:10.1111/j.1748-7692.2006.00098.x.

Warne, MStJ, Batley, GE, van Dam, RA, Chapman, JC, Fox, DR, Hickey, CW & Stauber, JL, 2018, Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants — updated of 2015 version. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, 48 pp.

Wilson, S., Polovina, J., Stewart, B., Meekan, M., 2006. Movements of whale sharks (Rhincodon typus) tagged at Ningaloo Reef, Western Australia. Marine Biology 148: 1157–1166.

Woodside Energy Limited, 2006. Pluto LNG development draft Public Environment Report/Public Environment Review (EPBC Act Referral No. 2006/2968). Woodside Energy Limited, Perth.

Woodside Energy, 2005. Environmental impacts of drill cuttings at North Rankin A and Goodwyn A (No. ENV-646 Rev 0). Woodside Energy Limited, Perth.

Yender, R., Michel, J., Lord, C., 2002. Managing seafood safety after and oil spill. National Oceanic and Atmospheric Administration, Seattle.

Zieman, J.C., Orth, R., Phillips, R.C., Thayer, G., Thorhaug, A., 1984. Effects of oil on seagrass ecosystems, in: Cairns Jr., J., Buikema, A.L. (Eds.), Restoration of Habitats Impacted by Oil Spills. Butterworth-Heinemann, Boston, pp. 37–64.

APPENDIX A: ENVIRONMENTAL IMPACTS AND RISKS

Physical Presence: Disturbance to Marine Users

Impacts Evaluation Summary													
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	***Marine Sediment***	***Water Quality***	***Air Quality (incl. Odour)***	***Ecosystems/Habitat***	***Species***	***Socio-Economic***	***Decision Type***	***Consequence/Impact***	***Likelihood***	***Risk Rating***	***ALARP Tools***	***Acceptability***
Presence of NRC and subsea infrastructure excluding and/or displacing other users from Petroleum Safety Zone and Operational Areas respectively	-	-	-	-	-	-	X	A	F	-	-	LCS GP PJ	Broadly Acceptable

Description of Source of Impact

The NRC commenced operation in 1984 and has been marked on nautical charts since that time. The NRC is surrounded by a 500 m radius petroleum safety zone (approximately 0.95 km2), which other users are prohibited from entering unless authorised by Woodside to reduce the likelihood of interactions between vessels and the NRC.

The NRC is well lit and highly visible under most conditions, and the nature of the NRC (large steel structure) ensures a clear radar return to alert ships fitted with anti-collision radars.

Routine vessel activities associated with the Petroleum Activities Program are concentrated within the petroleum safety zone (e.g. platform support vessels at the NRC facility). Subsea support vessels may undertake activities (e.g. IMMR activities) within the Operational Area at any time. The duration and location of these activities varies depending on the activity being undertaken.

Impact Assessment

Exclusion and Displacement of Other Users

Commercial Fishing

Twelve commercial fisheries overlap the Offshore Facility Operational Area and the Export Trunkline Operational Area. The likely presence of commercial fishing vessels was assessed based on fishing gear type, historical effort and consultation.

Commercial fishing vessels in the vicinity of the Offshore Facility Operational Area are most likely to be participants of the Pilbara Demersal Scalefish Fishery and the Onslow Prawn Fishery and may employ several gear types (including trawling). However, the majority of the Offshore Facility Operational Area lies within Zone 2 Area 6, an area closed to trawling since 1997.

The Export Trunkline Operational Area overlaps with Zone 2 Area 1 of the Pilbara Demersal Scalefish Fishery (including trawling) and lies entirely within the Onslow Prawn Fishery. The region of the Export Trunkline Operational Area located within Zone 2 Area 1 is approximately 164 km^2, or less than 0.7% of the total Zone 2 Area 1 area (approximately 24,580 km^2) available for trawling. Both are trawling fisheries; therefore, the presence of subsea infrastructure could present a hazard to bottom trawl fisheries due to risk of equipment entanglement and subsequent equipment damage/ loss. However, impacts from the physical presence of the NRC facility and subsea infrastructure are expected to be confined to localised displacement of fishing effort from the Operational Area with no lasting effect.

Tourism and Recreation

Tourism and recreation activity in the Offshore Facility Operational Area and Export Trunklines Operational Area is expected to be infrequent, with recreational and charter fishing from vessels the only activities potentially occurring within the Operational Area. Any recreational and charter fishing from vessels is largely undertaken using lines. These activities are most likely to occur around Glomar Shoals (25 km east from the Operational Area at the closest point) and Rankin Bank (54 km west from the Operational Area at the closest point). The Export Trunklines Operational Area is 36 km to the Dampier boat ramp at its closest point (at the state boundary) and therefore, low numbers of recreational vessels may be encountered within that nearshore point of the Operational Area, near the State/Commonwealth boundary.

Given the distance from boating facilities, lack of natural attractions and water depth of the Operational Area, very little recreational or charter fishing is expected to occur. As such, impacts to recreational and charter fishing (entanglement of equipment, displacement of fishers) are expected to be localised with no lasting effect.

Shipping

Significant commercial shipping occurs in the region, with commercial shipping traffic comprising vessels such as:

- bulk carriers (e.g. mineral ore, salt etc.) from Port Hedland and Dampier
- offtake tankers
- support vessels for offshore oil and gas activities
- LNG carriers from Dampier, Barrow Island and Ashburton North.

To reduce the likelihood of interactions between commercial vessels and offshore facilities, AMSA has introduced a series of shipping fairways, within which commercial vessels are advised to navigate. The fairways are not mandatory, but AMSA strongly recommends commercial vessels remain within the fairway when transiting the region. The use of shipping fairways is considered to be good seafaring practice, with Australian Ship Reporting System (AUSREP) data from AMSA indicating cargo ships and tankers routinely navigate within the established fairways.

No shipping fairways interact the with Offshore Facility Operational Area, however one fairway overlaps with the southern end of the Export Trunklines Operational Area:

- A fairway travelling parallel to the coast, from Barrow Island to the Dampier Shipping Fairways.

As the facility has been operational since 1984, is marked on nautical charts and the riser platform is surrounded by a 500 m Petroleum Safety Zone, the likelihood of interactions between commercial vessels and the facility is inherently low.

The presence of the facility, vessels and subsea infrastructure will not result in impacts to commercial shipping beyond a localised exclusion of shipping traffic from the Petroleum Safety Zone, and the temporary displacement of commercial shipping from subsea support vessels as a result of vessels undertaking activities in the Operational Area. This is considered to be a localised impact, and of no lasting effect.

Oil and Gas

The nearest other oil and gas platform is the GWA facility which is connected to the NRC by the IFL. GWA is operated by Woodside; impacts from the Petroleum Activities Program to GWA will not affect third parties. The nearest facility not operated by Woodside is the Santos-owned Reindeer platform, which lies approximately 10 km south-east of the Operational Areas. Given the distance between the Operational Areas and petroleum activities undertaken by other operators, no impacts to other operators will occur as a result of the presence of the riser platform, vessels or subsea infrastructure.

Summary of Control Measures

- Support vessels complying with Marine Orders for safe vessel operations:
  - Marine Order 21 (Safety of navigation and emergency procedures) 2012
  - Marine Order 30 (Prevention of Collisions) 2009
- Implementation of a 500 m Petroleum Safety Zone around riser platform
- Notifying AHS of locations of new permanent infrastructure to enable AHS to update maritime charts
- Undertaking consultation program to advise relevant persons of the Petroleum Activities Program and provide opportunity to raise objections or claims
- Notify AMSA Joint Rescue Coordination Centre (JRCC) of stationary vessel based IMMR activities undertaken within shipping lane.

Physical Presence: Disturbance to Seabed

Impacts Evaluation Summary													
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Presence of NRC and subsea infrastructure modifying marine habitats	-	X	X	-	X	-	-	A	F	-	-	LCS GP PJ	Broadly acceptable
Subsea operations, inspection, maintenance and repair activities resulting in disturbance to seabed	-	X	X	-	X	-	-	A	E	-	-		

Description of Source of Impact

Seabed disturbance associated with the Petroleum Activities Program can occur during operations and activities including:

- physical presence of the facility and subsea infrastructure
- scour, spans, and flowline movement inherent in design
- subsea IMMR activities.

Subsea infrastructure occurs throughout the Operational Area. Subsea equipment has been installed historically, subject to separate EPs. Installation and historical operations have described the benthic footprint/ disturbance. The physical footprint of existing subsea infrastructure is described in this section for completeness.

The NRC, subsea infrastructure and export trunklines provide hard substrate habitat from the sea surface through the water column to the seabed (e.g. jackets and risers), as well as along the seabed (e.g. pipelines, flowlines, manifolds, etc.).

The presence of subsea infrastructure may result in localised scouring around the infrastructure due to currents, subsurface waves and seabed sediment fluid dynamics. Scour around subsea infrastructure may necessitate IMMR activities as part of integrity management practices.

Flowline movement may occur as per design and within integrity margins along the flowline corridor. Normal flowline operational movement occurs due to factors such as flowline buckling, walking and varying metocean conditions. Lateral movement can occur within the flowline corridor. Management of flowline buckling, and walking may necessitate IMMR activities. Refer to MEE-02 Subsea Equipment Loss of Containment which includes controls to limit scour and flowline movement within integrity requirements.

To maintain the integrity of subsea infrastructure, Woodside may be required to undertake routine subsea IMMR activities. Activities that constitute IMMR may impact the benthic environment in the vicinity of the activity. IMMR activities identified as impacting the benthic environment include (but are not limited to):

- inspections – minor localised sediment resuspension by ROV
- marine growth removal – minor, localised resuspension of sediment; removal of marine biota from subsea infrastructure
- sediment relocation – localised modification of benthic habitat and sediment resuspension
- span rectification, pipeline protection and stabilisation – minor, localised modification of benthic habitat within footprint of area subject to rectification/protection/stabilisation
- jumper and umbilical replacement – minor, localised modification of benthic habitat in the vicinity of the jumper/umbilical
- spool repair/replacement – minor, localised modification of benthic habitat in the vicinity of the spool.

Impact Assessment
Scour may result in localised impact to soft sediment benthic habitats, typically on the scales of metres to tens of metres. Soft sediment benthic habitats are very widely represented in the Operational Area and NWS Province more broadly. Operational experience indicates scour around subsea infrastructure associated with the Petroleum Activities Program is localized, with no lasting impact to environmental receptors. Flowline movement is limited to areas within design and integrity envelopes, and may result in slight, localised impact to soft sediment benthic habitats, typically on the scales varying between metres to tens of metres laterally along the flowline corridors. IMMR activities can be categorised into two potential impacts: • direct physical disturbance of benthic habitat • indirect disturbance to benthic habitats from sedimentation. ***Water and Sediment Quality*** Indirect seabed disturbance may include localised and temporary decline in water quality due to increased suspended sediment concentrations and increased sediment deposition caused by IMMR activities. However, sediment loads are not expected to be significant due to the relatively small footprint for each IMMR activity. Each discrete IMMR activity near the seabed is likely to cause a single brief disturbance resulting in a transient plume of suspended sediment. This plume will subsequently be deposited down-current as particles resettle. Such localised and short-term events may affect small areas of the seabed and consequently impact the associated biota (typically sparsely distributed infauna and sessile fauna). Given the expected nature and scale of resuspension resulting from IMMR activities, impacts such as smothering or burial are not expected. Rather, impacts are likely to be restricted to increased ingestion of inedible sediments by filter feeders. Biota in the region are well adapted to periodic turbidity events caused by cyclones and tidal movements. As such, impacts from turbidity caused by IMMR activities are not expected to have any lasting effect on benthic biota. ***Benthic Habitats*** The area of benthic habitat predicted to be impacted varies depending on the nature and scale of the IMMR activity. Span rectification activities are considered to be IMMR activities with the greatest potential to modify benthic habitats, due to the alteration of the existing soft sediment habitat to hard substrate. Woodside's operational experience on the North West Shelf indicates these activities are typically restricted to relatively short (tens of metres) linear sections of pipeline, with areas of up to approximately 100 m^2 impacted. The benthic habitat within the Operational Areas is predominantly soft sediment with sparsely associated epifauna, which is broadly represented throughout the NWS Province. Benthic communities of soft sediment are characterised by burrowing infauna such as polychaetes, with biota such as sessile filter feeders occurring on areas of hard substrate (such as subsea infrastructure). The infauna communities are representative of the NWS Province being of low abundance and dominated by polychaetes and crustaceans (RPS Environment and Planning 2012b). Direct physical seabed disturbance, including permanent modification of benthic communities and minor loss of filter feeder habitat, may result as a consequence of IMMR activities. Although impacts to filter feeding communities resulting from IMMR activities may result in permanent loss, this is expected to be restricted to a very small portion of filter feeder habitat, which is broadly represented in the wider NWS Province. Where the IMMR activity creates hard substrate habitat (e.g. span rectification, pipeline protection and stabilisation), this habitat may be suitable for recruitment of filter feeding communities and is expected to be colonised by sessile benthic biota (e.g. sponges, gorgonians, etc.) over time, which may support higher biodiversity than soft sediment habitats. IMMR activities generally disturb small areas (typically < 100 m^2). The estimated overall extent of such direct seabed disturbance is extremely small in relation to the extent of the soft sediment habitats which are broadly represented within the Operational Areas and the wider NWS Province. As such, impacts to filter feeders due to IMMR activities are expected to be localised and not significant. <u>Artificial Habitat</u> The presence of the NRC and subsea infrastructure provides hard substrate for the settlement of marine organisms; the availability of hard substrate is often a limiting factor in benthic communities. As such, the presence of the facility and subsea infrastructure has led to the development of ecological communities which would not have existed otherwise. For example, pipeline infrastructure has been shown to support demersal fish assemblages and benthic biota (e.g. sessile filter feeding communities) (McLean et al. 2017). These communities are relatively diverse compared to the open water and soft sediment habitats in the broader Operational Areas. The provision of artificial habitat associated with the facility and subsea infrastructure will have either no adverse environmental impact or a low level of positive environmental impact through increasing biological diversity. ***Values and Sensitivities*** *<u>Ancient Coastline at 125 m Depth Contour</u>* The Operational Area overlaps approximately 40 km^2 of the 16,189.8 km^2 Ancient Coastline, which is approximately 0.2% of the KEF. Benthic habitat surveys in the region (including within the Ancient Coastline at 125 m Depth Contour KEF) indicate that benthic habitats within the KEF are characterised by sand interspersed with areas of rubble and outcroppings of limestone pavement (AIMS 2014b, RPS 2011). Such habitats are widely distributed in the NWS Province. No significant

escarpments, species of conservation significance, emergent features or areas of high biological productivity characteristically associated with the Ancient Coastline at 125 m KEF have been observed in the Operational Area. *The KEF's geomorphic feature is represented worldwide and represents the coastline during a previous glacial period. Therefore, potential impacts to this regional-scale KEF are expected to be negligible.*
Summary of Control Measures
• Anchoring in the NRC petroleum safety zone will be prohibited except in emergency situations or under issuing of a specific permit • All vessels used for IMMR / heavy lift activities will be DP capable • Monitoring and maintenance of subsea infrastructure to manage scour and flowline movement within integrity envelope.

Routine Acoustic Emissions: Generation of Noise during Routine Operations

Impacts Evaluation Summary													
Source of Impact	**Environmental Value Potentially Impacted**							**Evaluation**					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Noise generated within the Operational Area from: • facility and associated infrastructure • vessels • subsea IMR activities • helicopters.						X		A	F	-	-	LCS GP PJ	Broadly acceptable

Description of Source of Impact

The facility, vessels, IMMR activities and helicopters will generate noise both in the air and underwater, due to normal operation of machinery noise and propeller movement. Typical noise levels for these sources are provided in **Table 12-1** and **Table 12-2**, with more detailed descriptions provided below. This noise will contribute to and can exceed ambient noise levels which range from around 90 dB re 1 μPa sound pressure level (SPL) under very calm, low wind conditions, to 120 dB re 1 μPa SPL under windy conditions (McCauley, 2005).

Table 12-1: Indicative source characteristics of continuous underwater noise associated with the Petroleum Activities Program as reported in †Jiménez-Arranz et al. (2017) and by ‡McCauley (2005) and §McCauley (2002)

Acoustic Noise Sources	Estimated SPL (dB re 1 μPa SPL) @1 m unless otherwise stated	Frequency Range (kHz)
Vessels (Continuous)		
Support and HLV using DP‡	171 (calm) 179 (moderate) 187 (rough)	Broadband
Wellhead, Flowlines and Subsea Infrastructure (Continuous)		
Wellhead§	113	Broadband
Choke valve§	155	Broadband
Production platforms		
Riser platform†	110–130 @100 m	Broadband (mainly < 100 Hz)

* *Range provided was not measured at the noise source; therefore, this should be used as an indicative estimate only and cannot be used to estimate exposure thresholds closer to the source.*

Vessels

Vessels may emit noise through the hull acting as a transducer (e.g. machinery vibration being converted to underwater noise), as well as through cavitation from fast moving surfaces such as propellers and thrusters. The main source of noise from vessels (both platform support and subsea support vessels) relates to the use of DP thrusters (i.e. cavitation from thruster propellers). The vessels undertaking the Petroleum Activities Program are expected to spend considerable time holding station during DP, which requires the use of thruster. Thruster noise (from cavitation caused by propellers) is typically the most significant noise source for vessels holding station, with other noise sources typically relatively minor (McCauley 1998).

Thruster noise is typically high intensity and broadband in nature. McCauley (1998) measured underwater broadband noise up to approximately 182 dB re 1 μPa at 1 m (rms SPL) from a support vessel holding station in the Timor Sea. Quijano and Mcpherson (2018) measured underwater broadband noise from a large offshore heavy lift vessel offshore

DP trial and calculated DP source levels for calm, moderate and rough sea conditions as 171, 179 and 187 dB re 1 µPa^2 m^2, respectively. It is expected that noise levels up to this this level may be generated by vessels using DP during the Petroleum Activities Program.

All support vessels are required to comply with EPBC Regulation 2000 – Part 8 Interacting with Cetaceans to reduce the likelihood of collisions with cetaceans. Implementing this control may incidentally reduce the noise generated by vessels in proximity to cetaceans as vessels will be travelling slower; slower vessel speeds may reduce underwater noise from machinery noise (main engines) and propeller cavitation.

Helicopters

Helicopter engines and rotor blades are recognised as a source of noise emissions, which may constitute a source of environmental risk resulting in behavioural disturbance to marine fauna. Activities relevant to the Operational Area will relate to the landing and take-off of helicopters on the NRC (which occurs typically at 1-2 day intervals) and potentially subsea support vessels. During these critical stages of helicopter operations, safety takes precedence. Helicopter flights are at their lowest (i.e. closest point to the sea surface) during these periods of take-off and landing from heli-decks, which constitutes a relatively short phase of routine flight operations.

Wellhead, Pipelines and Subsea infrastructure

The noise produced by an operational wellhead was measured by McCauley (2002). The broadband noise level was very low, 113 dB re 1 µPa, which is only marginally above rough sea condition ambient noise. For a number of nearby wellheads, the sources would have to be in very close proximity (< 50 m apart) before their signals summed to increase the total noise field (with two adjacent sources only increasing the total noise field by three dB). Hence for multiple wellheads in an area, the broadband noise level in the vicinity of the wellheads would be expected to be of the order of 113 dB re 1 µPa and this would drop very quickly to ambient conditions on moving away from the wellhead, falling to background levels within < 200 m from the wellhead.

Based on the measurements of wellhead noise discussed in McCauley (2002), which included flow noise in pipelines, noise produced along a pipeline may be expected to be similar to that described for wellheads, with the radiated noise field falling to ambient levels within a hundred meters of the pipeline.

Woodside has undertaken acoustic measurements on the noise generated by the operation of choke valves associated with the Angel facility (JASCO 2015) similar to the design employed across NRC subsea valves. These measurements indicated choke valve noise is continuous, and the frequency and intensity of noise emitted is dependent on the rate of production from the well. Noise intensity at low production rates (16% and 30% choke positions) were approximately 154-155 dB re 1 µPa, with higher production rates (85% and 74% choke positions) resulting in lower noise levels (141-144 dB re 1 µPa). Noise from choke valve operation was broadband in nature, with the majority of noise energy concentrated above 1 kHz. Noise from choke valve operation was considered minor compared to noise generated by vessels using thrusters in the area.

Platform Machinery

Production platforms have machinery mounted on decks raised above the sea, hence, most noise is transmitted to the marine environment from the air. Machinery noise onboard the NRC platform may be radiated into the underwater environment via the jacket legs and risers, which may act as transducers. Underwater noise generated by the NRC is expected to be minimal, with monitoring programs indicating that underwater noise from platforms is typically very low or not detectable (McCauley 2002).

The HP and LP flare system will generate noise from combustion. Noise from flaring represents a health and safety risk to personnel, and noise from flaring was considered in the design of the NRC to manage the occupational health and safety risks associated with noise (e.g. height specification of flare tower). Noise from flaring is emitted at the top of the flare tower, which is approximately 175 m above sea level. Noise from the tip of the flare is not constrained and will spread spherically in all directions.

Gales (1982) assessed noise from 18 oil and gas platforms, including 11 bottom-standing fixed platforms during production operations (i.e. consistent with the NRC riser platform). The study found the strongest noise levels were relatively low frequency (< 100 Hz, and mostly between 4 and 38 Hz), with sound levels of 110 to 130 dB re 1 µPa @100 m (Gales, 1982). Noise from the platforms was found to be lower than levels recorded from support vessels, with a cumulative increase in overall underwater noise of 20–30 dB from the noise produced by a support vessel operating in the vicinity of an operations platform (Gales, 1982). Noise emitted from machinery on the riser platform is limited relative to other operating facilities due to its NNM status, smaller size and the lack of processing facilities on the riser platform. Therefore, it is likely that the range provided by Gales (1982) is a conservative estimate. In summary, noise emissions generated by the facility is expected to be minimal.

Subsea IMMR Activities

Subsea IMMR activities may result in localised, temporary increased in underwater noise. Sources proposed (**Table 12-2**) have frequency outputs ranging from 2 kHz (SBP CHIRP) to 900 kHz (SSS).

High frequency acoustic signals attenuate more rapidly underwater compared to lower frequencies. Given the operating frequency of the MBES and SSS, underwater noise generated from these equipment is expected to attenuate rapidly in the water column. The position of the acoustic source in the water column will also influence the horizontal transmission of noise. Sources towed close to the seabed, typically via an AUV have a smaller distance between the source and the seabed, reducing received levels in the horizontal direction due to seafloor scattering and absorption. Therefore, received noise levels at defined horizontal distances from the system will be lower compared a surface towed source. Given the nature and scale of expected IMMR activities, noise generated during these activities is expected to be similar to, or less than, noise generated by subsea infrastructure during routine operations.

Table 12-2: Frequency ranges of IMMR sources and marine fauna

IMMR source	Frequency Range (kHz) (Jimenez-Arranz et al., 2017)	Estimated range of Source Level (dB re 1 µPa SPL @1 m	Potential disturbance from acoustic source						
			Low-frequency cetaceans[1]	Mid-frequency cetaceans[1]	High frequency cetaceans[1]	Marine turtles[3]	Whale sharks[2]	Fish - hearing specialists[4]	Fish - hearing generalists[4]
Auditory frequency range (kHz)			***0.07 - 22***	***0.15 - 160***	***0.2 - 180***	***0.1–0.7***	***0.02–0.8***	***0.1–3***	***0.2–0.8***
MBES	12–700 (deep) 150 – 700 (shallow)	210–247	Deep only	✓	✓				
SSS	75–900	200–234		✓	✓				
SBP – Chirp	2–23	167–212	✓	✓	✓			✓	
SBP – Pinger	2–20	161–205	✓	✓	✓			✓	
USBL / Acoustic Array	18–36	187 – 196	✓	✓	✓				

[1] *Southall et al 2007*

[2]*The estimated auditory bandwidth of whale sharks is unknown, a range of 0.02 – 0.8 kHz has been applied which is the known approximate sensitivity of among sharks as outlined in Myrberg 2001. Although there are no known studies on whale shark auditory hearing bandwidths, research suggests the large hearing structures of the whale shark would be most responsive to long-wave length, low-frequency sound (Myrberg, 2001).*

[3]*The estimated auditory bandwidth of turtles is 0.1 – 0.7 kHz as determined by electro-physical studies (McCauley 1994)*

[4]*Effects of seismic airguns and other sources of pulsed sound on marine fishes (URS, 2007).* IMMR

Impact Assessment

Depths in the Operational Area range from 30 m to 130 m. The fauna associated with this area will be predominantly pelagic species of fish, with migratory species such as turtles, birds, whale sharks and cetaceans present in the area seasonally. In particular, a number of EPBC listed marine species have BIAs which overlap the Operational Area, which are discussed below. Two KEFs also overlap the Operational Area. Fauna associated with the Ancient Coastline at 125 m KEF and Continental Slope Demersal Fish Communities KEF, such as demersal fish, may also be impacted upon by noise emissions. While the Ancient Coastline at 125 m KEF may be associated with outcroppings of hard substrate, no evidence of significant reefs associated with such outcroppings has been found in the Operational Area. Note some demersal fish are also likely to be associated with subsea infrastructure such as the export pipeline.

Cetaceans

The potential impacts of anthropogenic noise on marine mammals have been the subject of considerable research; reviews are provided by Richardson et al. (1995), Nowacek et al. (2007), Southall et al. (2007), Weilgart (2007) and Wright et al. (2007).

Southall et al. (2007), Finneran and Jenkins (2012) Wood et al. (2012), and more recently NFMS) reviewed available literature to determine exposure criterion for temporary hearing threshold shift (TTS) and injury, referred to as the onset of non-recoverable permanent hearing loss (PTS). In addition behavioural thresholds were taken from the US's National Fisheries Marine Services (NFMS). These thresholds are outlined in **Table 12-3** and are considered appropriate for the assessment of impacts from acoustic discharges to cetaceans from the Petroleum Activities Program.

Table 12-3: Impulsive thresholds at which physiological and behavioural impacts to cetaceans may occur from impulsive acoustic discharges

Reference	Impact Type	Minimum Threshold	
		SPL	SEL
Southall et al. 2007	PTS (All Cetaceans)	230 dB re 1 µPa (peak)	198 dB re: 1 µPa2.s (m-weighted)
	TTS (Low Frequency Cetaceans)	224 dB re 1 µPa (peak)	192 dB re: 1 µPa2.s (m-weighted)
NMFS 2014 and Southall et al. 2007	Behavioural Response Adults (Cetaceans)	160 dB re 1 µPa (rms)	-

To inform the assessment, the continuous source impact thresholds provided in **Table 12-4** were considered in relation to the credible sources of acoustic emissions.

Table 12-4: Continuous Sources - Impact threshold for environmental receptors based on *Southall et al. (2007) & National Marine Fisheries Services (NMFS, 2005).

Receptor	Mortality and potential mortal injury			
		PTS	***TTS***	**Behaviour**
Low-frequency cetaceans*	n/a	198 db re 1 µPa^{2}s M-weighted SEL	183 db re 1 µPa^{2}s M-weighted SEL	120 dB re 1 µPa rms SPL
Mid-frequency cetaceans*	n/a	198 db re 1 µPa^{2}s M-weighted SEL	183 db re 1 µPa^{2}s M-weighted SEL	120 dB re 1 µPa rms SPL
High-frequency cetaceans*	n/a	198 db re 1 µPa^{2}s M-weighted SEL	183 db re 1 µPa^{2}s M-weighted SEL	120dB re 1 µPa rms SPL

Note: a range of sound units are provided in the table above, reflecting the range of studies from which this data has been derived. The difference in units presents difficulty in reliably comparing threshold values. Where practicable, the threshold values have been compared with indicative sound sources levels of the same sound unit types to facilitate comparison. The sound units provided in the table above include:

- *M-weighted sound exposure level (SEL): a weighted sound metric that emphasises the audible frequency bands for the receptor groups – low, mid- and high frequency cetaceans. SEL units are time integrated and best suited for continuous noise sources, such as vessels holding station or continuous machinery noise.*

Marine Turtles

Because of their rigid external anatomy, it is possible that sea turtles are highly protected from impulsive sound effects (Popper et al. 2014). McCauley et al. (2003), Popper et al. (2014) and O'Hara and Wilcox (1990), however, reference behavioural exposure thresholds for impulsive noise sources on caged green and loggerhead turtles and turtle injury thresholds (**Table 12-5**).

Moein et al. (1994) tested if hearing sensitivity of caged loggerhead turtles altered after being exposed to several hundred pulses within 30 to 65 m of a single airgun (pulse numbers and received sound levels not stated). Hearing was tested before, within a day, and then two weeks after exposure. About 50% of the exposed individuals indicated altered hearing sensitivity when tested within a day of their exposure, but compared to the pre-exposure tests, none provided any sign of altered hearing two weeks later. These results corroborate the thresholds provided in **Table 12-5** that suggest the risk of PTS is low, even when close to the acoustic source. Thresholds provided in **Table 12-5** and **Table 12-6** are considered appropriate for the assessment of impacts from acoustic discharges to cetaceans from the Petroleum Activities Program.

Table 12-5: Impulsive noise exposure thresholds for injury and behavioural response for marine turtles

Species	Received Level			Effect	Source
	(dB re 1 µPa RMS)	(dB re 1 µPa pk)	(cSEL (dB re 1 µPa.s^2)		
Sea Turtles	-	>207	210	Injury	Popper et al. (2014)
Loggerhead turtle	175-176	-	-	Avoidance response	O'Hara and Wilcox (1990)
One green and one loggerhead turtle	166	-	-	Noticeable increase in swimming behaviour, presumed avoidance response	McCauley et al. (2003)
One green and one loggerhead turtle	175	-	-	Behaviour becomes increasingly erratic, presumed alarm response	McCauley et al. (2003)

Table 12-6: Continuous Sources – Turtle Impact threshold for environmental receptors based †Popper et al. (2014)

Receptor	Mortality and potential mortal injury				Behaviour
		PTS	***TTS***	***Masking***	
Sea turtles†	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low

Note: a range of sound units are provided in the table above, reflecting the range of studies from which this data has been derived. The difference in units presents difficulty in reliably comparing threshold values. Where practicable, the threshold values have been compared with indicative sound sources levels of the same sound unit types to facilitate comparison. The sound units provided in the table above include:

- *Relative risk (high, medium and low) is given for fish (all types), turtles and eggs and larvae at three distances from the source defined in relative terms as near (N), intermediate (I) and far (F) (after Popper et al. 2014).*

Fish

Sound is received by fish through the ears and the lateral line which are sensitive to vibration. Some species of teleost or bony fish (e.g. herring) have a structure linking the gas filled swim bladder and ear and these species usually have increased hearing sensitivity. These species are considered to be more sensitive to anthropogenic underwater noise sources than species such as cod (*Gadus sp.*) which do not possess a structure linking the swim bladder and inner ear. Fish species that either do not have a swim bladder (e.g. elasmobranchs and scombrid fish (mackerel and tunas) or have a much-reduced swim bladder (e.g. flat fish) tend to have a relatively low auditory sensitivity. Considering these differences in fish physiology, Popper et al. (2014) recently developed sound exposure guidelines for fish and these are presented in **Table 12-7** and **Table 12-8** which are considered appropriate to assess potential impacts of acoustic discharges to fish.

Table 12-7: Impulsive noise exposure thresholds for different types of fish (Popper et al. 2014)

Type of Fish	Recoverable Injury (PTS)	Temporary Threshold Shift (TTS)	Behaviour*
Type 1 - no swim bladder (particle motion detection)	>216 dB re 1µPa^{2}s (cSEL) or >213 dB re 1µPa (SPL peak)	>>186 dB re 1µPa^{2}s (cSEL)	(N) High (I) Moderate (F) Low
Type 2 - Swim bladder is not involved in hearing (particle motion detection)	>207 dB re 1µPa^{2}s (cSEL) or >203 dB re 1µPa (SPL peak)	>186 dB re 1µPa^{2}s (cSEL)	(N) High (I) Moderate (F) Low
Type 3 - Swim Bladder involved in hearing (primarily pressure detection)	207 dB re 1µPa^{2}s (cSEL) or >203 dB re 1µPa (SPL peak)	186 dB re 1µPa^{2}s (cSEL)	(N) High (I) High (F) Low
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).			

Table 12-8: Continuous Sources – Fish and Turtle Impact threshold for environmental receptors based †Popper et al. (2014)

Receptor	Mortality and potential mortal injury				Behaviour
		PTS	*TTS*	*Masking*	
Fish: no swim bladder†	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder not involved in hearing†	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder involved in hearing†	(N) Low (I) Low (F) Low	170 dB rms SPL for 48 hrs	158 dB rms SPL for 12 hrs	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles†	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low

Note: a range of sound units are provided in the table above, reflecting the range of studies from which this data has been derived. The difference in units presents difficulty in reliably comparing threshold values. Where practicable, the threshold values have been compared with indicative sound sources levels of the same sound unit types to facilitate comparison. The sound units provided in the table above include:

- *Root mean square (rms) sound pressure level (SPL): root mean square of time-series pressure level, useful for quantifying continuous noise sources (as per SEL point above).*
- *Relative risk (high, medium and low) is given for fish (all types), turtles and eggs and larvae at three distances from the source defined in relative terms as near (N), intermediate (I) and far (F) (after Popper et al. 2014).*

Vessel Noise

Vessels holding station are considered to be the predominant noise source related to the Petroleum Activities Program. Using the thruster noise measured by Quijano and Mcpherson (2018) as an indicative value for the potential thruster noise generated by vessels during the Petroleum Activities Program and the thresholds presented in **Table 12-4**, the potential for noise-induced mortality or injury of cetaceans, fish, sea turtles and eggs/larvae is not considered credible. However, other impacts such, masking and behavioural impacts may occur. Modelling of vessel DP sound propagation was undertaken using dBSEA parabolic equation solver and DP vessel worst case (rough) thruster noise of 187 dB re 1 µPa.

Potential impacts may include:

- Cetaceans: Potential behavioural disturbance out to approximately 5-7 km for cetaceans, likelihood of PTS or TTS is considered not to be credible, given individuals would need to be directly next to the noise source for prolonged duration and vessels are not point sources (i.e. sound is distributed from multiple locations of the vessel over a large area).
- Fish: Potential masking and behavioural disturbance at near and intermediate range; likelihood of PTS or TTS is considered not to be credible given fish would move away from the source. Site attached fish (e.g. demersal fish) are not expected to be exposed to underwater noise above impact thresholds given water depths in the area where these fish may be more prevalent (i.e. the Ancient Coastline at 125 m KEF and Continental Slope Demersal Fish Communities KEF).
- Turtles: Potential masking and behavioural disturbance at intermediate and far range, likelihood of PTS or TTS is considered not to be credible given turtles would need to be directly next to the noise source.

These estimated propagation ranges are considered to under-estimate TL, and are, hence, inherently conservative, due to:

- Use of high intensity thruster noise (i.e. thruster operating at full power in rough weather); most time using thrusters is at lower than full power, with concomitant reduction in cavitation noise intensity.

Fauna such as cetaceans, fish, and turtles are capable of moving away from potential noise sources, and there are no constraints to the movement of these fauna within the Operational Area.

IMMR Activities

JASCO (2013) conducted noise modelling for five low energy survey instruments off the coast of California. Three of these instrument types are comparable; MBES, SSS, SBP (chirp). All equipment types were modelled in the sandy bottom environment, similar to that of the Operational Area, and in 64 m water depth. Although the bathymetry, salinity, water temperature and sub seafloor sediment type may differ, given the similarities in equipment type, seafloor habitat and water depth, the modelling is considered comparable for the nature and scale of the low energy IMMR survey equipment.

The modelling reported distances to specific threshold levels for different types of marine mammals. Where applicable m-weighted R_{max} (the distance to the farthest occurrence of the threshold level) estimates were used. Since receptors include a greater range of species, unweighted R_{max}, was used for species where m-weighted estimates were not appropriate, which is considered conservative. The distance at which the 160 dB re 1 µPa (rms SPL) behavioural threshold was reached at the following distances (R_{max}):

- MBES – 290 m
- SSS – 682 m
- SBP (chirp) – 36 m
- Acoustic Transponder – 50 m.

The equipment presented in **Table 12-1,** which were not modelled in the JASCO (2013), include the SBP (pinger) and USBL. The SBP (pinger) equipment operates at similar frequencies and pressure to the SBP (chirp) and behavioural impact ranges are estimated to similar.

Table 12-9: Summary of impact thresholds and R_{max} for different species

Species	Effect	Threshold (impulsive noise)		R_{max} (metres)				
		SPL	SEL	MBES*	SSS*	SBP (Chirp)*	SBP (Pinger)†	USBL†
Cetaceans	PTS (All Cetaceans)[1]	230 dB re 1 µPa (peak)	198 dB re: 1 µPa2.s (m-weighted)	N/A	N/A	N/A	N/A	N/A
	TTS (Low Frequency Cetaceans)[1]	224 dB re 1 µPa (peak)	192 dB re: 1 µPa2.s (m-weighted)	N/A	N/A	N/A	N/A	N/A
	Behavioural Response Adults (Cetaceans)[1,2]	160 dB re 1 µPa (rms)	-	290	<693	<36	<50	<50
Marine turtles	Injury[3]	> 207 dB re 1 µPa (peak)	210 dB re 1 µPa.s2	N/A	N/A	N/A	N/A	N/A
	Avoidance response[4]	175-176 dB re 1 µPa (rms)	-	N/A	N/A	<20	N/A	N/A
	Noticeable increase in swimming behaviour, presumed avoidance response[5]	166 dB re 1 µPa (rms)	-	N/A	N/A	<36	N/A	N/A
	Behaviour becomes increasingly erratic, presumed alarm response[5]	175 dB re 1 µPa (rms)	-	N/A	N/A	<20	N/A	N/A
Fish – Type 1	PTS[3]	>213 dB re 1µPa (SPL peak)	>216 dB re 1µPa2s	N/A	N/A	<1	N/A	N/A
	TTS[3]	-	>>186 dB re 1µPa2s	<20	N/A	<20	N/A	N/A
Fish Type - 2	PTS[3]	>203 dB re 1µPa (SPL peak)	>207 dB re 1µPa2s	N/A	N/A	<5	N/A	N/A
	TTS[3]	-	>186 dB re 1µPa2s	<20	N/A	<50	N/A	N/A
Fish – Type 3	PTS[3]	>203 dB re 1µPa (SPL peak)	207 dB re 1µPa2s	N/A	N/A	<20	N/A	N/A
	TTS[3]	-	186 dB re 1µPa2s	<20	<20	<50	N/A	N/A

Notes:

N/A stated where operating frequency is outside species auditable hearing range or where exceeding threshold is not credible

** Rmax provided as presented in JASCO (2013)*

†Rmax provided based on spreading calculations

1. *Southall et al. 2007*
2. *NMFS 2013*
3. *Popper et al. 2014*
4. *O'Hara and Wilcox (1990)*
5. *McCauley et al. (2003)*
6. *Hastings (2010)*

Summary

Cetaceans

There is the potential for cetaceans to be exposed to underwater noise from vessels associated with the Petroleum Activities Program. However, as the peak underwater noise levels that may be generated by vessels and IMMR activities are below those resulting injury or mortality, only behavioural impacts are credible out to 5-7 km (DP Vessel)

and up to 700m from IMMR activities, any other potential impacts are considered negligible. Impacts are expected to be limited to localised avoidance of the noise source as there are no physical barriers in or near the Operational Area that may prevent cetaceans from moving away from vessels. ***Fishes*** Fish may temporarily be displaced from the immediate vicinity of a noise source; however, they would be expected to behave normally once the noise emissions ceased. A foraging BIA for whale sharks overlaps the Operational Area, and the species may be seasonally present (particularly between March and July) during their annual migration to and from the aggregation area off Ningaloo Reef. Whale sharks are not considered to be particularly vulnerable to underwater noise, and they do not have a swim bladder (considered to increase the vulnerability of a fish to noise related impacts). Potential impacts to whale sharks from continuous noise is are expected to consist of no more than a short-term temporary displacement from noise sources while transiting the Operational Area. Given the IMMR activities noise sources are all higher in frequency (>2 kHz) they are mostly outside the range of fish hearing, (2-4 kHz) Demersal and pelagic fish species will be present in the Operational Area, including fish communities associated with the Continental Slope Demersal Fish Communities and Ancient Coastline at 125 m Depth KEFs. Impacts to fish are expected to be localised, of short duration, and restricted to behavioural responses such as avoidance of noise sources. ***Turtles*** Noise interference is listed as a key threat to threatened marine turtles identified as potentially occurring within the Operational Area. Turtles may occur in the Operational Area although the area does not contain any known significant foraging habitat (i.e. no emergent islands, reef habitat or shallow shoals/banks). A flatback turtle internesting buffer BIA overlaps the Operational Area. The BIA for flatback turtles have also been designated as habitat critical to the survival of the species in the Recovery Plan for Marine Turtles in Australia 2017–2027 (Commonwealth of Australia, 2017); however, these areas are likely to hold the same significance as the existing BIAs with slightly differing spatial areas. Turtles may exhibit behavioural responses when exposed to underwater noise, such as diving. IMMR related noise is not expected to result in behavioural response, injury or mortality of individuals, or any other lasting effect, as the source frequency of proposed equipment (2 -900 kHz) is well outside the known hearing frequency range of turtles (0.1 - 0.7 kHz).
Summary of Control Measures
• Maintaining helicopter separation from cetaceans as per EPBC Regulations 2000 Part 8 Division 8.3 (Regulation 8.07), which include the following measures: - Helicopters shall not operate lower than 1650 feet or within a horizontal radius of 500 m of a cetacean known to be present in the area, except for take-off and landing.

Routine and Non-Routine Discharges: Discharge of Hydrocarbons and Chemicals during Subsea Operations and Activities

Impacts Evaluation Summary													
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	***Marine Sediment***	***Water Quality***	***Air Quality (incl. Odour)***	***Ecosystems/Habitat***	***Species***	***Socio-Economic***	***Decision Type***	***Consequence/Impact***	***Likelihood***	***Risk Rating***	***ALARP Tools***	***Acceptability***
Discharge of subsea control fluids.		X	X		X			A	F	-	-	LCS GP PJ	Broadly Acceptable
Discharge of hydrocarbons remaining in subsea pipework and equipment as a result of subsea intervention works (including pigging).		X	X		X			A	E	-	-		
Discharge of chemicals remaining in subsea pipework and equipment or the use of chemicals for subsea IMMR activities.		X	X		X			A	F	-	-		
Discharge of minor fugitive hydrocarbons/chemicals from subsea equipment.			X					A	F	3	M		

Description of Source of Impact

Hydrocarbons and chemicals may be discharged as a result of planned routine and non-routine operations and activities for:

Operational discharges including:

- Discharge of subsea control fluids – HW443 subsea control fluid is used to control subsea and well-head valves remotely. Persephone wells utilize an open-loop system, designed to release control fluid from the subsea system.
- Potential non-routine subsea fluid discharges associated with subsea equipment losses/weeps.
- Potential discharge of minor fugitive hydrocarbons from subsea equipment (e.g. weeps / seeps / bubbles).

IMMR activities (nominal discharge) including:

- Discharge of residual hydrocarbons in subsea lines and equipment as a result of subsea IMMR and intervention activities (including pigging).
- Discharge of residual chemicals in subsea lines and equipment or the use of chemicals for subsea IMMR activities (including pigging).

Subsea Control Fluids

Subsea control fluid is used to control well-head valves remotely from the NRC. Control fluid is supplied to valves via an open-loop system, designed to release small quantities of control fluid during operation (e.g. upon valve actuation), up to ~2 m^3/day use across the subsea system. Subsea control fluid may also be discharged during IMMR activities (e.g. leak detection and SCM change outs).

Hydrocarbons

Typical hydrocarbon releases are associated with IMMR activities. IMMR activities may also result in small gas releases associated with isolation testing and breaking containment. Risk management processes are applied during activity planning to control IMMR activity potential impacts and demonstrate ALARP through the use of techniques such as flushing. This process also includes an assessment to ensure the activity is undertaken in compliance with this EP.

Chemicals

Chemicals may be introduced into subsea infrastructure and the production stream, either as process or non-process chemicals (e.g. corrosion inhibitors, biocides, scale inhibitors, etc.). Chemicals flow through the production process, with residual chemicals discharged as a component of the PW discharged overboard.

Chemicals may also be introduced into subsea infrastructure during IMMR activities. These chemicals are used and discharged intermittently in small volumes. Small quantities of chemicals may remain in the flushed infrastructure, which may be released to the environment after disconnection.

The use of operational chemicals is restricted to that needed to complete a required task. All operational (process and non-process) chemicals are selected in accordance with the requirements of the chemical selection process.

Impact Assessment

There is potential for localised water column impact and adverse effects on marine biota as a result of planned routine and non-routine hydrocarbon and chemical discharges. However, planned discharge volumes of hydrocarbons and chemicals are negligible for routine discharges, highly infrequent for non-routine discharges, and are minimised as far as practicable via flushing of the lines back to the facility. Discharge locations are normally associated with subsea valves (subsea control fluid) or at disconnection points in subsea infrastructure.

Subsea Control Fluids

Subsea control fluids are selected in conformance with the chemical selection process.

The subsea control fluid used in Persephone subsea system is Oceanic HW443, which is water-based and has an OCNS rating of D with a substitution warning. The substitution warning is a result of the fluorescein dye which is approximately 150 ppm within the product. The dye is used to support leak detection and subsea IMMR troubleshooting. The product is non-toxic and does not have a potential to bioaccumulate.

Subsea control fluids are discharged from subsea valves at or near the seabed in relatively small volumes. Once released, control fluids are expected to mix rapidly in the water column and become diluted. Impacts from the release of subsea control fluids are considered to be localised to the immediate vicinity of the release location with no lasting effect, based on:

- the relatively small volumes of discharges
- the low sensitivity of the receiving environment
- the rapid dilution of the release.

Hydrocarbons

The small quantities of hydrocarbons discharged during pipeline pigging operations, or that may be released during IMMR activities that break containment of isolated subsea infrastructure are buoyant and float upwards towards the surface. Given the water depth, pressure, and the small volumes released, these hydrocarbons are not expected to reach the sea surface. Rather, the release disperses and dissolves within the water column. While recognising the potential ecotoxicity and physical effects of released hydrocarbons, the low release volumes, dispersion and dissolution is expected to result in hydrocarbon contamination rapidly decreasing to background levels. As such, impacts from routine and non-routine releases of hydrocarbons from IMMR activities are assessed as being highly localised with slight, short term impacts. Given the highly infrequent nature of export pipeline pigging activities and low release volumes, impacts from pipeline pigging, are assessed as short term and localised.

Chemicals

Chemicals introduced into subsea infrastructure during IMMR activities, including pigging, may be released. These releases would be intermittent and small volumes. Any release of chemicals from routine and non-routine discharges will be localised to the immediate vicinity of the release location, and have no lasting environmental effects, based on:

- the low potential for toxicity and bioaccumulation
- the relatively small volumes of discharges
- the low sensitivity of the receiving environment
- the rapid dilution of the release.

Values and Sensitivities

KEFs

There is one KEF which overlaps the Operational Area, Ancient coastline at 125 m depth contour. The Ancient coastline at 125 m depth contour overlap the Facility Operational Area and a small section of the Export Trunklines Operational Area. No significant escarpments, species of conservation significance, emergent features or areas of high biological productivity characteristically associated with the Ancient coastline at 125 m KEF have been observed in the Operational Area. Therefore, potential impacts to these regional-scale KEFs are expected to be negligible.

Summary of Control Measures

- Chemical Selection and Assessment Environment Guideline:
  - Where Gold/Silver/E/D OCNS rating (and no OCNS substitution or product warning), chemicals are selected, no further control required

  - If chemicals with a different OCNS rating, sub-warning or non- CNS rated chemicals are required, chemicals will be assessed in accordance with the procedure prior to use
- Subsea infrastructure flushed where practicable during IMMR disconnection activities to reduce volume/ concentration of hydrocarbons released to the environment
- Monitoring subsea control fluid use, investigating material discrepancies to support identification of potential integrity failures.

Routine and Non-Routine Discharges: Produced Water

Impacts Evaluation Summary														
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/ Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Discharge of produced water (PW) from riser platform.		X	X		X	X		B	E	-	-	LCS GP PJ RBA CV SV	Broadly Acceptable

Description of Source of Impact
Produced formation water is brought to the surface from the reservoir, and water is separated out from the hydrocarbon components during the production process before being discharged to the marine environment. Produced water (PW) consists of formation water (derived from a water reservoir below the hydrocarbon formation) or condensed water (water vapour present within gas/condensate which condenses when brought to the surface), or a combination of both. Separation of formation water from reservoir fluids is not 100% effective and separated formation water often contains small amounts of naturally occurring contaminants including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons, organic acids and phenols), inorganic compounds (e.g. soluble inorganic chemicals, dissolved metals, etc.) and residual process chemicals. In 2018, approximately 761 m^3/day of PW was discharged from NRC. PW discharge rates are expected to increase as the field ages. The maximum daily discharge is 1,900 m^3/day (integrity limit); however, based on historical discharge rates actual discharge rates are expected to be much lower. Note that if no PW is discharged; this impact and associated requirements would cease. Potential environmental impacts of discharged PW include changes in water quality, sediment quality and biota potentially reducing ecosystem integrity.

Monitoring and Management Framework

This section describes the monitoring and management framework which Woodside has developed to support the monitoring of PW discharges from offshore assets. In the absence of Commonwealth guidelines, the *State Waters Technical Guidance: Protecting the Q*uality of Western Australia's marine *environment* (EPA 2016) has been considered and is consistent with the principles of the National Water Quality Management Strategy.

Environmental values are defined as particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and which require protection from the effects of pollution, waste discharges and deposits (Australian and New Zealand Environment Conservation Council (ANZECC)/Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000). The relevant environmental values considered are:

- Ecosystem integrity – maintaining ecosystem processes (primary production, food chains) and the quality of water, biota and sediment.
- Cultural and spiritual – in the absence of any specific environmental quality requirements for protection of this value, it is assumed that if water quality is managed to protect ecosystem integrity this value is achieved in line with the guideline.

The relationship between key elements of ecosystem integrity, indicators and relevant monitoring activities undertaken on a routine and non-routine basis are shown in **Figure 12-1**. As per EPA guideline (2016) key elements to maintain ecosystem integrity have been identified as water quality, sediment quality and biological indicators (biota). By limiting the changes to these key elements to an acceptable level there is high confidence ecosystem integrity is maintained. For each element an indicator has been identified and monitoring designed to identify change. Monitoring change in water quality and sediment quality (at representative facilities) as well as investigating potential toxicity via WET testing and implementing management to maintain acceptable level of change is standard industry practice in Commonwealth and State waters. The relevant indicator to understand change in key elements and, therefore, potential for impact to ecosystem integrity, are physio-chemical stressors, toxicants in water, biological indicators and toxicants in sediment. A number of trigger values for each indicator have been defined and are monitored to detect change. Trigger values serve as an early warning that potential changes beyond the acceptable limits may occur. The acceptable limits of change are no impacts from PW beyond the approved mixing zone: To determine if acceptable limits have been exceeded routine monitoring of trigger values is undertaken. An approved mixing zone protects 99% of species, as calculated using the Warne et al (2018) statistical distribution methodology on the results of direct toxicity assessment using sub-lethal chronic endpoints. The protection of 99% of species maintains a high level of ecological protection and represents no detectable change from natural variation (as per ANZECC/ARMCANZ (2018);

The approved mixing zone boundary for NRC is 300 m. The justification for these limits of change being 'acceptable' is provided in the impact assessment section below.

Operational Monitoring

OIW monitoring is undertaken via an online analyser or manual sampling when the analyser is not available. Online analyser information is sent via transmitter instantaneously and reported to the control system (DCS) and is also captured within the process historian database (PHD). The DCS facilitates visibility in the control room, for manual or automated process control changes to be made, and/or annunciate alarms (e.g. high oil in water specification). PHD information is available onshore for analysis and trending. The results of manual sampling while the analyser is not available, are stored in a spreadsheet contained on the NRC server.

Routine Monitoring

The monitoring and management framework is implemented in accordance with the Offshore Marine Discharges Adaptive Management Plan (OMDAMP). The OMDAMP details trigger values, routine monitoring assessment against trigger values, analytical methods, and actions when a trigger value is exceeded.

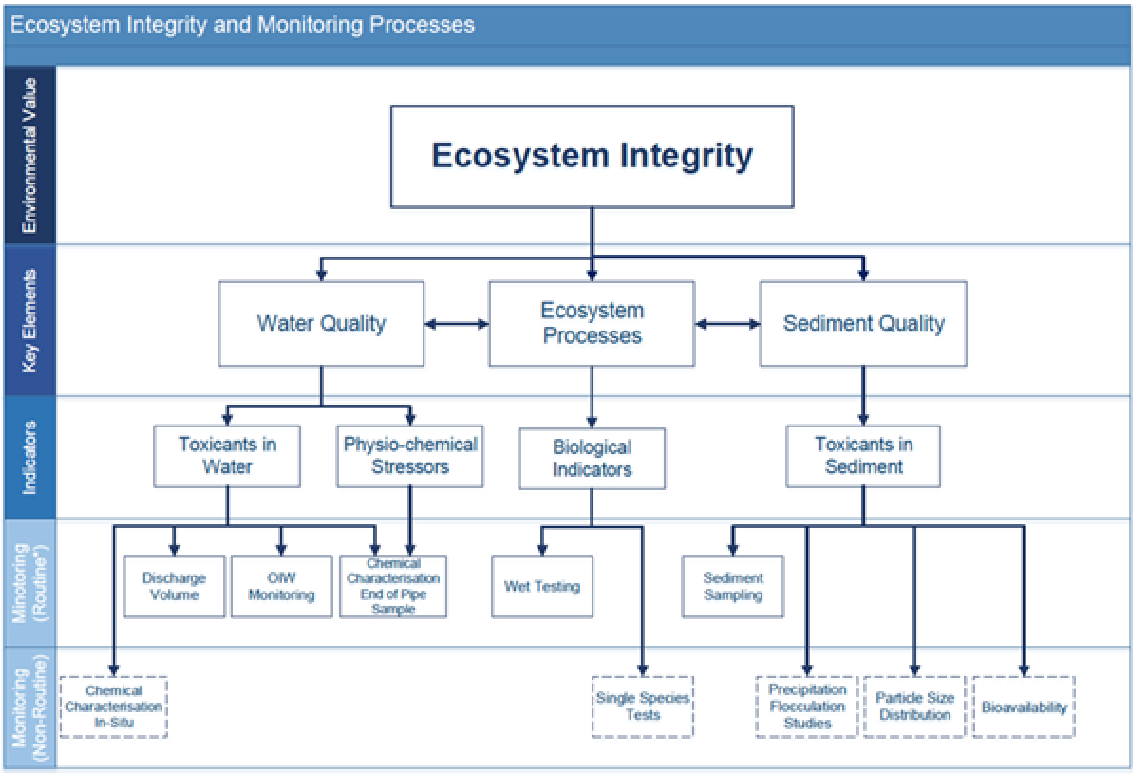

Figure 12-1: Ecosystem integrity and monitoring

The trigger values are applied through a risk-based approach that is intended to capture uncertainty around the level of impact, by staging monitoring and management responses according to the degree of risk to ecosystem integrity. The approach provides a level of confidence that management responses are not triggered too early (i.e. when there is no actual impact), or too late after significant or irreversible damage to the surrounding ecosystem (EPA 2016). Routine monitoring applicable to the facility, to compare against trigger values, is described in **Table 12-10**. Unacceptable changes in water quality and raw PW toxicity are able to be detected early and can indicate the potential for an impact prior to an impact occurring.

WET testing confirms if there is a potential for impact on biota. It is not appropriate to monitor for changes in species composition, diversity etc. as there are limited receptors in the approved mixing zone (a surface buoyant plume) and such changes may be detected after an impact occurs and therefore are not considered appropriate for early detection. PW samples should represent normal operations and be undertaken during periods of normal production at the facility. Where practicable, samples are taken at a time when all PW-producing wells are online (or as many as reasonably possible).

The WET tests are undertaken on a broad range of taxa of ecological relevance for which accepted standard test protocols are well-established. WET tests are mainly focused on the early life stages of test organisms, when organisms are typically at their most sensitive to contaminants are designed to represent local trophic level receptors. For the WET testing, a range of tropical and temperate Australian marine species were selected based on their ecological relevance, known sensitivity to contaminants, availability of robust test protocols, and known reproducibility and sensitivity as test species. The dilutions required to protect 99% of species, is calculated using the Warne et al (2018) methodology. The protection of 99% of species maintains a high level of ecological protection at the boundary of the approved mixing zone.

Table 12-10: Trigger values used during routine monitoring

Parameter	Trigger Value Summary	Frequency*
Chemical characterisation: end of pipe sample – physio chemical and toxicants	Results that are predicted to be higher than the 99% species protection guideline value at approved mixing zone boundary and are above the results from the earlier toxicity year[1] or above the toxicity year when no guideline was available.	Annual, timed to consider if sample is representative.
WET testing[1]	The 99% species protection safe dilutions derived from WET testing species sensitivity distributions are not predicted to be achieved at the boundary of approved mixing zone and are higher than previous years.	Three yearly. Conducted in parallel with annual chemical characterisation where feasible.
Review of continuous operational monitoring results	Increases in the average monthly OIW concentration by 5 mg/L for more than six consecutive months or by 10 mg/L for two consecutive months.	Monthly

Note:

[1] *Earlier toxicity year means the year in which the most recent WET test occurred.*

[2] *Non-routine monitoring is described below under impact assessment.*

If a trigger value is met, it triggers uncertainty around whether the environmental value is being protected, and further investigation is required (**Figure 12-2**).

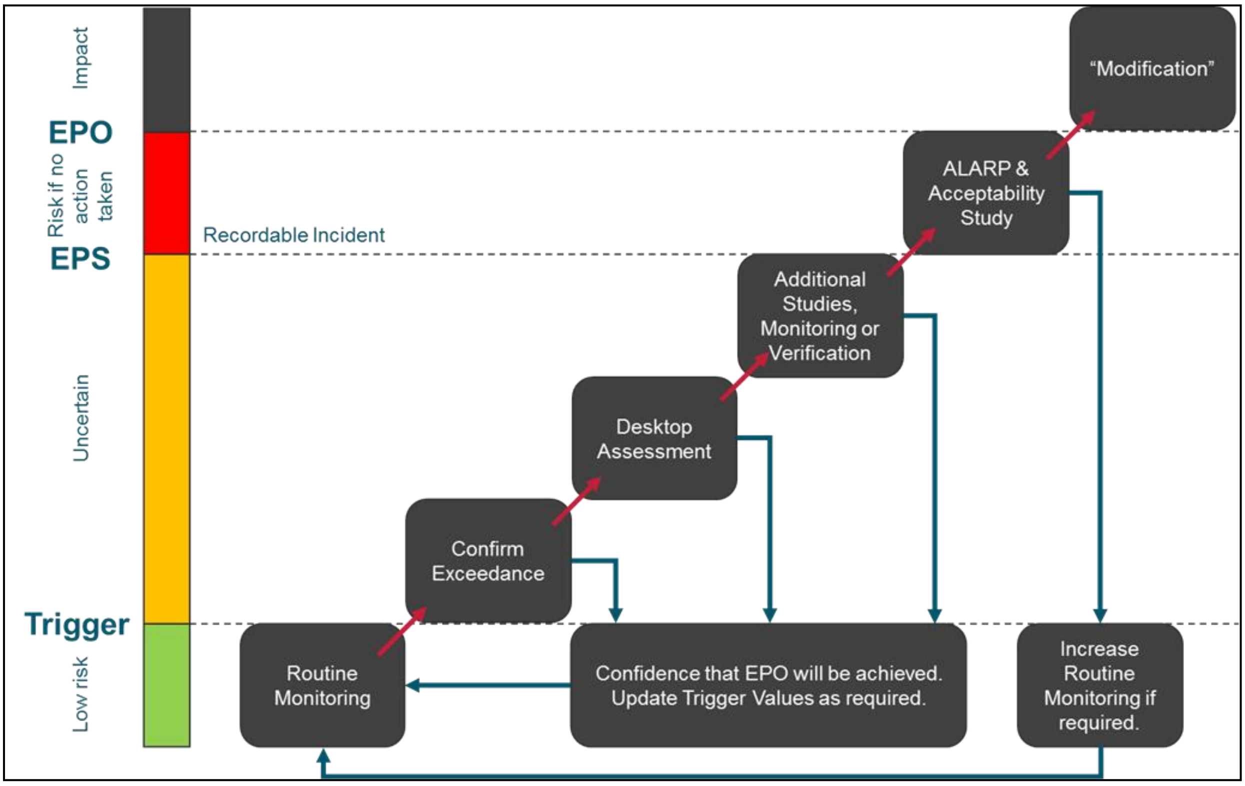

Figure 12-2: Routine monitoring and adaptive management framework for produced water

Further Investigations

Detectable exceedances in trigger values may occur without impacting ecosystem integrity. To provide confidence that ecosystem integrity has been maintained, further investigation is required in the form of a desktop study to initially assess the exceedance in the context of available data (multiple lines of evidence) and confirm if there is potential for impact to the environmental value. A desktop assessment is necessary before undertaking any additional infield monitoring. This ensures monitoring programs are designed and implemented to provide robust findings based on good survey design.

A range of methods can be used to detect trigger value exceedances (e.g. relative percentage difference, control charts, multivariate analysis, etc.), depending on the dataset available. An appropriate method is selected as described in the OMDAMP due to the variable nature of environmental data. If critical data are not available, the desktop study identifies potential data gaps and may recommend additional non-routine studies and/or monitoring to ensure the assessment is appropriately undertaken. The purpose of the further investigations is to provide certainty that the EPS has been achieved, if a trigger value has been exceeded. The key investigation steps are described below:

1. **Confirm the trigger value has been exceeded** – Review quality assurance and quality control, methodology and possible sources of contamination to determine if the results are reliable, or if any factors have occurred that may compromise the integrity of the monitoring or data.
2. **Complete a desktop assessment to understand whether the EPS is at risk** – If a trigger value is confirmed to be exceeded, multiple lines of evidence are considered including historical and current data from routine and non-routine monitoring and studies. This assessment shall consider whether there is adequate evidence to demonstrate that acceptability criteria have been met and ecological integrity is not at risk (EPS not breached). If the desktop assessment determines the existing body of evidence is insufficient, it shall outline what additional monitoring or studies are required. The desktop assessment is required before undertaking all additional infield monitoring. It ensures monitoring programs are designed and implemented to provide robust findings based on valid survey design. Potential additional monitoring/studies may include but are not limited to:

- single species test (collected annually in parallel with routine chemical characterisation should further investigation be required)
- dilution modelling and/or studies
- settling velocity analysis
- metal bioavailability
- scanning electron microscopy and particle size distribution analyses
- in-situ water quality chemical characterisation
- routine monitoring activities may be required ahead of schedule; additional monitoring not listed may be undertaken as appropriate. Field monitoring (routine and non-routine) is undertaken in accordance with a plan that details timing, locations and objectives of monitoring.

3. **Conduct additional studies to confirm the EPS is not at risk** – Monitoring results provide additional lines of evidence to determine whether there is a risk to ecosystem integrity due to unacceptable changes in water quality, sediment, or biological indicators. Given the significant health, safety and technical risks, monitoring of the receiving environment is typically only considered when all other sources of evidence are insufficient to demonstrate that ecological integrity is not at risk. The OMDAMP provides detailed guidance on the steps and actions to be undertaken if a trigger value is exceeded, and this may include additional non-routine monitoring to verify that ecological integrity is maintained.

If environmental impact is deemed to be within acceptable limits of change, the desktop assessment may consider a review of trigger values to ensure they are appropriate. If the environmental impact is deemed to be outside of acceptable limits of change, an ALARP/Acceptability study is required to determine what additional controls can be implemented to ensure the impacts are acceptable.

ALARP/Acceptability Study

An ALARP/Acceptability study is conducted once it has been determined, as a result of further investigations, that there is potential for an impact which exceeds the acceptable limits of change.

The ALARP/Acceptability study shall be conducted in accordance with the ALARP Demonstration Procedure (Woodside Reference WM1040PF9258835), to determine additional controls that may be necessary to reduce the potential impacts. Additional controls may include technology or process upgrades or reservoir management. Woodside implements the additional controls identified in the ALARP/Acceptability study, which are required to give confidence that the acceptable limits on environmental impact can be achieved. Field validation of model assumptions, and additional monitoring to assess whether impacts have been realised, is considered.

Impact Assessment

Potential impacts of PW discharge include:

- changes to water quality
- toxicity to biota
- changes to sediment quality.

In order to understand potential impacts from PW discharges, Woodside has undertaken a suite of comprehensive in-situ testing and sampling related to PW discharges representing long-term operational periods from its offshore production facilities. The details of this testing and resultant understanding of potential environmental impacts are outlined below.

Potential Impacts to Water Quality

PW is discharged from the riser platform either directly overboard above the water (17 m above LAT) or via the drain sump caisson below the water line (40 m below LAT). The plume initially plunges and then rises to the surface as positively buoyant plume in both scenarios. Potential impacts to water quality have been assessed through chemical characterisation of PW and potential discharge volumes.

Chemical Characterisation of PW (Physio-chemical Parameters and Toxicants)

Monitoring indicates the approved mixing zone has not been exceeded historically and provides high confidence that impacts from PW discharge are highly localised and pose negligible effects to environmental receptors. Samples of undiluted PW collected annually from the end of pipe between 2011 to 2018 were analysed for key physio-chemical parameters and toxicants. In most cases, results are below trigger values, or similar to the results of chemical characterisation when the previous year's WET testing was undertaken (i.e. previous toxicity year).

Four metals, BTEX and phenols were sometimes present at levels above the ANZECC/ARMCANZ (2000a) guideline values at the end of the pipe. To achieve the 99% species protection guideline values, the highest dilution required was 500 for 2,4-Dimethylphenol. Modelling predicts 2474 and 6044 dilutions were achieved 200 m from discharge point at the maximum discharge rate (1,900 m^3/day) and 2017 average discharge rate (761 m^3/day) respectively. Routine chemical characterisation has indicated a stable discharge with no additional non routine monitoring triggered.

There is potential for slight, localised decrease in water quality at the discharge location within the mixing zone and adverse effects on marine biota. Within the approved mixing zone impacts to pelagic fish are expected to be limited to avoidance of the localised area of the plume and short-term, localised decline in planktonic organisms in the immediate vicinity of the discharge plume.

Discharge Volumes

The average daily volume of PW discharged from the facility shown in **Figure 12-3** is lower than the maximum capacity of the PW system on the NRC that was modelled (1,900 m^3/day). Future discharges are expected to increase as the fields age based on historical discharge rates and Persephone wells cutting water (expected mid 2019 – 2022).

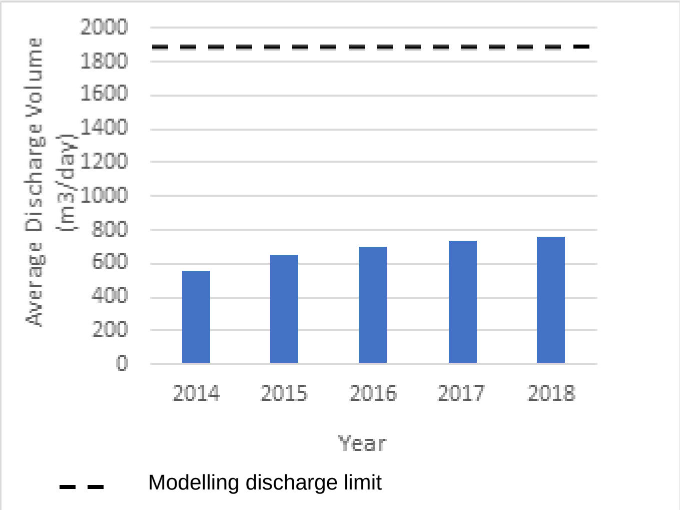

Figure 12-3: Historical average daily PW discharge volumes

Potential Impacts to Biological Indicators

Most treated PW has low to moderate toxicity (Neff et al. 2011), with actual toxicity of discharge dependant on the chemical constituents of the PW and any added process chemicals, the level of treatment and dilution with condensed water prior to release, and the dilution of the discharge as it mixes with sea water. Most hydrocarbons in PW are considered non-specific narcotic toxins with additive toxicities; therefore, the toxicity of a PW, in part, depends on the total concentration and range of bioavailable hydrocarbons (Neff 2002). Potential impacts of PW to biota have been assessed through WET testing and dilution modelling to verify the approved mixing zone is being achieved.

WET Testing

WET testing has been undertaken to allow for interactions between toxicants and consider toxicants which cannot readily be measured or are not known to be present in the sample. Routine WET testing was completed as required by the previous revision of the EP in 2017, 2014 and 2011 (**Table 12-11**). The number of dilutions required to achieve 99% species protection safe dilutions increased in 2017 compared to the previous two years of testing. This increase is likely driven by poor fit of the single species distribution model at the low concentration range, however increase was determined not significant different using control charts.

Table 12-11: PC99 concentrations and safe dilutions

Species Protection Level	Predicted No Effect Concentrations (PNEC) concentrations		
PCx	***2011***	***2014***	***2017***
PC99 (50)	0.12 (1 in 830)	0.21 (1 in 480)	0.032 (1 in 3,130)

Determination of Approved Mixing Zone

To determine the potential impact of the PW to the marine environment, modelling has been conducted to predict the distance at which 99% species protection safe dilutions are achieved, using the most recent WET testing results available at the time to reflect the current potential toxicity (**Table 12-11**). The latest modelling study was carried out in 2018 and informs this impact assessment (Jacobs 2018).

Model simulations of dilutions were undertaken for three main seasons prevalent on the NWS, based on measured current and wind data. Ocean current data was collected at multiple depths through the water column at NRC. As the modelling of ocean current speed and direction varies substantially within each season, the full current records were analysed to select periods typical of the three seasons on the NWS but erring on the side of low current speeds to give conservative model results (Jacobs 2016).

Further to these hydrodynamic inputs, the Rob Phillips Consulting produced formation water discharge model was validated in 2006 using the results from a dye dispersion study (Oceanic Field Services 2006) undertaken from the North Rankin A platform. The predicted plume dilutions reasonably matched those measured.

The results from the WET testing undertaken in 2017 were used to develop PNEC values that were inputs to the model. The four-day averaged PW concentrations provide estimates of the mean in-situ exposure concentration. The four-day PEC value is used to determine the PEC/PNEC ratios and the distances from the discharge point at which 99% species protection safe dilutions (PC99) are achieved. Based on the 2017 discharge rate (761 m^3/day) and maximum discharge rate (1,900 m^3/day). The modelling shows a surface buoyant plume that is readily diluted to 99% species protection safe dilution within 250 m of the discharge location under worst-case conditions at actual and maximum discharge rates.

The approved mixing zone boundary was derived using 2017 WET testing results as the worst case historically (**Table 12-11**) with a 50 m buffer to allow for increased formation water once Persephone wells cuts water. Therefore, for operational flexibility, it is proposed to maintain a 300 m approved mixing zone to reflect 99% species protection safe dilutions at maximum expected discharge 1,900 m^3/day.

Impacts to Australian Marine Parks, KEFs and Biologically Important Areas

NRC sits within a KEF, the Ancient Coastline 125 m Depth Contour but as PW forms a buoyant plume which does not reach the KEF depth, no contact and therefore no change in water quality at the KEF is expected from the plume. Glomar Shoals and the Montebello Marine Park are approximately 45 km and 57 km from the discharge point respectively.

Given the distance from the discharge source no impacts to the Montebello Marine Park are anticipated. Routine monitoring (end of pipe chemical characterisation and WET testing) detects changes at the approved mixing zone boundary. If trigger values are predicted to be exceeded at this distance further investigation is required as described above. This may include a review of single species toxicity test results, additional WET testing or insitu monitoring. If trigger values are not exceeded there can be high confidence that maximum ecological protection is achieved by the Marine Park.

The approved mixing zone is within the BIA pygmy blue whale migration corridor (northern migration April to August; southern migration October to January) from Indonesian Waters to southwest Australia and BIA foraging for whale sharks along the 200 m isobath, with seasonally high use (April–June). The pygmy blue whale migration is thought to follow deep oceanic routes (DEWHA, 2008). In the NWMR, pygmy blue whales migrate along the 500 m to 1000 m depth contour on the continental slope where they are likely to opportunistically feed on ephemeral krill aggregations (DEWHA, 2008). Given the water depths in the approved mixing zone are approximately 125 m and that PW forms a surface buoyant plume, impacts are not expected to this value. This is assessment is consistent with the blue whale recovery that also identifies chronic chemical pollution (toxins) as unlikely to impacts pygmy blue whales and a low risk (DoE, 2015. The 200 m isobath is located about 27 km outside the approved mixing zone. Given the localised area of impact and that whale sharks are transiting the area, no impacts are expected.

<u>Bioaccumulation</u>

Bioaccumulation refers to the amount of a substance taken up by an organism through all routes of exposure (water, diet, inhalation, epidermal). The Bioaccumulation Factor is the ratio of the steady-state tissue concentration and the steady-state environmental concentration (assuming uptake is from food and water). The test developed to measure the ability of a substance to bioaccumulate, namely, the octanol-water partition (pow), is based on the preferential partitioning of lipophilic organic compounds into the octanol phase. Partitioning into octanol can be correlated with the attraction for such compounds to the fatty tissue (lipid) of organisms.

The average concentration of BTEX in PW discharged from the facility is approximately 31 mg/L (Jacobs, 2018) Bioaccumulation of BTEX compounds has been observed to occur in the laboratory, but only at concentrations far in excess of that discharged from the NRC (for example refer to Berry 1980); hence, it is unlikely BTEX would bioaccumulate at the exposure concentrations that may be experienced by biota around the NRC.

In contrast to BTEX compounds, PAH compounds have high log pow values indicative of the potential for bioaccumulation (Vik et al. 1996). Neff and Sauer (1996) reviewed the available literature for laboratory and field studies investigating the bioaccumulation of PAHs. The bioaccumulation values for PAHs in marine organisms collected near PW discharges in the Gulf of Mexico, reported by Neff and Saur (1996), indicate that the highest bioaccumulation factor were in the tissues of bivalve molluscs and the lowest in the muscle tissue of fish.

The most comprehensive field study assessing bioaccumulation of hydrocarbons and metals from PW discharged into offshore waters is that by Neff et al. (2011). At the request of the U.S. Environmental Protection Agency (USEPA), the Gulf of Mexico Offshore Operators Committee sponsored a study of bioconcentration of selected PW chemicals by marine invertebrates and fish around several offshore production facilities, discharging more than 731 m^3 per day of PW to outer continental shelf waters of the western Gulf of Mexico (by comparison, NRC discharges are currently around 761 m^3/day). The target chemicals identified by USEPA included five metals (As, Cd, Hg, 226Ra and 228Ra), three volatile Monocyclic Aromatic Hydrocarbons (MAH), benzene, toluene, and ethylbenzene, and four semi-volatile organic chemicals (SVOC), phenol, fluorene, benzo(a)pyrene, and di (2-ethylhexyl) phthalate (DEHP). Additional MAH (m-, p-, and o-xylenes) and a full suite of 40 parent and alkyl-PAH and dibenzothiophenes were also analysed by Neff et al. (2011) in PW, ambient water and tissues at some platforms.

Concentrations of MAH, PAH and phenol as determined by Neff et al. were orders of magnitude higher in PW than in ambient seawater. There was no evidence of MAH or phenol being bioconcentrated. All MAH and phenol were either not detected (> 95% of tissue samples) or were present at trace concentrations in all invertebrate and fish tissue samples. Concentrations of several petrogenic PAHs, including alkyl naphthalene's and alkyl dibenzothiophenes, were slighter, but significantly higher in some bivalve molluscs but not fish, from discharging than from non-discharging platforms. These PAH could have been derived from PW discharges or from tar balls or small fuel spills. Concentrations of individual and total PAH in mollusc, crab and fish tissues were well below concentrations that might be harmful to the marine animals or to humans who might collect them for food at offshore platforms (Neff et. al. 2011).

Bioaccumulation is therefore unlikely to result in increased levels of BTEX in biota surrounding NRC; however, there may be an elevation in PAH levels.), The results from Neff et al. (2011) can be used to infer the very low potential for adverse bioaccumulation effects to marine organisms, or to humans, if they were to consume any affected fish, molluscs or crabs found on upper near-surface legs of the facility. The potential environmental impact associated with bioaccumulation of PW constituents in the water column and in the sediments, is considered to be very low, and limited to a potential localised effect on a small number of non-threatened species in waters immediately surrounding the facility as described below. Potential health risks are unlikely as a result of negligible exposure: the PSV prohibits fishing from or near the riser platform as there is very little or no activity within the Operational Area. The findings of the Routine Sediment Sampling/Analysis and Water Quality Monitoring field studies completed in 2015 at GWA (BMT Oceanica, 2015) validated the conclusion that states "the potential environmental impact associated with bioaccumulation of PW constituents in the water column and in the sediments, is considered to be very low and limited to a potential localised effect on a small number of non-threated species in waters immediately surrounding each facility". Given the nature of the PW discharge from the riser platform, the potential for bioaccumulation of PW contaminants (in particular BTEX) is considered to be highly localised with no lasting effect.

Potential Impacts to Sediment Quality

Potential impacts to sediment quality have been assessed through sediment surveys at nearby facilities and supported by the results of flocculation studies and potential for impacts to water quality.

Toxicants in sediments

Accumulation of PW contaminants in sediments depends primarily on the volume/concentration of particulates in PW discharges or constituents that sorb onto seawater particulates, the area over which those particulates could settle onto the seabed (dominated by current speeds and water depths), and the re-suspension, bioturbation and microbial decay of those particulates in the water column and on the seabed. As described above the potential for PW to impact sediment, based on chemical characterisation, is unlikely due to the concentrations observed.

The plume is buoyant, due to lower salinity and/or higher temperature than surrounding seawater. Therefore, potential contaminants in the PW discharge may be introduced into sediments around the riser platform through precipitation of soluble contaminants and flocculation and sedimentation of the particles in the PW plume. Studies into potential sediment accumulation from PW discharge have been undertaken by Woodside, including analysis of a sample of PW from the facility (Jacobs 2016). The study found that the PW at NRC has very small amounts of solid material, with very little potential of settling out due to small particle sizes (100% particles <40 μm), and that it is unlikely to flocculate.

Dr Graeme Hubbert categorised particulate behaviour based on oceanographic experience and mathematical calculations using settling rates and resuspension velocities for various particle sizes. He determined that particles of a size 1 to 5 μm would never permanently settle out of the water column, and that particles from 5 to 40 μm would not permanently settle out of the water column, unless they were in very deep water (> 5000 m) or in areas where hydrodynamic conditions were very weak and did not continuously resuspend the particles. All particles in NRC PW were smaller than 40 μm (Jacobs 2016), therefore, have little chance of settling within the dynamic open ocean environment surrounding the facilities.

In 1991 and 2006 sediment sampling was conducted at NRA to investigate impacts of historical water based and non-water-based drilling muds on sediment quality (SKM 2006). The 2006 sampling program found historical contamination with elevated levels of TPH, arsenic, barium, lead, mercury and zinc. 100 m away from the platform, which decreased with distance. Levels of hydrocarbons had greatly reduced in the sediments since 1991. Opportunistic sediment sampling was also undertaken by Jacobs in 2013 as part of the Persephone development. Findings were consistent with sampling completed in 1991 and 2006 with elevated levels of barium, mercury and lead found within approximately 100 m. However elevated levels of TPH and arsenic were no longer observed. The historical contamination at NRC makes it difficult to ascertain if PW is contributing to elevated levels of lead, mercury and zinc but given the concentration are lower than or similar to historical data and the concentrations observed in PW chemical characterisation (lead is consistently below the limit of detection) it is highly unlikely elevated levels are due to PW.

Historically potential for PW to impacts to sediment quality have been managed by comparing the NRC relative to other nearby facilities name GWA which also has historical contamination. It was considered impacts are likely to be detected at facilities with a greater volume of PW with a higher concentration and volume of toxicants in similar water depth and currents. However, to investigate uncertainty a non-routine sediment sampling event is to be conducted to ascertain if impacts to sediment quality outside of the approved mixing zone have occurred prior to 2022 in accordance with the previously approved EP. Toxicant concentrations in sediments are influenced by natural variability in sediment granulometry and mineralogical composition therefore a number of replicates are collected at each site. The mean concentrations are compared against national guidelines to ascertain if the trigger (**Table 12-12**) has been exceeded Should the trigger value be exceeded further investigations as described above and managed via the OMDAMP are implemented. In this instance it is known that elevated levels are likely up to 100 m from the platform due to historic drill muds therefore careful investigation will be required identify if contamination is consistent with PW discharge or historical. If there is potential for PW to impact ecosystem integrity; an ALARP/Acceptability study is required to determine what additional controls can be implemented to ensure the impacts are not realised.

A sampling plan to demonstrate compliance with the approved mixing zone boundary will be developed for the sediment survey. The sampling plan outlines and justifies sampling locations and when concentration and bioavailability testing occur.

Table 12-12: Trigger value used during non-routine sediment monitoring

Parameter	Trigger Value
Sediment sampling	Results that are higher than the low trigger guideline values[1], detailed in the national guidelines, at the boundary of approved mixing zone.

[1] *Where no guideline is specified for a contaminant of concern, derive a value on the basis of natural background (reference) concentration multiplied by an appropriate factor (2–3) as described by the ANZECC guidelines*

Summary of Control Measures

- Chemical Selection and Assessment Environment Guideline:
  - Where Gold/Silver/E/D OCNS rating (and no OCNS substitution or product warning), chemicals are selected, no further control required
  - If chemicals with a different OCNS rating, sub-warning or non- CNS rated chemicals are required, chemicals will be assessed in accordance with the procedure prior to use
- Monitoring and manage OIW concentrations in accordance with PARCOM 1997/16 Annex 3 methodology
- Continuous reservoir management, i.e. changing the relative contribution to facility production of each well to maintain OIW concentrations below Performance Standard
- Implementation of the Monitoring and Management Framework for Produced Water
- Online monitoring and/or procedural controls in place to monitor and control PW OIW concentrations and prevent discharge of PW with high OIW concentrations. Process performance monitored by OIW concentration analyser. Conduct manual sampling on a 6-hourly basis when online analyser is unavailable where safe and practicable to do so
- The online analyser is calibrated with a manual sample analyser in accordance with Laboratory Procedure.

Routine and Non-Routine Marine Wastewater Discharges: Discharges from the Utility Systems and Drains

Impacts Evaluation Summary														
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**		**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Discharge of sewage, grey water and putrescible waste from vessels and NRC to the marine environment.			X					A	F	Cumulative E	-	-	LCS GP PJ	Broadly acceptable
Discharge of deck, bilge and drain water from vessels and NRC to the marine environment.			X					A	F		-	-		
Discharge of reverse osmosis brine from vessels and NRC to the marine environment.			X					A	F		-	-		
Discharge of cooling water from vessels and NRC to the marine environment.			X					A	F		-	-		

Description of Source of Impact

Sewage, Putrescible Waste and Grey Water

Sewage and grey-water is treated onboard the NRC by maceration and then disposed to ocean via the sewage caisson. Putrescible wastes, such as food scraps, are also discharged via the sewage caisson from the NRC after being ground to < 25 mm diameter.

Vessels may also discharge sewage, grey water and putrescible wastes. Sewage onboard vessels is routinely treated (either via a sewage treatment plant (STP) or macerator) prior to discharge.

Sewage discharged from the NRC is macerated prior to discharge. Treatment systems may require routine maintenance or repair during operations, which may require infrequent, short periods in which sewage is directly discharged overboard. The volume of sewage and grey-water generated is estimated to be in the order of 15 m^3 per day (based on an average volume of 75 L/person/day). The actual volume of discharge will vary depending on personnel levels on the NRC and vessels.

Drain Systems

Non-hazardous open drains, which collect from sources not containing hydrocarbons, diesel, lubricating or seal oils. The water collects in the non-hazardous open drain header and discharged directly to sea. The drainage collection from sources potentially containing diesel, lubricating oils are collected via a header system which feeds into the hazardous open drains caisson via a seal pot.

Hazardous open drains, which collect oily water from hazardous areas on the NRC, including wash down water and spillage of liquids on decks, equipment drip trays or bunded areas. The hazardous open drains collect in the hazardous open drains tanks for gravity separation. Residual oil is transferred to the ISO waste oil containers. The drains for both North Rankin A and B platforms flow to each open hazardous drains caisson for gravity separation. Accumulated oil in the caisson is pumped to waste oil tank and then to waste iso-containers.

Outfall from the North Rankin A hazardous open drains caisson is through is at the bottom of the caisson 23.5 meters below the minimum sea level. Outfall from the North Rankin B hazardous open drains caisson is at the bottom of the caisson 25 meters below the minimum sea level.

The hazardous closed drain system collects liquids from normally pressurised equipment prior to maintenance, and intermittent flow from other process equipment. The Drains sump caisson receives liquids from the LP closed drain system, the test separator, the skimmer vessel when in use and the HP flare KO liquids dump. The produced water header discharges to the drains sump caisson at an elevation of 15 meters which is well below the normal operating level of the oil layer (refer to section 5.6.5 PW risk description). The drain sump caisson discharges to sea at an elevation of 40 meters.

Chemicals used onboard the NRC platform may be introduced to the environment via the drains system, including;

- Deck washdown, maintenance drainage of treated water systems (e.g. tempered water), and other cleaning/flushing activities.
- Mandatory annual testing of the active fire deluge and foam system for safety requirements.
- Marine growth treatment of drain caissons.

Bilge Water

Vessels routinely generate and discharge relatively small volumes of bilge water. Bilge tanks receive fluids from many parts of the vessel, including machinery spaces. Bilge water can contain water, oil, detergents, solvents, chemicals, particles and other liquids, solids or chemicals. Vessels may also discharge drainage water from decks directly overboard or via deck drainage systems; deck drainage may also contain traces of chemicals. Water sources could include rainfall events and/or from deck activities such as cleaning/wash-down of equipment/decks.

Cooling Water

The seawater system is routinely used onboard the NRC to process cooling for seawater / tempered water heat exchangers and provide seawater to service water system via service water pumps, which is returned to the ocean via two caissons approximately 15 m below the water surface. Seawater used for cooling is dosed with sodium hypochlorite at approximately 2 ppm to inhibit marine growth. Seawater system discharge temperature and volumes are typically 45 °C and 15,200 m^3 per hour respectively.

Brine

The RO plant onboard the NRC is used to produce potable water, with the brine from the RO plant discharged to the marine environment at the NRA facility. Brine from the RO plant is generally 55-60 parts per thousand salts, with approximately 9.5 m^3 of brine produced per hour. Small quantities of anti-scaling and cleaning chemicals may also be discharged with the brine.

Impact Assessment

Sewage, Putrescible Waste and Grey Water

The potential environmental impact associated with ocean disposal of sewage, grey water and putrescible waste is eutrophication. Eutrophication occurs when the addition of nutrients, such as nitrates and phosphates, causes adverse changes to the ecosystem, such as oxygen depletion and phytoplankton blooms.

No significant impacts from the planned (routine and non-routine) discharges to the marine environment are anticipated, given the minor volumes involved and high level of dilution expected in the open water marine environment of the Operational Area.

Although the NWS Province is characterised as a low nutrient environment (DEWHA 2008), studies of adjacent shelf water have found the area to be “a highly productive ecosystem in which nutrients and organic matter are rapidly recycled” (Furnas and Mitchell 1999). The estimated daily loading from sewage and putrescible waste from vessels (up to 0.45 m^3 a person per day) is not significant in comparison to the daily turnover of nutrients in the area. Furthermore, vessels are typically moving when in the Operational Area, which facilitates the mixing of sewage, putrescible wastes and grey water from vessels

This is supported by infield monitoring undertaken around the nearby GWA platform (approximately 18 km from the Operational Area). A platform would typically have more personnel onboard and therefore discharge larger volumes of sewage and putrescible waste than a vessel. Monitoring at GWA indicated there was no detectable decrease in oxygen saturation, nutrients or increase in oxygen demand at the GWA platform (BMT Oceanica 2015a). In addition, monitoring of sewage discharge demonstrated that a 10 m^3 sewage discharge reduces to approximately 1% of its original concentration within 50 m of the discharge location (Woodside, 2008).

The impact of nutrients associated with discharge of sewage, grey-water and putrescible waste from the NRC and support vessels is considered localised with no lasting effect due to the small mass, relative to daily turnover, and the assimilative capacity of the receiving environment.

Drain and Bilge Water

The impacts of drainage can include a decline in water quality and may directly affect marine organisms, with impacts varying depending on volumes and type of contaminants. Drain water from the NRC may contain small quantities of hydrocarbons, and other chemicals such as detergents. Impacts from drainage water from the NRC are assessed as being highly localised and short-lasting.

Water foaming agents used in aqueous firefighting foam (AFFF), by nature of the surfactant properties by which it effectively extinguishes liquid fires, may be harmful to aquatic organisms within freshwater environments like ponds and streams. This surfactant effect is greatly diminished in the offshore environment (due to wave and wind action) and does not present the same risks to pelagic fish and other marine life. Nevertheless, the planned release of these materials is restricted to testing activities to ensure safe and effective operation of the system in an emergency.

Bilge and deck drainage from vessels is expected to mix rapidly in the marine environment upon discharge. Given the rapid mixing, relatively small typical bilge and deck drainage water, and expected low levels of potential contaminants, impacts from bilge and deck drainage water from vessels and the facility are assessed as highly localised with no lasting effect.

Cooling Water

The impacts of cooling water can include a decline in water quality and may directly affect marine organisms due to temperature changes, with impacts varying depending on volumes, temperature and type of contaminants. Cooling water from the NRC may contain small quantities of residual chlorine. Cooling water modelling was undertaken to assess potential temperature changes at typical discharge rates (15,180 m^3/hr) and at the maximum discharge rates (16,900 m^3/hr) with discharge temperatures varying from 34°C to 50°C (SKM,2008). During summer and winter, the thermal plume typically cooled to within 3°C of ambient temperature within 200 m. In transition season under certain conditions low flushing and water pooling around the discharge are observed. Under worst case conditions this can result in temperatures greater than 3°C above ambient temperature at 200 m for short periods. Results indicate temperatures cool to within 3°C of ambient temperature within 200 m of the caissons 97% of the time.

Electrochlorination is used to generate sodium hypochlorite in the cooling system. Sodium hypochlorite functions as a biocide in the cooling water system and is expected to readily dissociate and break down once discharged. A dosage rate of chlorine equivalent will be 2ppm leads to a discharge concentration of Total Residual Chlorine (TRC) in the cooling water of about 1ppm. Modelling of the total residual chlorine was undertaken for NRC (SKM) at TRC concentration of 1 ppm. In all scenarios the modelled concentrations were below the PNECs for acute and chronic effects at 200 m distance from the discharge. The modelling report also states that discharged TRC would need to be 2.7 ppm before the acute or chronic predicted no effect concentration is not reached at 200 m from the discharge source. NRC is dosed at 2 ppm in the procedures, once through the system and discharged it is expected this will be reduced to less than 1 ppm. Therefore, discharges are well below the 2.7 ppm within a 200 m mixing zone. Impacts from cooling water from the NRC are assessed as being highly localised and short-lasting.

Brine

Brine plumes may result in osmotic stress to marine biota that rely on gills or diffusion across cell membranes to maintain osmotic pressure within cells. Mobile fauna such as fish can move away from the brine plume; hence impacts are restricted to planktonic and sessile organisms. Once discharged into the marine environment, the brine plume is expected to sink due to its relatively high density. Sinking of the plume facilitates turbulent mixing, as do surface currents and waves. Monitoring of water in the mixing zone around the nearby GWA platform confirm salinity within the mixing zone was consistent with the surrounding environment (BMT Oceanica 2015); these results provide evidence that the RO brine plume is mixed rapidly. Impacts from RO brine discharge will have no lasting effects on the environment and are highly localised to the discharge location.

Cumulative Impacts

Given the activities that may be conducted during the Petroleum Activities Program, there is the potential for cumulative impacts from routine discharges of sewage, putrescible waste, grey water, bilge water or drain water, due to:

- periodic, repeated discharges at the same location (NRC) over the course of the Petroleum Activities Program
- cumulative discharges from differing point sources (NRC and vessels).

Given the nature of these routine discharges, the localised spatial extent of impacts and the well mixed receiving environment, the cumulative impacts from these discharges are expected to be localised, and not considered to result in impacts greater than slight, short-term impact. Given the highly localised nature of the impacts of routine discharges, no cumulative impacts from similar discharges from other production facilities or support vessels (e.g. GWA) are expected.

Summary of Control Measures

- Support vessels compliant with Marine Orders for safe vessel operations:
  - Marine Orders 91 (Oil)
  - Marine Orders 95 (Pollution prevention – Garbage)
  - Marine Orders 96 – (Pollution prevention – sewage)
- Chemical Selection and Assessment Environment Guideline:
  - Where Gold/Silver/E/D OCNS rating (and no OCNS substitution or product warning), chemicals are selected, no further control required
  - If chemicals with a different OCNS rating, sub-warning or non- CNS rated chemicals are required, chemicals will be assessed in accordance with the procedure prior to use
- Putrescible waste from NRC macerated prior to overboard discharge
- Sewage system macerator maintained
- Facility open hazardous drains systems integrity maintained, and open hazardous and closed drain caisson sump pumps available to support hydrocarbon recovery
- Maintain level instrumentation to monitor and support hydrocarbon level management in Open Hazardous and Closed Drain Caissons.

Routine and Non-Routine Atmospheric Emissions: Fuel Combustion, Flaring and Fugitives

Impacts Evaluation Summary														
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	***Marine Sediment***	***Water Quality***	***Air Quality (incl. Odour)***	***Ecosystems/Habitat***	***Species***	***Socio-Economic***	***Decision Type***	***Consequence/Impact***	***Likelihood***	***Risk Rating***	***ALARP Tools***	***Acceptability***
NRC internal combustion engines, operational flaring and fugitive emissions, and vessel emissions (including incinerators)				X				A	F	-	-	LCS GP PJ	Broadly Acceptable

Description of Source of Impact

Atmospheric emissions will be generated predominantly from the NRC during the Petroleum Activities Program. Sources include emissions from internal combustion engines (including all equipment and generators), flares, fugitives and process vents. Vessel emissions include those from internal combustion engines, fugitives and on-board incinerators. Emissions and combustion products typically include CO_2, water vapour, NO_x, SO_2, methane, refrigerant gases, particulates and Volatile Organic Compounds (VOCs).

Fuel Emissions: Internal Combustion Engines and Waste Incinerators

Fuel gas consumption for compression and power generation is the largest source of combustion emissions from the NRC. The largest users are the gas export compressors for each train and the four gas turbine generators that supply power to the facility.

Diesel is used for firewater pumps, emergency generators, cranes and back-up fuel for the turbine generators. In FY2017/2018, 179,950 t of fuel gas was used on the NRC, the combustion of which equated to the emission of 460,128 t of CO_2 equivalent. Diesel usage on the facility (excluding support vessels) in FY2017/18 was 615 t, the combustion of which equated to the emission of 1,996 t of CO_2 equivalent. Annual fuel gas and diesel usage is not expected to significantly increase over the period in which this EP is in force.

The forecast annual emissions from fuel combustion on the NRC is been estimated using emissions factors (as per National Pollutant Inventory Emission Estimation Techniques) and are presented in **Table 12-13**.

Incinerators may be used onboard vessels to dispose of flammable domestic wastes such as cardboard. Incinerators are typically used infrequently, with wastes generally segregated and transported to shore for disposal.

Table 12-13: Estimated annual emissions from fuel combustion at the NRC (excluding support vessels) (based on FY2017/18)

Emission Type	Metric	Estimated annual emissions from fuel gas combustion (tonnes)[1]	Estimated annual emissions from diesel combustion (tonnes)[2]	Estimated total annual emissions from fuel combustion (tonnes)
CO_2	Tonnes CO_2-e	458,968	1,986	460,954
CH_4	Tonnes CH_4-e	893	2.84	895,84
N_2O	Tonnes CO_2-e	268	5.68	273
CO_2 eq	CO_2 eq	460,128	1,996	462,124
NO_x	Tonnes	1,838	38.7	1,876
SO_x	Tonnes	0	0.012	0

CO	Tonnes	470	10.3	480

[1] Based on combustion of 63,600 tonnes of fuel gas during FY2017–18

[2] Based on combustion of 650 tonnes of diesel during FY2017–18.

Operational Flaring

Gas flaring has the potential to increase the volumes of greenhouse gases emitted to the atmosphere. Flaring also consumes natural gas, a non-renewable resource. Emissions and combustion products include CO_2, NO_x, SO_2, methane, particulates, and VOCs. Incomplete combustion under certain scenarios may also generate dark smoke.

The release of hydrocarbon gas to atmosphere by flaring is an essential practice, primarily for safety requirements. Operational flaring is comprised of two elements:

- Normal operational flaring associated with flare system purge and pilot, process flows and glycol regeneration.
- Non-routine flaring that may result from activities such as planned or unplanned shutdowns and ESD testing, production restarts, equipment outage/failures, subsea flowline depressurisation and well remediation activities.

During flaring, the burnt gas generates mainly water vapour and CO_2. It is estimated that between 17,000 and 23,000 tonnes of gas is flared per year (**Table 12-14**). Flaring volumes will vary as a result of production rates and non-routine activities, outages and shutdowns. The forecast annual atmospheric emissions from flaring have been estimated using the National Inventory Emissions Estimation Techniques.

Table 12-14: Estimated annual emissions from flaring at the NRC

Component	Metric	Estimated lower flaring emissions (tonnes)[1]	Estimated upper flaring emissions (tonnes)[2]
CO_2	Tonnes CO_2-e	45,900	62,100
CH_4	Tonnes CH_4-e	1,700	2,300
N_2O	Tonnes CO_2-e	510	690
CO_2eq	CO_2 eq (total)	48,110	65,900
NO_x	Tonnes	26	34.5
SO_x	Tonnes	0	0
CO	Tonnes	148	200

Reference: NPI EET Manual for Oil and Gas v2.0 2013, Table 8.

[1]Based on lower flare estimate (17,000 tonnes hydrocarbon)

[2]Based on upper flare estimate (23,000) tonnes hydrocarbon)

Non-routine Venting of Process Hydrocarbons via Flare System

During normal operations, hydrocarbon gas is flared via the HP and LP flare systems for both NRA and NRB. These systems are maintained to effectively combust hydrocarbons as a critical component for the safe operation of the NRC. In the unlikely event that the flares are extinguished or unavailable (such as following a major shutdown prior to system ramp-up), the hydrocarbon gas discharged via the flare system may initially not be combusted during the period required to purge the flare system and re-establish flare ignition. This may result in the short term (days) low-rate release of hydrocarbon gas to the atmosphere. Intermittent venting from the NRC represents only a minor source of atmospheric emissions and is not considered to pose a risk beyond the routine air emissions described in this section.

Fugitive Emissions

Fugitive emissions can occur from pressurised equipment, and are inherent in design, required for infrequent operational activities, or can be caused by unintentional equipment leaks. Sources can include valves, flanges, pump seals, compressor seals, relief valves, vents, sampling connections, process drains, open-ended lines, casing, tanks and other potential leakage sources from pressurised equipment. Fugitive emissions are quantified and reported as requirements set under the National Greenhouse and Energy Reporting scheme.

As much of the safe operation of the NRC relies on the effective containment of hydrocarbons, the volumes of routine and non-routine fugitive emissions are considered to be small. The DoEE's National Greenhouse and Energy Reporting (Measurement) Determination is applied for the estimation of greenhouse gas emissions by facilities in Australia, including from fugitive emissions. Using these estimation techniques, NRC reported 11 tonnes of gas lost through fugitive emissions in FY2017/2018. This equates to approximately 265 tonnes of CO_2 equivalents.

Discrete relatively small volumes of packed gases and charged systems including non-ozone depleting refrigerant gases are used across the NRC and vessels which have potential for small volume leaks (typically less than 100 kg per isolatable inventory). The NRC is fitted with a gaseous fire extinguishing system utilising CO_2 and Inergen, which has zero ozone depleting potential and a low global warming potential. The gaseous fire extinguishing agents are only released as demanded by the applicable safety system or as per certification testing requirements.

Impact Assessment

Facility and vessel routine and non-routine emissions have the potential to result in localised, temporary reduction in air quality, occasional generation of dark smoke and contribution to greenhouse gas emissions. Potential impacts of emissions depend on the nature of the emissions, as well as the location and nature of the receiving environment. NRC platform design (including the rapidly dispersive characteristics of the gas turbine exhausts, flare and other equipment), the estimated level of pollutants in the emissions, and the absence of elevated background ambient levels have been considered in estimating the potential for interaction with human and environmental sensitivities. The Operational Area is in a remote offshore location, with no expected adverse interaction with populated areas or sensitive environmental receptors associated with air emissions. There is a foraging BIA for the wedge-tailed shearwater overlapping the Operational Area; as such, wedge-tailed shearwaters may occur near to the facility airshed. The nearest potential seabird roosting habitat, the Montebello Islands, are over 115 km south of the Offshore Facility Operational Area. Given the highly dispersed nature of facility air emissions, no adverse impacts to birds are anticipated due to air emissions. The wedge-tailed shearwater foraging BIA and breeding BIAs for the roseate tern and Australian fairy tern overlap the Export Trunkline Operational Area, however atmospheric emissions from vessels are highly localised and quickly dispersed, therefore no impacts are expected to the wedge-tailed shearwater, roseate tern and Australian fairy tern. Potential impacts are expected to be localised air quality changes, limited to the airshed local to the NRC with no lasting effect. Air emission impacts are not expected to have direct or cumulative impacts on sensitive environmental receptors, or above National Environmental Protection (Ambient Air Quality) Measures. Additionally, air quality around the NRC is maintained to provide a safe working environment for operational staff. The offshore location means the flare and potential black smoke resulting from emissions are not directly visible from the nearest landfall (Montebello Islands, 39 km south of the Operational Areas at the closest point). Hence, no impacts to visual amenity for residential communities are expected. Visual amenity impairment to tourism activities is not expected.
Summary of Control Measures
• Support vessels complying with Marine Order 97 (Marine Pollution Prevention – Air Pollution) • NGERS and NPI reporting • Regularly monitoring, estimating and reporting facility fuel and flare emissions (in accordance with NGERS/NPI) to inform optimisation management practices • Maintaining flare to maximise efficiency of combustion and minimise venting.

Routine Light Emissions: Platform Lighting, Vessel Operations and Operational Flaring

Impacts Evaluation Summary														
Source of Impact	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Light emissions from NRC and vessels.						X		A	F	-	-	LCS GP PJ	Broadly Acceptable
Light emissions from NRC during flaring.						X		A	F	-	-		

Description of Source of Impact

Lighting is used to allow safe operations during night hours, as well as to communicate the presence of the NRC and vessels to other marine users (i.e. navigation lights). Lighting is required for safe operation and cannot reasonably be eliminated.

External lighting is located over the entire NRC, as well as vessels, with most external lighting directed towards working areas such as the production deck, or the back deck of vessels. The production deck of NRA is approximately 23 m above sea level and NRB comprises an integrated float over deck at an elevation of 28 m above sea level, with the highest point of the facility (the top of the flare tower) reaching approximately 135 m above sea level. External lighting of vessels is typically lower than the NRC lights, with vessel lighting usually reduced to improve night vision of bridge crew.

The distance to the horizon at which components of the NRC platform will be directly visible can be estimated using the formula below:

$$\text{horizon distance} = 3.57 \times \sqrt{\text{height}}$$

Where 'horizon distance' is the distance to the horizon at sea level in kilometres, and 'height' is the height above sea level of the light source in metres. Using this formula, the approximate distances at which the production deck and flare tower top will be visible at sea level are:

- production deck: approximately 18.90 km from NRC production deck
- flare tower tip: approximately 42 km from NRC flare tower.

During IMMR activities, underwater lighting is generated over short periods of time while ROVs are in use, as well as from vessel deck lighting. Given the typical intensity of ROV lights and the attenuation of light in seawater, light from ROVs will be localised to the vicinity of the ROV and vessels.

Impact Assessment

Light emissions can affect fauna in two main ways:

- <u>Behaviour:</u> many organisms are adapted to natural levels of lighting and the natural changes associated with the day and night cycle as well as the night time phase of the moon. Artificial lighting has the potential to create a constant level of light at night that can override these natural levels and cycles.
- <u>Orientation:</u> organisms such as marine turtles and birds may also use lighting from natural sources to orient themselves in a certain direction at night. In instances where an artificial light source is brighter than a natural source, the artificial light may act to override natural cues, leading to disorientation.

The fauna within the Operational Areas are predominantly pelagic fish and zooplankton, with a low abundance of transient species such as marine turtles, whale sharks, large whales and migratory seabirds transiting through the Area. Additionally, there is no known critical habitat within the Operational Areas for EPBC listed species, although there are

BIAs that overlap. Given the lack of significant fauna populations expected to occur within the Operational Areas, impacts from light emissions are considered to be highly unlikely.

Seabirds

The risk associated with collision from seabirds attracted to the light is considered to be low given the there is no critical habitat for these species within the Operational Areas. There is a foraging BIA for the wedge-tailed shearwater overlapping the Export Trunklines Operational Area and just the overlaps the edge of the Offshore Facility Operational Area; as such, wedge-tailed shearwaters may occur within the Operational Areas. Foraging wedge-tailed shearwaters may be attracted to sources of light emission to feed upon fish drawn to the light; however, the species feeds predominantly during the day in association with pelagic predators (Catry et al. 2009, Whittow 1997). The majority of foraging trips are short, with single day foraging trips significantly more common than any other length trip, with birds returning to nesting/roosting sites between trips (Congdon et al. 2005). As such, the number of wedge-tailed shearwaters present in the Operational Areas at night is expected to be low relative to daylight hours, and any potential changes to behaviour would only affect a relatively low number of birds. Given the species' global distribution and primarily diurnal foraging behaviour, impacts to wedge-tailed shearwaters from artificial lighting are considered to be highly unlikely.

Wiese et al. (2001) presented a literature review relating to the effect of light from platforms in the North Sea on seabirds. They noted seabirds are strongly visually orientated and that large attractions of birds, and in some cases mortality of birds, have often been documented by lighthouses, communication towers, buildings and oil platforms. Injuries can occur through direct collisions. The rate of collision is (they inferred from literature) related to the cross-sectional area of the obstacle, amount of light and number of birds present.

In a study of offshore oil platforms in the North Sea, Poot et al. (2008) observed that migrating seabirds can be attracted to the lights and flares of offshore oil platforms, particularly on cloudy nights and in between the hours of midnight and dawn. Migratory shorebirds travelling the East Asian-Australasian Flyway transit through the Operational Areas en-route to staging areas, before moving onto the mainland south in the spring or Indonesia in the north in the autumn. It is possible that some birds on migration may take advantage of ships and offshore facilities in the area to rest. The NRA platform has been operational for over 30 years, and in that time no large groups of birds have been observed on either platform. The environmental impact associated with seabirds attracted to the light, and hence diverted from their migratory pathway is considered to be localised with no lasting effect.

Black (2005) reported on two cases of mass seabird mortalities from striking of ships in the Southern Ocean. In both cases, mortalities occurred when the vessel was at anchor near seabird colonies and conducting night deck operations during periods of reduced visibility. There are no seabird colonies in the Operational Areas, therefore vessels operating in the Operational Areas at night are not expected to have the same impact as the vessels described by Black (2005). While two breeding BIAs (roseate tern and Australian fairy tern) overlap the Export trunkline Operational Area vessels in this area will be for IMMR activities and therefore infrequent and of short duration. Significant seabird mortality associated with fishing vessel operations has also been documented (e.g. Sullivan et al. 2006), with fishing gear such as trawl nets being the primary cause of mortality. Birds are strongly attracted to by-catch and baits from fishing vessels, however fishing does not occur from vessels undertaking the Petroleum Activities Program. Hence, comparisons of bird mortality between fishing vessels and vessels undertaking the Petroleum Activities Program are not reasonable.

Marine Turtles – Hatchlings

Light emissions reaching turtle nesting beaches are widely considered detrimental, owing to interference with important nocturnal activities including choice of nesting sites and orientation/navigation to the sea by post-nesting females and hatchlings (Lorne and Salmon 2007, Salmon 2003, Tuxbury and Salmon 2005). Hatchling turtles use light as a visual cue to orientate themselves towards the sea during the post-hatching dash after emerging from the nest, orientating themselves towards the relatively bright horizon above the sea and away from the relatively dark dunes (Salmon et al. 1995b, Salmon and Witherington 1995). Turtles disorientated by artificial lighting may take longer, or fail, to reach the sea, potentially resulting in increased mortality through dehydration, predation or exhaustion (Salmon and Witherington 1995).

The nearest potential nesting site in relation to the Offshore Facility Operational Area are the Montebello and Lowendal Islands, over 95 km from the Operational Area. Lighting and the tip of the flare tower will not be directly visible from this potential nesting site as the flare tower is located offshore. Given the nature of the light emitted from the NRC and vessels, and the distance to the nearest landfall (and nearest significant rookeries), artificial light from the NRC and vessels is not expected to be directly visible to hatchling turtles, therefore, impacts to hatchling turtles emerging from nests are not credible.

Marine Turtles – Adults

Artificial lighting may affect the location that turtles emerge onto the beach, the success of nest construction, whether nesting is abandoned, and even the seaward return of adults (Salmon et al. 1995a, 1995b, Salmon and Witherington 1995). Lighting that affects adult turtles is typically from residential and industrial developments overlapping the coastline, rather than lighting offshore from nesting beaches. The Operational Areas do not contain any known critical habitat for any species of marine turtle, although the Trunkline Export Operational Area does overlap with the internesting buffer for green, flatback, hawksbill and loggerhead turtles. It is acknowledged that marine turtles may be present in the Operational Areas in low densities and that internesting buffers overlap the Trunkline Export Operational Areas, however the closest nesting sites are over 95 km from the Offshore Facility Operational Areas therefore no impacts to nesting turtles will occur due to light generated during the Petroleum Activities Program.

Fish
Lighting from activities in the Operational Areas may result in the localised aggregation of fish below the source of light. Note, fish may also be aggregating around the NRC due to the habitat provided by the facility and subsea infrastructure. These aggregations of fish would be confined to a small area. Any long-term changes to fish species composition or abundance is highly unlikely.
Summary of Control Measures
The potential impacts and risks from light emissions is deemed to be ALARP in its risk state. No reasonable additional/alternative controls were identified that would further reduce the impacts without grossly disproportionate sacrifice.

5.7.1 Unplanned Hydrocarbon or Chemical Release: Hydrocarbon Release during Bunkering, Refueling and Chemical Release during Transfer, Storage and Use

Risks Evaluation Summary

Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Accidental spill of hydrocarbons to the environment during bunkering	-	-	X	-	-	X	-	A	D	1	M	LCS GP PJ ER	Broadly Acceptable
Accidental discharge of chemicals to the marine environment from transfer, storage or use	-	-	X	-	-	X	-	A	E	2	M		

Description of Source of Risk

Marine diesel fuel is bunkered to the facility and may be bunkered to key support vessels stationed at the NRC for extended periods (e.g. ASV). Chemicals such as glycol (MEG and TEG) are also transferred by hose to the facility.

Marine Diesel Bunkering/Refuelling and Bulk Chemical Transfer

Two key scenarios for the loss of containment of marine diesel during bunkering operations were identified:

- Partial or total failure of a bulk transfer hose or fittings during bunkering or chemical transfer, due to operational stress or other integrity issues could spill marine diesel on to the deck and/or into the marine environment. This would be in the order of less than 0.2 m^3**,** based on the likely volume of a bulk transfer hose (assuming a failure of the dry break and complete loss of hose volume).
- Partial or total failure of a bulk transfer hose or fittings during bunkering, refuelling or chemical transfer, combined with a failure in procedure to shutoff fuel pumps for a period of up to five minutes, resulting in approximately 8 m^3 marine diesel loss to the deck and/or into the marine environment.

Mechanisms are available to capture diesel from process/piping associated with bunkering and fuel transfers, which can be used to drain to a caisson with an oil recovery system. The diesel unloading stations have isolation and vent valves to allow draining of bunkering hoses between uses.

Chemicals Use and Storage

Chemicals will be used during the Petroleum Activities Program for a variety of purposes. Selection of chemicals is undertaken in accordance with the Woodside Chemical Selection and Assessment Environment Guideline. Spills of chemicals (including non-process hydrocarbons) can originate from stored hydrocarbons/chemicals or equipment on the platform, vessel decks or subsea. Operational process chemicals on the NRC are typically stored in dedicated vessels which have similar controls of those related to mitigating hydrocarbon releases (e.g. dedicated tanks, permanent piping to the process, isolatable by valves etc.). The chemical stored in the largest volume on the NRC is TEG, being an operational process chemical stored in bulk (35 m^3), followed by MEG and corrosion inhibitor approximately 8 m^3 (4 m^3 each per container).

Operational non-process chemicals and maintenance chemicals present on the NRC and support vessels are generally held in low quantities. Subsea Support Vessels undertaking IMMR activities may also store quantities of chemicals for subsea use. Accidental releases of small quantities of subsea chemicals may occur (e.g. deck spills). Operational experience indicates potential volumes of such spills is small (< 20 L).

Chemical storage areas are typically set up in cabinets, or bunded storage areas to contain any releases to deck from transportable containers (e.g. IBCs, barrels, drums, pails etc.). Releases from equipment are predominantly from the failure of hydraulic hoses or minor leaks from process components, or spills during refuelling of equipment, which can either be located within bunded/drained areas or outside of bunded/drained areas

ROV hydraulic fluid is supplied through hoses containing approximately 20 L of fluid. Hydraulic lines to the ROV arms and other tooling may become caught resulting in minor leaks to the marine environment. Small volume hydraulic leaks may occur from equipment operating via hydraulic controls subsea (subsea control fluid). These include the diamond wire cutter, bolt tensioning equipment, ROV tooling etc.

Quantitative Spill Risk Assessment

Woodside commissioned RPS APASA to model several small marine diesel spills, including surface spill volumes of 8 m^3 in the offshore waters of northwest Western Australia. The results of these models indicated that exposure to surface hydrocarbons above the 10 g/m^2 threshold is limited to the immediate vicinity of the release site, with little potential to extend beyond 1 km. Therefore, it is considered that exposure to thresholds concentrations from an 8 m^3 surface spill from bunkering activities would be well within the ZoC for the diesel release scenario. Given this, the offshore location of the NRC, and the fact that the same hydrocarbon type is involved for both scenarios, specific modelling for an 8 m^3 marine diesel release was not required for a release at NRC.

Hydrocarbon Characteristics

Note the marine diesel scenario is significantly larger than the volumes considered here due to topside storage volumes.

Consequence Assessment

Marine Diesel

Given the low viscosity of marine diesel, along with the high portion of volatile components, a spill of up to 8 m^3 of marine diesel during transfer, storage or use would spread and weather rapidly. Environmental receptors at risk would be restricted to those in the vicinity (< 1 km from the release location) and may include:

- marine fauna, particularly fauna associated with the sea surface (e.g. seabirds, air breathing vertebrates)
- plankton.

Given the relatively small worst-case credible release volume, the non-persistent nature of marine diesel and the low sensitivity of the receiving environment within the Offshore Facility Operational Area (i.e. offshore open water environment), potential impacts are expected to be short term (< 1 year) and confined to less than 1 km from the release location. Such impacts may include:

- localised decrease in water quality
- acute toxic effects to planktonic organisms in the immediate area of the spill.

Impacts to plankton may include acute toxicity resulting in mortality of planktonic organisms. Given the rapid turnover of plankton communities, these impacts will be short-lived (hours to days).

Impacts to fish are expected to be of no lasting effect, as fish species are mobile and expected to avoid the area affected by a marine diesel spill. Impacts to larger fauna such as cetaceans and marine turtles are expected to be light fouling, potentially resulting in irritation of sensitive membranes such as the eyes, mouth and digestive system (Helm et al. 2015). Mortality of larger fauna is not expected to occur.

No impacts to ecosystem function are expected.

Although the Ancient Coastline KEF overlaps the Operational Area, no impacts are predicted as the KEF is on the seabed in 125 m water depth and an 8 m^3 diesel spill will remain predominantly on the surface and will not reach the seabed.

Minor, short term impacts may occur to other marine users (e.g. commercial fisheries); however, as the worst-case marine diesel spill is only 8 m^3, and there is already no fishing within the Offshore Facility Operational Area and minimal fishing activity within 1 km of NRC (limited to the Pilbara Demersal Scalefish Fishery Area 6 of Zone 2 (which has been closed to trawling since 1998) and the Onslow Prawn Fishery (which targets species in water depths less than 45 m)), it is unlikely there would be any significant impact to commercial fishers.

Chemicals and Non-Process Hydrocarbons

MEG and TEG are miscible in water; both are considered PLONOR. A maximum credible spill of MEG or TEG is expected to mix with the receiving environment with no lasting environmental impact. Corrosion inhibitor is not OCNS rated but is expected to rapidly dilute in the receiving environment.

Accidental releases of chemicals or non-process hydrocarbons decrease the water quality in the immediate area of the release. The consequence is expected to be slight given the temporary and localised nature of the spill, the water depths, the open ocean mixing environment, Operational Area distance from sensitive receptors and relatively low credible release volumes. Depending on the chemical released the toxicity and/ or potential to bioaccumulate may potentially result in impacts to sediment quality, pelagic fish or other marine species in the vicinity of the discharge

Potential impacts to plankton from an accidental chemical spill may include acute toxicity resulting in mortality of planktonic organisms. Given the rapid turnover of plankton communities and nature and scale of the credible releases, these impacts will be short-lived (hours to days). Impacts to fish are expected to be of no lasting effect, as fish species are mobile and expected to avoid the area affected by an accidental chemical spill. Impacts to air-breathing fauna such as cetaceans, birds and marine turtles, are expected to be restricted to irritation of sensitive membranes such as the eyes, mouth, and digestive system.

Slight, short term impacts may occur to other marine users (e.g. commercial fisheries); however, as there is limited fishing within the Operational Areas, it is unlikely there would be any significant impact to commercial fishers.

Summary of Control Measures
• Support vessels complying with Marine Order 91 (Marine pollution prevention – oil) for safe vessel operations • Chemical Selection and Assessment Environment Guideline: - Where Gold/Silver/E/D OCNS rating (and no OCNS substitution or product warning), chemicals are selected, no further control required - If chemicals with a different OCNS rating, sub-warning or non- CNS rated chemicals are required, chemicals will be assessed in accordance with the procedure prior to use • Diesel bunkering hoses - have dry break couplings - be pressure rated at purchase; to reduce the risk of accidental hydrocarbon release during bunkering. • Implementation of bunkering procedures • Safely storing chemicals/diesel to prevent the release to the marine environment • Incident reports are raised for unplanned releases within event reporting system • Mitigation – hydrocarbon spill response.

Unplanned Discharges: Hazardous and Non-hazardous Waste Management

Risks Evaluation Summary													
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Incorrect disposal or accidental discharge of non-hazardous and hazardous waste to the marine environment.		X	X			X		A	E	2	M	LCS GP PJ	Broadly Acceptable

Description of Source of Risk
Non-hazardous and Hazardous Waste Normal operations on the NRC and support vessels results in a variety of hazardous and non-hazardous wastes. These materials could potentially impact the marine environment, if incorrectly disposed of, lost overboard, or discharged in significant quantities. Non-hazardous wastes include domestic and industrial wastes, such as aluminium cans, bottles, paper and cardboard, scrap steel. Hazardous wastes include recovered solvents, excess or spent chemicals, oil contaminated materials (e.g. sorbents, filters and rags), batteries, used lubricating oils and potentially material containing Naturally Occurring Radioactive Material (NORMs)[4]. Sand and sludges may also be periodically generated during well unloading and clean-up operations, desanding, vessel maintenance and removal of redundant equipment. All waste materials not suitable for discharge to the environment, including hazardous wastes (i.e. liquid and solid wastes), generated on the NRC are transported to shore for disposal or recycling by Woodside's licensed waste contractor.

Consequence Assessment
Non-hazardous and Hazardous Waste The potential impacts of non-hazardous and hazardous wastes accidentally discharged to the marine environment include direct pollution and contamination of the marine environment, potentially resulting in slight localised decreased water or sediment quality. Secondary impacts relate to potential contact of marine fauna with wastes resulting in entanglement or ingestion, leading to injury or death of individual animals. Solid material accidently lost to the marine environment could potentially lead to slight localised contamination of benthic sediments. The temporary or permanent loss of waste materials into the marine environment is not likely to have a significant environmental impact, based on the nature and scale of activities that may generate wastes, the location of the Operational Areas, the types, size and frequency of wastes that could occur, and species present.

Summary of Control Measures
• Support vessels compliant with Marine Orders for safe vessel operations: - Marine Order 94 (Marine pollution prevention – packaged harmful substances) 2014 - Marine Order 95 (Pollution prevention – Garbage) • Implementation of Waste Management Plan for Offshore Facilities

[4] Qualitative measure

• If safe and practicable to do so; vessel ROV or crane used to attempt recovery of material[5] environmentally hazardous or non-hazardous solid object/waste container lost overboard • Incident reports are raised for unplanned releases within event reporting system.

Physical Presence: Interactions with Marine Fauna

Risks Evaluation Summary														
	Environmental Value Potentially Impacted							***Evaluation***						
Source of Risk	**Soil and Groundwater**	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Physical presence of vessels resulting in collision with marine fauna.						X		A	E	1	L	LCS GP PJ	Broadly Acceptable

Description of Source of Risk
The vessels operating in and around the Operational Area may present a potential hazard to cetaceans and other protected marine fauna such as whale sharks and marine reptiles. Vessel movements can result in collisions between the vessel (hull and propellers) and marine fauna, potentially resulting in superficial injury, serious injury that may affect life functions (e.g. movement and reproduction) and mortality. The factors that contribute to the frequency and severity of impacts due to collisions vary greatly due to vessel type, vessel operation (specific activity, speed), physical environment (e.g. water depth) and the type of animal potentially present and their behaviours.

Consequence Assessment
The likelihood of vessel/whale collision being lethal is influenced by vessel speed; the greater the speed at impact, the greater the risk of mortality (Jensen and Silber 2004, Laist et al. 2001). Vanderlaan and Taggart (2007) found that the chance of lethal injury to a large whale as a result of a vessel strike increases from about 20% at 8.6 knots to 80% at 15 knots. According to the data of Vanderlaan and Taggart (2007), it is estimated that the risk is less than 10% at a speed of 4 knots. Vessel-whale collisions at this speed are uncommon and, based on reported data contained in the US National Ocean and Atmospheric Administration database (Jensen and Silber 2004) there only two known instances of collisions when the vessel was travelling at less than 6 knots, both of these were from whale watching vessels that were deliberately placed amongst whales. Vessels undertaking the Petroleum Activities Program within the Offshore Facility Operational Area are likely to be travelling less than 8 knots; much of the time vessels are holding station. Therefore, the risk of a vessel collision with protected species resulting in death is inherently low. No known key aggregation areas (resting, breeding or feeding) are located within or immediately adjacent to the Operational Area. The nearest recognised BIAs for cetaceans (considered to be at risk due to relatively slow movement and proportion of time spent at or near the sea surface) is the humpback whale migration BIA, which overlaps the Export Trunklines Operational Area. Vessels along the Export Trunkline undertake IMMR activities which are typically intermittent and of short duration. Adverse interactions between vessels and humpback or pygmy blue whales are considered to be unlikely. Whale sharks are at risk from vessel strikes when feeding at the surface or in shallow waters (where there is limited option to dive). Whale sharks may traverse offshore NWS waters including the Export Trunkline Operational Area during their migrations to and from Ningaloo Reef and a BIA for foraging whale sharks overlaps with the Export Trunkline Operational Area. However, it is expected that whale shark presence within the Export Trunkline Operational Area would not comprise of significant numbers given there is no main aggregation area within the vicinity of the Offshore Facility Operational Area and Export Trunkline Operational Area, and their presence would be transitory and of a short duration. There are no constraints preventing whale sharks from moving away from vessels (e.g. shallow water or shorelines). With consideration of the absence of potential nesting or foraging habitat (i.e. no emergent islands, reef habitat or shallow shoals) and the water depth (approximately 110 - 125 m), it is considered that the Offshore Facility Operational Area is unlikely to represent important habitat for marine turtles. An internesting buffer BIA for flatback turtles overlaps the Export Trunkline Operational Area; the nearest potential nesting habitat is the Dampier Archipelago (approximately 7 km south of the Operational Area). As such, individual turtles may infrequently transit the area. The typical response

from turtles on the surface to the presence of vessels is to dive (a potential "startle" response), which decreases the risk of collisions (Hazel et al. 2007). As with cetaceans, the risk of collisions between turtles and vessels increases with vessel speed (Hazel et al. 2007). Given the low speeds of vessels undertaking the Petroleum Activities Program, along with the expected low numbers of turtles within the Offshore Facility Operational Area and Export Trunkline Operational Area, interactions between vessels and turtles are considered to be highly unlikely. It is not deemed credible, that vessel movement associated with the Petroleum Activities Program could have a significant impact on marine fauna populations given (1) the low presence of transiting individuals, (2) avoidance behaviour commonly displayed by whales, whale sharks and turtles and (3) low operating speed of the activity support vessels in the Operational Areas (generally less than 8 knots or stationary, unless operating in an emergency). Activities are considered highly unlikely to result in a consequence greater than minor short-term disruption to individuals or a small proportion of the population and no impact on critical habitat or fauna activity.
Summary of Control Measures
• EPBC Regulations 2000 – Part 8 Division 8.1 Interacting with cetaceans, which includes the following measures: - Vessels will not travel greater than six knots within 300 m of a cetacean (caution zone) and not approach closer than 100 m from a whale - Vessels will not approach closer than 100 m for a whale (with the exception of animals' bow riding) • If the cetacean shows signs of being disturbed, activity support vessels will immediately withdraw from the caution zone at a constant speed of less than six knots.

Physical Presence: Introduction of Invasive Marine Species

Risks Evaluation Summary														
Source of Risk	Environmental Value Potentially Impacted							Evaluation						
	Soil and Groundwater	Marine Sediment	Water Quality	Air Quality (incl. Odour)	Ecosystems/Habitat	Species	Socio-Economic	Decision Type	Consequence/Impact	Likelihood	Risk Rating	ALARP Tools	Acceptability
Invasive species in vessel ballast tanks or on vessels/ submersible equipment.					X	X		A	E	1	L	LCS GP PJ	Broadly Acceptable

Description of Source of Risk

The NRC relies on a number of vessels to service routine needs (platform support vessels) and, less frequently, to provide specialist services (subsea IMMR activities, ASV, HLV etc.). Support vessels may be sourced from the local area (Dampier, Port Hedland, etc.) or from further afield, depending on the type of support vessel required and availability. In addition, infrequent import of materials (e.g. spares) from international suppliers may be required.

All support vessels are inherently subject to some level of marine fouling. Organisms attach to the vessel hull, particularly in areas where organisms can find a good surface (e.g. seams, strainers and unpainted surfaces) or where turbulence is lowest (e.g. niches, sea chests etc.). Organisms can also be drawn into ballast tanks during on-boarding of ballast water as cargo is unloaded or to balance vessels under load. Biofouling organisms can become established in an area through the release of propagules (e.g. egg or larvae), or by attaching to substrate after becoming detached from the host vessel.

Non-Indigenous Marine Species (NIMS) are organisms that have been introduced into a region beyond their natural biogeographic range and have the ability to survive, reproduce and establish founder populations. Not all NIMS introduced into an area will thrive or cause demonstrable impacts. Indeed, the majority of NIMS around the world are relatively benign and few have spread widely beyond sheltered ports and harbours. Only a subset of NIMS that become abundant and impact on social/cultural, human health, economic and/or environmental values can be considered Invasive Marine Species (IMS).

During the Petroleum Activities Program, the following vessel activities have the potential to lead to the introduction of IMS:

- discharge of ballast water from support vessels
- support vessel interactions with nearby fixed infrastructure/NRC platform.

The majority of vessels used during the Petroleum Activities Program are platform support vessels; these are typically sourced from Australia and are not considered high risk for IMS introduction.

Consequence Assessment

IMS have historically been introduced and translocated around Australia by a variety of human means including biofouling and ballast water. Species of concern are those that:

- are not native to the region
- are likely to survive and establish in the region
- are able to spread by human mediated or natural means.

Species of concern vary from one region to another, depending on various environmental factors such as water temperature, salinity, nutrient levels and habitat type. These factors dictate their survival and invasive capabilities.

Introducing IMS into the local marine environment may alter the ecosystem, as IMS have characteristics that make them superior (in a survival and/or reproductive sense) to indigenous species. They may prey upon local species which had previously not been subject to this kind of predation and therefore, not have evolved protective measures against the attack; they may outcompete indigenous species for food, space or light and can also interbreed with local species, creating hybrids such that the endemic species is lost.

IMS have also proven economically damaging to areas where they have been introduced and established. Such impacts include direct damage to assets (fouling of vessel hulls and infrastructure) and depletion of commercially harvested marine life (e.g. shellfish stocks). IMS have proven particularly difficult to eradicate from areas, once established. If the introduction is captured early, eradication may be effective but is likely to be expensive, disruptive and, depending on the method of eradication, harmful to other local marine life.

Despite the potential high consequence of the establishment of a marine pest within a high value environment as a result of introduction, like coastal or sheltered nearshore waters, the deep offshore open waters of the Offshore Facility Operational Area are not conducive to the settlement and establishment of IMS (Geiling 2016), due to the lack of light or suitable habitat to sustain growth or survival. The Offshore Facility Operational Area is in an offshore continental shelf location more than 12 nm from shorelines and/or critical habitat and in waters approximately 80 to 162 m deep.

Activities which may occur in more shallow waters (within Commonwealth Waters) along the export trunkline (approximately 30 to 120 m water depths) will occur infrequently.

The majority of vessels used during the Petroleum Activities Program are also typically sourced from Australia and are not considered high risk for IMS introduction. Given this, the likelihood of introducing/acquiring IMS during the Petroleum Activities Program is considered highly unlikely, and considered manageable given ballast water and biofouling controls which will be implemented.

Summary of Potential Impacts to Environment Values

In support of Woodside's assessment of the impacts and risks of IMS introduction associated with the Petroleum Activity Program, Woodside conducted a risk and impact evaluation of the different aspects of marine pest translocation associated with the activity and support vessels. The results of this assessment are presented in the table below.

The assessment evaluated all potential receptors and pathways between receptors to identify credible risks for the introduction of IMS. From this assessment the only credible pathway identified was the establishment of IMS on the riser platform, with no credible transfer of IMS to a secondary vessel. Woodside has presented the highest potential environmental consequence from this risk as Slight (E) and likelihood as Highly Unlikely (1), resulting in an overall Low risk following the implementation of identified controls.

Table 12-15: Assessment of the impacts and risks of IMS introduction associated with the Petroleum Activity Program

IMS Introduction Aspect	Credibility of Introduction	Consequence of Introduction	Likelihood
Transfer of IMS from infected vessel to Operational Area and establishment on the seafloor or subsea infrastructure.	**Not Credible** The deep offshore open waters of the Offshore Facility Operational Area, away from shorelines and/or critical habitat, more than 12 nm from a shore and in waters 110–162 m deep, are not conducive to the settlement and establishment of IMS.		
Transfer of IMS from infected vessel to and subsequent establishment on the NRC platform.	**Credible** There is potential for the transfer of marine pests to occur.	Slight (E) – Environment Minor (D) – Reputation and Brand If IMS were to establish, this would potentially result in fouling of intakes (depending on the pest introduced), and would likely result in quarantine of the NRC until eradication could occur (through cleaning and treatment of infected areas), which would be costly to undertake. Such introduction would be expected to have Minor (D) impact to Woodside's	Highly Unlikely (1) The transfer of IMS from vessels to NRC is highly unlikely with the implementation of ballast water and biofouling controls and Woodside's IMS risk assessment. Spread of marine pests via ballast water or spawning in these open ocean environments is considered Highly Unlikely (1).

		reputation and brand, and close scrutiny of asset level operations or future proposals. Environmental consequence of introduction of IMS to the NRC platform is considered Slight (E), localised and would relate to habitat directly on the NRC.	
Transfer of IMS from infected vessel to and subsequent establishment on NRC platform, then transfer of IMS to a secondary vessel from the NRC.	**Not Credible** Risk is considered so remote that it is not credible for the purposes of the Petroleum Activity Program. The transfer of a marine pest from an infected activity vessel to the NRC was already considered highly unlikely given the offshore open ocean environment. For a marine pest to then establish into a mature spawning population on the NRC and then transfer to another support vessel is not considered credible. The NRC is located in an offshore, open ocean, deep environment. Support vessels only spend short periods of time alongside NRC (i.e. during backloading or bunkering activities). There is also no direct contact (i.e. they are not tied up alongside) during these activities. It is also noted that Woodside has been conducting marine vessel movements between the NRC and Western Australia ports (such as Dampier) for a long period of time, and no IMS has been detected in these ports (Department of Fisheries 2017).		
Transfer of IMS from infected vessel to the export trunkline during IMMR activities.	**Not Credible** The risk is considered so remote that it is not considered credible for the purposes of the Petroleum Activity Program. The transfer of a marine pest from an infected activity vessel onto the export pipeline is not		

	considered credible (i.e. beyond the Woodside risk matrix). The export trunkline is located in an open ocean environment in depths between 30–120 m. Vessels will only spend short periods of time near the pipeline (i.e. during IMMR activities). There is also no direct contact (i.e. the vessel will not be tied to the pipeline) during these activities.		

Summary of Control Measures

- All vessels undertaking ballast water exchange or treating ballast water using an approved ballast water treatment method/system
- Applying Woodside's IMS risk assessment process to vessels undertaking the Petroleum Activities Program. Based on the outcomes of each IMS risk assessment, management measures commensurate with the risk (such as the treatment of internal systems, IMS Inspections or cleaning) will be implemented to minimise the likelihood of IMS being introduced.

Unplanned Hydrocarbon Release: Loss of Well Containment (MEE-01)

Risks Evaluation Summary													
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Release of hydrocarbons resulting from loss of platform well containment.		X	X	X	X	X	X	B	B	1	M	LCS GP PJ RBA CV SV	Acceptable if ALARP
Release of hydrocarbons resulting from loss of subsea well containment.		X	X	X	X	X	X	B	A	0	M		

Description of Source of Risk

Background

A loss of well containment can lead to an uncontrolled release of reservoir hydrocarbons or other well fluids to the environment resulting in a well blowout. Woodside has identified a well blowout as the scenario with the worst case credible environmental outcome as a result of this event. Due to the potential consequences, a loss of well containment is considered to be a MEE (MEE-01). A loss of well containment could occur due to a variety of causes including:

- internal corrosion
- external corrosion
- erosion
- overpressure of the annuli
- fatigue
- loss of well integrity during interventions
- loss of well integrity during hydraulic workover
- premature detonation of explosives during intervention on platform wells
- loss of control of suspended load from vessel (operating near subsea wells).

A number of common failure causes due to human error and Safety Critical Equipment (SCE) failures are presented in the generic Human Error and SCE failure bowties.
There are three escalation scenarios (from other MEEs) that can also lead to loss of well containment on the NRC, including:

- loss of structural integrity (MEE-04)
- loss of marine vessel separation (MEE-05)
- loss of control of suspended load from facility lifting operations (MEE-06).

Loss of Well Containment – Credible Scenarios

The Petroleum Activities Program includes production from a series of platform and subsea wells. Two credible worst-case loss of well containment scenarios were identified for the Petroleum Activities Program:

- Scenario 1 - Well blow-out at surface – platform wellhead release
- Scenario 2 - Well blow-out at seabed – highest flow rate subsea well.

For platform well blow-out, the NRC was selected as the release location for Scenario 1. The credible worst-case subsea release was based on the maximum credible release volume from the highest flow rate subsea well (Scenario 2). Each of the loss of well containment scenarios were modelled to a duration of 77 days. This duration is within the estimated time of 76-81 days required to successfully drill an intervention well for each of these wells. The characteristics of each of these release scenarios are summarised in **Table 12-16**. The characteristics of NWS condensate were used as the basis in the modelling for both scenarios.

Table 12-16: Summary of worst-case loss of containment hydrocarbon release scenarios

Scenario	***Hydrocarbon***	***Rate (m^3/day***	***Duration (days)***	***Depth (m)***	***Latitude (D° M'S'' S)***	***Longitude (D° M'S'' E)***	***Total Condensate Release Volume (m^3)***
Scenario 1 – Well blowout at surface – platform wellhead release	Perseus Condensate	357	77	Surface	19° 35’ 08.02” S	116° 08’ 12.28” E	27,510 m^3
Scenario 2 – Well blow-out at seabed – subsea well with highest flow rate	NWS Condensate	1582	77	126	19°32'24.30"S	116°10'49.96"E	122,167 m^3

Decision Type, Risk Analysis and ALARP Tools

Woodside has a good history of implementing industry standard practice in well design and construction. The NRC has never experienced a worst-case loss of well containment in its operational history.

Decision Type

A decision type ‘B’ has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie Methodology and hydrocarbon spill trajectory modelling. Company and societal values were also considered in the demonstration of ALARP and acceptability, through peer review, benchmarking and stakeholder consultation.

The release of hydrocarbons as a result of well loss of containment is considered a Major Environment Event (MEE-01). The hazard associated with this MEE is hydrocarbons in reservoirs, wells, wellheads and xmas trees for NRC platform wells or subsea wells tied-back to the NRC platform.

Quantitative Spill Risk Assessment

Spill modelling of each of the worst-case credible loss of well containment spill scenarios was undertaken by RPS, on behalf of Woodside, over a 77-day simulation length to determine the fate of hydrocarbons released in each scenario based on the assumptions. Modelling was undertaken over all seasons to address year-round operations. This is considered to provide a conservative estimate of the ZoC and the potential impacts from the identified worst-case credible release volumes for all loss of well containment scenarios.

Likelihood

In accordance with the Woodside Risk Matrix, a worst-case loss of well containment has been defined as a ‘Highly Unlikely’ event for platform wells and as ‘Remote’ for subsea wells. Information to support this likelihood determination is outlined below.

Review of industry statistics indicates that the probability of a loss of well containment for production wells is low (10.6% of blowouts) relative to other activities in other hydrocarbon provinces (Gulf of Mexico and the North Sea), such as exploration drilling (31.5% of blowouts), development drilling (23.6% of blowouts) and well workovers (20.5% of blowouts) (SINTEF 2017).

When considering likelihood from an ‘Experience’ perspective, the review also concluded:

- When considering likelihood of the environmental consequence of the blowout event, historic blowouts from production wells that have had a major, long-term impact to the environment (‘B’ consequence rating) have not occurred many times in the industry. This also further supports the likelihood ranking of ‘Highly Unlikely’ for platform wells.
- When considering likelihood of the environmental consequence of the blowout event, historic blowouts from production wells that have had a catastrophic impact to the environment (‘A’ consequence rating) have not occurred in the industry. This also further supports the likelihood ranking of ‘Remote’ for subsea wells.

Consequence
The spatial extent and fate (incl. weathering) of the spilled hydrocarbon were considered during the impact assessment for a worst-case loss of well containment (presented in the following section). These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS, available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.

Consequence Assessment

Zone of Consequence

Surface Hydrocarbons

The ZoC is a summary of all the locations where environmental thresholds could be exceeded for modelled scenarios. No surface hydrocarbons above impact thresholds are expected to occur for the subsea release scenario (Scenario 2). For Scenario 1, the modelled hydrocarbon slick is forecast to drift in all directions, reflecting the competing influence of both surface currents and winds across the wide area in which a large and persistent slick could travel over the long duration of the release. At the surface threshold of 10 g/m^2, floating oil is forecast to be localised around the release site, extending less than 25 km. Due to the volatile, non-persistent nature of the condensates modelled, surface hydrocarbons are expected to readily evaporate, resulting in the surface ZoC being relatively small compared to the dissolved and entrained ZoCs (discussed further below).

Entrained Hydrocarbons

Modelling results indicated a number of environmental sensitivities may be contacted by entrained hydrocarbons above impact thresholds, with time to contact ranging from 1.8 days (Montebello Marine Park) to 47 days (Murion Islands Marine Management Area). In the event of a worst-case loss of well containment scenario occurring, entrained hydrocarbons at or above 94 ppb are forecast to potentially extend up to 546 km from the release site. The most likely direction of drift is south-westerly towards the Ningaloo Coast, reflecting the prevailing current patterns. Results also indicate that entrained oil may also drift towards the north-east and in the offshore directions at lower probabilities.

Dissolved Hydrocarbons

In the event of a subsea loss of well containment scenario, dissolved hydrocarbons at or above 94 ppb (environmental impact threshold) are forecast to potentially occur up to 672 km from the release site (Scenario 2).

Accumulated Hydrocarbons

There are no accumulated hydrocarbons, above predicted impact thresholds, predicted by the modelling.

Table 12-17: Key receptor locations and sensitivities potentially contacted above impact thresholds by the loss of well containment scenario with summary hydrocarbon spill contact (table cell values correspond to scenario numbers)

Environmental setting	Location / name	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions																													Hydrocarbon contact and fate (Condensate			
		Physical		Biological																						Socio-economic and Cultural								
		Water Quality	Sediment Quality	Marine Primary Producers			Other Communities / Habitats								Protected Species									Other Species										
		Open water – (pristine)	Marine Sediment - (pristine)	Coral reef	Seagrass beds / Macroalgae	Mangroves	Spawning/nursery areas	Open water – Productivity/upwelling	Non-biogenic reefs	Offshore filter feeders and/or deep-water benthic communities	Nearshore filter feeders	Sandy shores	Estuaries / tributaries / creeks / lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and interesting areas and significant nesting	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident /Demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and Recreation	Protected Areas / Heritage – European and Indigenous / Shipwrecks	Offshore Oil and Gas Infrastructure (topside and subsea)	Surface hydrocarbon (≥10 g/m²)	Entrained hydrocarbon (≥94 ppb)	Dissolved aromatic hydrocarbon (≥94 ppb)	Accumulated hydrocarbons (>100 g/m²)
Offshore[6]	Commonwealth waters	✓	✓					✓		✓					✓	✓				✓	✓	✓	✓	✓		✓		✓		✓	1	1,2	2	
	Montebello AMP	✓	✓	✓			✓	✓							✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			2	2	
	Ningaloo AMP	✓	✓					✓		✓					✓	✓			✓		✓	✓	✓	✓	✓	✓		✓	✓			2		
	Gascoyne AMP	✓	✓												✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		2	2	
	Argo-Rowley Terrace AMP	✓	✓					✓							✓	✓			✓			✓	✓	✓		✓			✓				2	
	Shark Bay AMP	✓	✓					✓							✓	✓			✓			✓	✓	✓		✓			✓				2	
Submerged Shoals and	Rankin Bank	✓	✓	✓			✓	✓		✓						✓				✓		✓		✓	✓	✓		✓				1,2	2	
	Glomar Shoals	✓	✓	✓			✓	✓		✓						✓				✓		✓		✓	✓	✓		✓				1,2	2	
Islands	Montebello Islands (including State Marine Park)	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			2	2	

[6] Note: hydrocarbons cannot accumulate on open ocean, submerged receptors, or receptors not fully emergent.

Environmental setting	Location / name	Open water – (pristine)	Marine Sediment - (pristine)	Coral reef	Seagrass beds / Macroalgae	Mangroves	Spawning/nursery areas	Open water – Productivity/upwelling	Non-biogenic reefs	Offshore filter feeders and/or deep-water benthic communities	Nearshore filter feeders	Sandy shores	Estuaries / tributaries / creeks / lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and interesting areas and significant nesting	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident /Demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and Recreation	Protected Areas / Heritage – European and Indigenous / Shipwrecks	Offshore Oil and Gas Infrastructure (topside and subsea)	Surface hydrocarbon (≥10 g/m²)	Entrained hydrocarbon (≥94 ppb)	Dissolved aromatic hydrocarbon (≥94 ppb)	Accumulated hydrocarbons (>100 g/m²)
		Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions																													Hydrocarbon contact and fate (Condensate			
		Physical		Biological																						Socio-economic and Cultural								
		Water Quality	Sediment Quality	Marine Primary Producers			Other Communities / Habitats								Protected Species									Other Species										
	Barrow Island (including State Nature Reserves, State Marine Park and Marine Management Area)	✓	✓	✓	✓		✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		1,2		
	Lowendal Islands (including State Nature Reserve)	✓	✓	✓	✓		✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		2		
	Pilbara Islands – Southern Island Group (Serrurier, Thevenard and Bessieres Islands – State Nature Reserves)	✓	✓		✓		✓		✓			✓		✓		✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓			2		
	Muiron Islands (WHA, State Marine Park)	✓	✓	✓	✓		✓	✓		✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓			2		
Mainland (nearshore	Ningaloo Coast (North/North West Cape, Middle and South) (WHA, and State Marine Park)	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓			2		

Summary of Potential Impacts to Environmental Values(s)	
Summary of Potential Impacts to protected species	
Setting	***Receptor Group***
Offshore, Oceanic Reefs and Islands	***Cetaceans*** A range of cetaceans were identified as potentially occurring within the Operational Areas and wider ZoC. In the event of a well loss of containment, entrained and dissolved hydrocarbons exceeding environmental impact threshold concentrations may drift across habitat for oceanic cetacean species and the migratory routes and BIAs of cetaceans considered to be MNES, including humpback whales and pygmy blue whales (north- and south-bound migrations). Cetaceans that have direct physical contact with entrained or dissolved aromatic hydrocarbons may suffer ingestion of hydrocarbons (from prey, water and sediments), aspiration of oily water or droplets and inhalation of toxic vapours (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). This may result in the irritation of sensitive membranes such as the eyes, mouth, digestive and respiratory tracts and organs, impairment of the immune system, neurological damage (Helm *et al.* 2015), reproductive failure, adverse health effects (e.g. lung disease, poor body condition) and potentially mortality (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). A review of cetacean observations, in relation to large scale hydrocarbon spills, was undertaken for the Deepwater Horizon spill. It is worth noting that the Deepwater Horizon hydrocarbon release was crude oil which is much more persistent in the environment than the condensate that may be released during the Petroleum Activities Program, and also more amenable to the formation of surface slicks, which cetaceans may be exposed to when breathing. The review concluded that exposure to oil from the Deepwater Horizon resulted in increased mortality to cetaceans in the Gulf of Mexico (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Given the non-persistent nature of the hydrocarbons from this Petroleum Activities Program and the relatively small floating hydrocarbon ZoC, the area where potential impacts from inhalation may occur is localised around the release location. Cetacean populations that are resident within the ZoC may be susceptible to impacts from spilled hydrocarbons if they interact with an area affected by a spill. Such species are more likely to occupy coastal waters (refer to the *Mainland and Islands* section below for additional information). Suitable habitat for oceanic toothed whales (e.g. sperm whales) and dolphins (e.g. spinner dolphin) is broadly distributed throughout the region and as such, impacts are unlikely to affect an entire population. Other species may also have possible transient interactions with the ZoC (**Table 12-17)** for the list of receptor locations important for cetaceans). Physical contact with hydrocarbons to these species is likely to have biological consequences for individuals however it is unlikely to affect an entire population and is not predicted to impact on the overall population viability. Given the nature of the hydrocarbon, it is expected to weather rapidly and remain entrained in the water column; cetaceans that may interact with spilled hydrocarbons are most likely to be subject to physical impacts. Given cetaceans have thick skin and blubber, external exposure to hydrocarbons may result in irritation to skin and eyes. Entrained hydrocarbons may also be ingested, particularly by baleen whales which feed by filtering large volumes of water. Fresh hydrocarbons (i.e. typically in the vicinity of the release location) may have a higher potential to cause toxic effects when ingested, while weathered hydrocarbons are considered to be less likely to result in toxic effects. Pygmy blue whales and humpback whales are known to migrate seasonally through the wider ZoC. A major spill in May to November would coincide with humpback whale migration through the waters off the Pilbara, North West Cape and Shark Bay. A major spill in April to August or October to January would coincide with pygmy blue whale migration. Double *et al.* (2014) suggest that pygmy blue whales migrate in offshore waters north of the Operational Areas in approximately 200–1000 m of water. Both pygmy blue and humpback whales are baleen whales, and hence, are most likely to be significantly impacted by toxic effects when feeding. However, feeding during migrations is low level and opportunistic, with most feeding, for both species, occurring in the Southern Ocean prior to migration. As such, the risk of ingestion of hydrocarbons is low. Migrations of both pygmy blue whales and humpback whales are protracted through time and space (i.e. the whole population will not be within the ZoC), and as such, a spill from the well loss of containment is unlikely to affect an entire population. The humpback whale resting area in Exmouth Gulf and the calving area in Camden Sound are not predicted to be contacted by entrained or dissolved hydrocarbons above threshold concentrations.

Offshore, Oceanic Reefs and Islands	A loss of well containment resulting in a well blowout, during the migration periods, could result in disruption to humpback or pygmy blue whale populations. Such disruption could include behavioural impacts (e.g. avoidance of impacted areas), sub-lethal biological effects (e.g. skin irritation, irritation from ingestion or inhalation, reproductive failure) and, in rare circumstances, death. However, such disruptions or impacts are not predicted to impact on the overall population viability of cetaceans given the likelihood that only a small number of individuals may be impacted. ***Marine Turtles*** Adult sea turtles exhibit no avoidance behaviour when they encounter hydrocarbon spills (National Oceanic and Atmospheric Administration 2010). Contact with entrained hydrocarbon can result in hydrocarbon adherence to body surfaces (Gagnon and Rawson 2010), causing irritation of mucous membranes in the nose, throat and eyes leading to inflammation and infection (National Oceanic and Atmospheric Administration 2010). Given the hydrocarbon is expected to weather rapidly when released to the environment, relatively fresh entrained hydrocarbons (which are typically relatively close to the release location) are considered to have the greatest potential for impact. Given the offshore location of the wells it is unlikely that large numbers of turtles would be within the vicinity of the release location. Hydrocarbons in surface waters may also impact turtles when they surface to breathe and inhale toxic vapours. Their breathing pattern, involving large 'tidal' volumes and rapid inhalation before diving, results in direct exposure to petroleum vapours which are the most toxic component of the hydrocarbon spill (Milton and Lutz 2003). This can lead to lung damage and congestion, interstitial emphysema, inhalant pneumonia and neurological impairment (National Oceanic and Atmospheric Administration 2010). Given the non-persistent nature of the hydrocarbons and the relatively small floating hydrocarbon ZoC, the area where potential impacts from inhalation may occur is localised around the release location, therefore limiting impacts to a small number of individual turtles that may be present. Due to the offshore location and therefore the absence of potential nesting habitat, the Offshore Facility Operational Area is unlikely to represent important habitat for marine turtles. It is, however, acknowledged that marine turtles may be present foraging within the ZoC, and the ZoC may overlap with the BIAs, in particular, the internesting BIAs for flatback turtles which extend for ~80 km from known nesting locations. The Petroleum Activities Program will coincide with nesting season for marine turtles in the region. In the event of a loss of well containment, there is potential that entrained and dissolved hydrocarbons exceeding environmental impact threshold concentrations will be present in offshore waters (see *Mainland and Islands* section below for nearshore waters). Therefore, a hydrocarbon spill may disrupt a portion of the population; however, there is no threat to overall population viability given the non-persistent nature of predicted hydrocarbons. Potential impacts to nesting and internesting marine turtles are discussed in the *Mainland and Islands (nearshore)* impacts discussion.
	Sea snakes Impacts to sea snakes from direct contact with hydrocarbons are likely to result in similar physical effects to those recorded for marine turtles and may include potential damage to the dermis and irritation to mucus membranes of the eyes, nose and throat (International Tanker Owners Pollution Federation 2011a). They may also be impacted when they return to the surface to breathe and inhale the toxic vapours associated with the hydrocarbons, resulting in damage to their respiratory system. In general, sea snakes frequent the waters of the continental shelf area around offshore islands and potentially submerged shoals (water depths < 100 m; see *Submerged Shoals* below). It is acknowledged that sea snakes may be present in the Offshore Facility Operational Area (however no protected species were identified in the Offshore Facility Operational Area in when using the PMST tool) and wider ZoC (refer to **Table 12-17**); however, their abundance is not expected to be high in the deep water and offshore environment. Therefore, a hydrocarbon spill may have a minor disruption to a small number of individuals, but it is not expected to result in a threat to overall population viability given the non-persistent nature of hydrocarbons predicted.

	Sharks and Rays Hydrocarbon contact may affect whale sharks through ingestion (entrained/dissolved hydrocarbons), particularly if feeding. Whale sharks may transit offshore open waters when migrating to and from Ningaloo Reef, where they aggregate for feeding from March to July. A whale shark foraging BIA overlaps the Offshore Facility Operational Area, and a foraging (high prey density) BIA lies approximately 330 km south-west of the Operational Areas (off the Ningaloo Coast and outside of the wider ZoC). Therefore, individual whale sharks that have direct contact with hydrocarbons within the spill affected area may be impacted. Impacts to sharks and rays may occur through direct contact with hydrocarbons and include contamination of tissues and internal organs either through direct contact or via the food chain (consumption of prey). As gill breathing organisms, sharks and rays may be vulnerable to toxic effects of dissolved hydrocarbons (entering the body via the gills) and entrained hydrocarbons (coating of the gills inhibiting gas exchange). In the offshore environment, it is probable that pelagic shark species are able to detect and avoid surface waters underneath hydrocarbon spills by swimming into deeper water or away from the affected areas. Therefore, any impact on sharks and rays is predicted to be minor and localised. A hydrocarbon spill is not expected to result in a threat to overall population viability.
	Seabirds and Migratory Shorebirds Seabirds and migratory birds are particularly vulnerable to contact with floating hydrocarbons, which may mat feathers. This may lead to hypothermia from loss of insulation and ingestion of hydrocarbons when preening to remove hydrocarbons; both impacts may result in mortality (Hassan and Javed 2011). The credible loss of well containment scenarios result in a relatively small floating hydrocarbon ZoC centered around the release location; hence the potential for seabird exposure to floating hydrocarbons is considered to be low. Migratory shorebirds are unlikely to interact with spilled hydrocarbons; refer to the sections on *Islands and Mainland Coast* below for a discussion on the potential impacts to migratory shorebirds. Offshore waters are potential foraging grounds for seabirds associated with the coastal roosting and nesting habitat, which includes the numerous islands along the Pilbara coast. There are a number of BIAs for seabirds and migratory shorebirds that overlap with the wider ZoC. Given the relatively low likelihood of encounters between seabirds and floating hydrocarbons due to the small area of floating ZoC predicted, impacts to seabirds in offshore waters are expected to only consist of ecosystem effects, such as reduced prey abundance. Impacts from a loss of well containment to prey such as small pelagic fish (prey for the birds) are not expected to be significant, hence, subsequent impacts to a significant portion of seabirds are not expected.
Submerged Shoals and Banks[7]	***Marine Turtles*** There is the potential for marine turtles to be present at submerged shoals such as Glomar Shoals and Rankin Bank. These areas may at times, be foraging habitat for marine turtles, given the coral and filter feeding biota associated with this area, however Glomar Shoals and Rankin Bank are not recognised as known foraging locations. Tagging studies did not indicate any overlap of the tracked post-nesting migratory routes and the Operational Areas. It is, however, acknowledged that individual marine turtles may be present at Glomar Shoals and Rankin Bank and the surrounding areas. Therefore, a hydrocarbon spill may have a minor disruption to a small number of individuals; however, there is no threat to overall population viability.
	Sea snakes There is the potential for sea snakes to be present at submerged shoals such as Glomar Shoals and Rankin Bank. The potential impacts of exposure are as discussed previously in Offshore – Sea snakes. A hydrocarbon spill may have a minor disruption to a portion of the population but there is no threat to overall population viability. Sea snake species in Australia generally show strong habitat preferences (Heatwole and Cogger 1993); species that have preferred habitats associated with submerged shoals and oceanic atolls may be disproportionately affected by a hydrocarbon spill affecting such habitat.
	Sharks and Rays There is the potential for resident shark and ray populations to be impacted directly from hydrocarbon contact or indirectly through contaminated prey or loss of habitat. Spill model results indicate potential

[7] The preceding discussion of protected species in the offshore environment is considered to be relevant to protected species associated with submerged shoals and banks. The text in this section is intended to provide additional context and impact assessment for protected species in relation to submerged banks and shoals.

	impacts to the benthic communities of Glomar Shoals and Rankin Bank (approximately 25 km and 54 km from the Offshore Facility Operational Area) which may host shark and ray populations. Pelagic sharks and rays are expected to move away from areas affected by spilled hydrocarbons. Impacts to such species are expected to be limited to behavioural responses/displacement. Shark and ray species that have associations with submerged shoals and oceanic atolls may not move in response to such habitat being contacted by spilled hydrocarbons. Such species may be more susceptible to a reduction in habitat quality resulting from a hydrocarbon spill. Impacts to sharks and rays at Glomar Shoals are likely to be localised. It is expected that there will be no impacts at the population level.
Islands and Mainland (nearshore waters)	***All Species*** The information provided on protected species in this section is in addition to that provided in the preceding Offshore and Oceanic Reefs and Submerged Banks and Shoals sections. Refer to these preceding sections for additional discussion of protected species.
	Cetaceans and Dugongs In addition to a number of whale species that may occur in nearshore waters, coastal populations of small cetaceans and dugongs are known to reside or frequent nearshore waters, including the Ningaloo Coast, Montebello/Barrow/Lowendal Islands Group, Pilbara Southern Island Group, and a number of other nearshore and coastal locations (see **Table 12-17**) which may be potentially impacted by entrained hydrocarbons exceeding threshold concentrations in the event of a loss of well containment. The potential impacts of exposure are as discussed previously in Offshore – Cetaceans. However, nearshore populations of cetaceans and dugongs are known to exhibit site fidelity and are often resident populations. Therefore, avoidance behaviour may have greater impacts to population functioning. Nearshore dolphin species (e.g. spotted bottlenose dolphins) may exhibit higher site fidelity than oceanic species although Geraci (1988) observed relatively little impacts beyond behavioural disturbance. Additional potential environment impacts not described in sections above are the potential for dugongs to ingest hydrocarbons when feeding on oiled seagrass stands or indirect impacts to dugongs due to loss of this food source if seagrass dies back in worse affected areas. Therefore, a hydrocarbon spill may have an impact on feeding habitats and result in a disruption to a significant portion of local populations of resident nearshore cetaceans and dugongs but due to the non-persistent nature of the hydrocarbon, it is not predicted to result in impacts on overall population viability of either dugongs or coastal cetaceans.
	Marine Turtles Several marine turtle species utilise nearshore waters and shorelines for foraging and breeding (including internesting), with significant nesting beaches along the mainland coast and islands in potentially impacted locations such as the Ningaloo Coast, Montebello/Barrow/Lowendal Islands group and Pilbara Islands (Southern Island Group). Many of these locations have been identified as BIA and/or critical habitats (see **Table 12-17)**. There are distinct breeding seasons. The nearshore waters of these turtle habitat areas may be exposed to entrained and dissolved hydrocarbons exceeding threshold concentrations. The potential impacts of exposure are as discussed previously in Offshore – Marine Turtles. In the nearshore environment, turtles can ingest hydrocarbons when feeding or can be indirectly affected by loss of food source (e.g. seagrass due to dieback from hydrocarbon exposure) (Gagnon and Rawson 2010). In addition, hydrocarbon exposure can impact on turtles during the breeding season at nesting beaches. Contact with gravid adult females or hatchlings may occur in nearshore waters (entrained and dissolved hydrocarbons). If entrained/dissolved hydrocarbons reach the shoreline or internesting coastal waters (refer to **Table 12-17** for receptor locations), there is the potential for impacts to turtles utilising the affected area. During the breeding season, turtle aggregations near nesting beaches within the wider ZoC are most vulnerable due to greater turtle densities and potential impacts may occur at the population level and may impact on overall population viability of some marine turtle species. However, given the volatile nature of the hydrocarbons and no shoreline accumulation (above impact thresholds) predicted, population level impacts will not occur.
	Sharks and Rays Whale sharks and manta rays are known to frequent the Ningaloo Reef system and the Muiron Islands (forming feeding aggregations in late summer/autumn). Whale sharks and manta rays generally transit along the nearshore coastline and are vulnerable to entrained and dissolved aromatic hydrocarbon spill impacts, with both taxa having similar modes of feeding. Whale sharks are versatile feeders, filtering large amounts of water over their gills, catching planktonic and nektonic organisms

	(Jarman and Wilson 2004). Whale sharks at Ningaloo Reef have been observed using two different feeding strategies, including passive sub-surface ram-feeding and active surface feeding (Taylor 2007). Passive feeding consists of swimming slowly at the surface with the mouth wide open. During active feeding, sharks swim high in the water with the upper part of the body above the surface with the mouth partially open (Taylor 2007). These feeding methods would result in the potential for individuals that are present in worse affected spill areas to ingest potentially toxic amounts of entrained aromatic hydrocarbons into their body. Large amounts of ingested hydrocarbons may affect their endocrine and immune system in the longer term. The presence of hydrocarbons may cause displacement of whale sharks from the area where they normally feed and rest, and potentially disrupt migration and aggregations to these areas in subsequent seasons. Whale sharks may also be affected indirectly by entrained aromatic hydrocarbons through the contamination of their prey. The preferred food of whale sharks are planktonic organisms which are abundant in the coastal waters of Ningaloo Reef in late summer/autumn, driving the annual arrival and aggregation of whale sharks in this area. If the spill event were to occur during the spawning season, this important food supply (in worse spill affected areas of the reef) may be diminished or contaminated. The contamination of their food supply and the subsequent ingestion of this prey by the whale shark may also result in long term impacts as a result of bioaccumulation. There is the potential for other resident shark and ray (e.g. sawfish species) populations to be impacted directly from hydrocarbon contact or indirectly through contaminated prey or loss of habitat. However, it is probable that shark species will move away from the affected areas, although sawfish may exhibit high habitat fidelity. **Table 12-17** indicates the receptor locations predicted to be impacted from entrained aromatic hydrocarbons to the benthic communities of nearshore, subtidal communities, and it is considered that there is the potential for habitat loss to occur. Shark populations displaced or no longer supported due to habitat loss would be expected to redistribute to other locations. Therefore, the consequences to resident shark and ray populations (if present) from loss of habitat, may result in a disruption to a significant portion of the population; however, it is not expected to impact on the overall viability of the population.
	Seabirds and/or Migratory Shorebirds In the event of a loss of well containment, there is the potential for seabirds, and resident/non-breeding overwintering shorebirds that use the nearshore waters for foraging and resting, to be exposed to entrained hydrocarbons. This could result in lethal or sub-lethal effects. Although breeding oceanic seabird species can travel long distances to forage in offshore waters, most breeding seabirds tend to forage in nearshore waters near their breeding colony, resulting in intensive feeding by higher seabird densities in these areas during the breeding season and making these areas particularly sensitive in the event of a spill. Pathways of biological exposure that can result in impact may occur through ingestion of contaminated fish (nearshore waters) or invertebrates (intertidal foraging grounds such as beaches, mudflats and reefs). Ingestion can also lead to internal injury to sensitive membranes and organs (International Petroleum Industry Environmental Conservation Association 2004). Whether the toxicity of ingested hydrocarbons is lethal or sub-lethal will depend on the weathering stage and its inherent toxicity (note the shortest entrained hydrocarbon time to contact with a shoreline is three days (Montebello Islands)). Exposure to hydrocarbons may have longer term effects, with impacts to population numbers due to decline in reproductive performance and malformed eggs and chicks, affecting survivorship and loss of adult birds. Migratory shorebirds may also be exposed to indirect impacts, such as reduced prey availability (Henkel *et al.* 2012). Important areas for foraging seabirds and migratory shorebirds are identified**.** Refer to **Table 12-17** for locations within the predicted extent of the ZoC that are identified as habitat for seabirds/migratory shorebirds. Suitable habitat or seabirds and shorebirds are broadly distributed along the mainland and nearshore island coasts within the ZoC. Of note are important nesting areas including: • Ningaloo Coast • Montebello/Barrow/Lowendal Islands group (including known nesting habitats on Boodie, Double and Middle Islands) • Pilbara Islands North and South Island Group. Therefore, a hydrocarbon spill may result in impacts on key feeding habitat and a disruption to a significant portion of the habitat; however, this is not expected to result in a threat to the overall population viability of seabirds or shorebirds.
Summary of potential impacts to other species	
Setting	***Receptor Group***
All Settings	***Pelagic and Demersal Fish***

	Fish mortalities are rarely observed to occur as a result of hydrocarbon spills (International Tanker Owners Pollution Federation 2011b). This has generally been attributed to the possibility that pelagic fish are able to detect and avoid surface waters underneath hydrocarbon spills by swimming into deeper water or away from the affected areas. Fish that have been exposed to dissolved aromatic hydrocarbons are capable of eliminating the toxicants once placed in clean water, hence individuals exposed to a spill are likely to recover (King *et al.* 1996). Where fish mortalities have been recorded, the spills (resulting from the groundings of the tankers Amoco Cadiz in 1978 and the Florida in 1969) have occurred in sheltered bays where access to fresh water was limited. Laboratory studies have shown that adult fish are able to detect hydrocarbons in water at very low concentrations, and large numbers of dead fish have rarely been reported after hydrocarbon spills (Hjermann *et al.* 2007). This suggests that juvenile and adult fish are capable of avoiding water contaminated with high concentrations of hydrocarbons. However, sub-lethal impacts to adult and juvenile fish may be possible, given long-term exposure (days to weeks) to PAH concentrations (Hjermann *et al.* 2007). While modelling of the loss of well containment indicates the potential ZoC for dissolved hydrocarbons is extensive, no time-integrated exposure metrics were modelled; given the oceanographic environment within the wider ZoC, PAH exposures in the order of weeks for pelagic fish are not considered credible. The effects of exposure to oil on the metabolism of fish appears to vary according to the organs involved, exposure concentrations and route of exposure (waterborne or food intake). Oil reduces the aerobic capacity of fish exposed to aromatics in the water and to a lesser extent affects fish consuming contaminated food (Cohen *et al.* 2005). The liver, a major detoxification organ, appears to be the organ where anaerobic activity is most impacted, probably increasing anaerobic activity to facilitate the elimination of ingested oil from the fish (Cohen *et al.* 2005). Fish are perhaps most susceptible to the effects of spilled oil in their early life stages, particularly during egg and planktonic larval stages, which can become entrained in spilled oil. Contact with oil droplets can mechanically damage feeding and breathing apparatus of embryos and larvae (Fodrie and Heck 2011). The toxic hydrocarbons in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) (Fodrie and Heck 2011). More subtle, chronic effects on the life history of fish as a result of exposure of early life stages to hydrocarbons include disruption to complex behaviours such as predator avoidance, reproductive and social behaviour (Hjermann *et al.* 2007). Prolonged exposure of eggs and larvae to weathered concentrations of hydrocarbons in water has also been shown to cause immunosuppression and allows expression of viral diseases (Hjermann *et al.* 2007). PAHs have also been linked to increased mortality and stunted growth rates of early life history (pre-settlement) of reef fishes, as well as behavioural impacts that may increase predation of post-settlement larvae (Johansen *et al.* 2017). However, the effect of a hydrocarbon spill on a population of fish in an area with fish larvae and/or eggs, and the extent to which any of the adverse impacts may occur, depends greatly on prevailing oceanographic and ecological conditions at the time of the spill and its contact with fish eggs or larvae. The continental slope demersal fish communities KEF in the region has been identified as a key ecological feature and overlaps the ZoC. Additionally, demersal species are associated with the Ancient Coastline KEF (overlaps the Offshore Facility Operational Area) and Glomar Shoal KEF (approximately 25 km east of the Operational Area). These KEFs may host relatively diverse or abundant fish assemblages compared to relatively featureless continental shelf habitats. Mortality and sub lethal effects may impact populations located close to the well blow out and within the ZoC for entrained/dissolved aromatic hydrocarbons (≥ 94 ppb). Additionally, if prey (infauna and epifauna) surrounding the well location and within the ZoC is contaminated, this can result in the absorption of toxic components of the hydrocarbons (PAHs) potentially impacting fish populations that feed on these. These impacts may result in localised medium/long term impacts on demersal fish habitat (e.g. seafloor).
Summary of potential impacts to marine primary producers	
Setting	***Receptor Group***
Submerged Shoals	The waters overlying the submerged Glomar Shoals and Rankin Bank have the potential to be exposed to hydrocarbons above threshold concentrations (> 94 ppb). This permanently submerged habitat represents sensitive oceanic reef benthic community receptors, extending from deep depths to relatively shallow water. Potential biological impacts could include sub-lethal stress and, in some instances, total or partial mortality of sensitive benthic organisms such as corals and the early life stages of resident fish and invertebrate species.
Mainland and Islands	***Coral Reef*** The quantitative spill risk assessment and ZoC indicate the potential for coral reef habitat to be exposed to dissolved and entrained hydrocarbons.

(nearshore waters)	There would be potential for entrained and dissolved hydrocarbons above threshold concentrations to reach reef habitat along the Ningaloo Coast and at identified offshore islands and coastline (see **Table 12-17**) such as the Montebello/Barrow/Lowendal Islands Group and Pilbara Southern Islands Group. The shallow coral habitats are most vulnerable to hydrocarbon coating by direct contact with surface slicks during periods when corals are tidally-exposed at spring low tides; such slicks are not expected to form in the event of a loss of well containment for the Petroleum Activities Program due to the nature of the hydrocarbon. Water soluble hydrocarbon fractions associated with surface slicks are also known to cause high coral mortality (Shigenaka 2001) via direct physical contact of hydrocarbon droplets to sensitive coral species (such as the branching coral species). There is significant potential for lethal impacts due to the physical hydrocarbon coating of sessile benthos (e.g. by entrained hydrocarbons), with likely significant mortality of corals (adults, juveniles and established recruits) at the small spill affected areas. This particularly applies to branching corals which are reported to be more sensitive than massive corals (Shigenaka 2001). Exposure to entrained hydrocarbons (≥ 94 ppb) has the potential to result in lethal or sub-lethal toxic effects to corals and other sensitive sessile benthos within the upper water column, including upper reef slopes (subtidal corals), reef flat (intertidal corals) and lagoonal (back reef) coral communities (with reference to Ningaloo Coast). Mortality in a number of coral species is possible and this would result in the reduction of coral cover and change in the composition of coral communities. Sub-lethal effects to corals may include polyp retraction, changes in feeding, bleaching (loss of zooxanthellae), increased mucous production resulting in reduced growth rates and impaired reproduction (Negri and Heyward 2000). This could result in impacts to the shallow water fringing coral communities/reefs of the offshore islands (e.g. Barrow/Montebello/Lowendal Islands and Pilbara Southern Islands) and also the mainland coast (e.g. Ningaloo Coast). With reference to Ningaloo Reef, wave-induced water circulation flushes the lagoon and may promote removal of entrained and dissolved hydrocarbons from this particular reef habitat. Under typical conditions, breaking waves on the reef crest induce a rise in water level in the lagoon creating a pressure gradient that drives water in a strong outward flow through channels. In the unlikely event of a spill occurring at the time of coral spawning at potentially affected coral locations or in the general peak period of biological productivity, there is the potential for a significant reduction in successful fertilization and coral larval survival due to the sensitivity of coral early life stages to hydrocarbons (Negri and Heyward 2000). Such impacts are likely to result in the failure of recruitment and settlement of new population cohorts. Some non-coral species may be affected via direct contact with entrained and dissolved aromatic hydrocarbons, resulting in sub-lethal impacts and in some cases mortality. This is with particular reference to the early life-stages of coral reef animals (reef attached fishes and reef invertebrates), which can be relatively sensitive to hydrocarbon exposure. Coral reef fish are site attached, have small home ranges and as reef residents they are at higher risk from hydrocarbon exposure than non-resident, more wide-ranging fish species. The exact impact on resident coral communities (which may include fringing reefs of the offshore islands and/or the Ningaloo Reef system) will be entirely dependent on actual hydrocarbon concentration, duration of exposure and water depth of the affected communities. Over the worst affected sections of reef habitat, coral community live cover, structure and composition is predicted to reduce, manifested by loss of corals and associated sessile biota. Recovery of these impacted reef areas typically relies on coral larvae from neighbouring coral communities that have either not been affected or only partially impacted. For example, there is evidence that Ningaloo Reef corals and fish are partly self-seeding (Underwood 2009) with the supply of larvae from locations within Ningaloo Reef of critical importance to the healthy maintenance of the coral communities. Recovery at other coral reef areas, may not be aided by a large supply of larvae from other reefs, with levels of recruits after a disturbance event only returning to previous levels after the numbers of reproductive corals had also recovered (Gilmour *et al.* 2013). Therefore, a hydrocarbon spill may result in large-scale impacts to coral reefs, particularly Ningaloo Reef, with long-term effects (recovery > 10 years) likely.
	Seagrass Beds/Macroalgae and Mangroves Spill modelling has predicted entrained hydrocarbons above threshold concentrations have the potential to contact a number of shoreline sensitive receptors such as those supporting biologically diverse, shallow subtidal and intertidal communities. The variety of habitat and community types, from the upper subtidal to the intertidal zones support a high diversity of marine life and are utilised as important foraging and nursery grounds by a range of invertebrate and vertebrate species. Depending on the trajectory of the entrained and dissolved hydrocarbon plume, macroalgal/seagrass communities including the Ningaloo Coast (patchy and low cover associated with the shallow limestone lagoonal platforms), the Barrow/Montebello/Lowendal Islands and the Pilbara Southern Island Group (documented as low and patchy cover) have the potential to be exposed (see **Table 12-17**for a full list of receptors within the ZoC).

	Seagrass in the subtidal and intertidal zones have different degrees of exposure to hydrocarbon spills. Subtidal seagrass is generally considered much less vulnerable to hydrocarbon spills than intertidal seagrass, primarily because freshly spilled hydrocarbons float under most circumstances. Dean *et al.* (1998) found that oil mainly affects flowering, therefore, species that are able to spread through apical meristem growth are not as affected (such as *Zostera*, *Halodule* and *Halophila* species). Seagrass and macroalgal beds occurring in the intertidal and subtidal zone may be susceptible to impacts from entrained hydrocarbons. Toxicity effects can also occur due to absorption of soluble fractions of hydrocarbons into tissues (Runcie *et al.* 2010). The potential for toxicity effects of entrained hydrocarbons may be reduced by weathering processes that should serve to lower the content of soluble aromatic components before contact occurs. Minimum time to contact with receptors that may host seagrasses are ~ 3 days (Montebello Islands). As such, hydrocarbons released in the event of a loss of well containment are expected to be weathered prior to any credible contact with seagrasses. Exposure to entrained aromatic hydrocarbons may result in mortality, depending on actual entrained aromatic hydrocarbon concentration received and duration of exposure. Physical contact with entrained hydrocarbon droplets could cause sub-lethal stress, causing reduced growth rates and a reduction in tolerance to other stress factors (Zieman *et al.* 1984). Impacts on seagrass and macroalgal communities are likely to occur in areas where hydrocarbon threshold concentrations are exceeded. Mangroves and associated mud flats and salt marsh at Ningaloo Coast (small habitat areas) and the Montebello Islands have the potential to be exposed to entrained hydrocarbons (see **Table 12-17** for the full list of receptors). Entrained hydrocarbons can coat the prop roots of mangroves when hydrocarbons in tidal waters are deposited on the aerial roots. Hydrocarbons deposited on the aerial roots can block the pores used to breathe or interfere with the trees' salt balance resulting in sub-lethal and potential lethal effects. Mangroves can also be impacted by entrained hydrocarbons that may adhere to the sediment particles. In low energy environments, such as in mangroves, deposited sediment-bound hydrocarbons are unlikely to be removed naturally by wave action and may be deposited in layers by successive tides (National Oceanic and Atmospheric Administration 2014). However, given the non-persistent nature of the hydrocarbons of the Petroleum Activities Program, no significant effects to mangroves are expected to occur. Entrained hydrocarbon impacts may include sub-lethal stress and mortality to certain sensitive biota in these habitats, including infauna and epifauna. Larval and juvenile fish, and invertebrates that depend on these shallow subtidal and intertidal habitats as nursery areas, may be indirectly impacted due to the loss of habitats and/or lethal and sub-lethal in-water toxic effects. This may result in mortality or impairment of growth, survival and reproduction (Heintz *et al.* 2000). In addition, there is the potential for secondary impacts on shorebirds, fish, sea turtles, rays, and crustaceans that utilise these intertidal habitat areas for breeding, feeding and nursery habitat purposes.
Summary of potential impacts to other habitats and communities	
Setting	***Receptor Group***
Offshore	***Benthic Fauna Communities*** In the highly unlikely event of a loss of well containment at the seabed, the stochastic spill model predicted hydrocarbons droplets would be entrained in a gas plume, transporting them to the water column and sea surface. As a result, the low sensitivity benthic communities associated with the unconsolidated, soft sediment habitat and any epifauna (filter feeders) within and outside the Offshore Facility Operational Area are not expected to be exposed to released hydrocarbons. A localised area relating to the hydrocarbon plume at the point of release is predicted, which would result in a small area of seabed and associated epifauna and infauna exposed to hydrocarbons.
	Open Water – Productivity/Upwelling Primary production by plankton (supported by sporadic upwelling events in the offshore waters of the NWS) is an important component of the primary marine food web. Planktonic communities are generally mixed including phytoplankton (cyanobacteria and other microalgae) and secondary consuming zooplankton, such as crustaceans (e.g. copepods), and the eggs and larvae of fish and invertebrates (meroplankton). Exposure to hydrocarbons in the water column can result in changes in species composition with declines or increases in one or more species or taxonomic groups (Batten *et al.* 1998). Phytoplankton may also experience decreased rates of photosynthesis (Tomajka 1985). For zooplankton, direct effects of contamination may include toxicity, suffocation, changes in behaviour, or environmental changes that make them more susceptible to predation. Impacts on plankton communities are likely to occur in areas where entrained or dissolved aromatic hydrocarbon threshold concentrations are exceeded, but communities are expected to recover relatively quickly (within weeks or months). This is due to high population turnover with copious production within short generation times that also buffers the potential for long-term (i.e. years) population declines

	(International Tanker Owners Pollution Federation 2011a). Therefore, any impacts to planktonic communities present in the ZoC are short-term.
Islands and Mainland (Nearshore Waters)	***Open Water – Productivity/Upwelling*** Nearshore waters and adjacent offshore waters surrounding the offshore islands (e.g. Barrow and Montebello Islands) and to the west of the Ningaloo Reef system are known locations of seasonal upwelling events and productivity. The seasonal productivity events are critical to krill production, which supports megafauna aggregations such as whale sharks and manta rays in the region. This has the potential to result in lethal and sub-lethal impacts to a certain portion of plankton in affected areas, depending on concentration and duration of exposure and the inherent toxicity of the hydrocarbon. However, recovery would occur (see offshore description above). Therefore, any impacts are likely to be on exposed planktonic communities present in the ZoC and temporary in nature.
	Spawning/Nursery Areas Fish (and other commercially targeted taxa) in their early life stages (eggs, larvae and juveniles) are at their most vulnerable to lethal and sub-lethal impacts from exposure to hydrocarbons, particularly if a spill coincides with spawning seasons or if a spill reaches nursery areas close to the shore (e.g. seagrass and mangroves) (International Tanker Owners Pollution Federation 2011b). Fish spawning (including for commercially targeted species) occurs in nearshore waters at certain times of the year and nearshore waters are also inhabited by higher numbers of juvenile fishes than offshore waters. Modelling indicated that in the unlikely event of a major spill there is potential for entrained hydrocarbons to occur in the surface water layers above threshold concentrations in nearshore waters including, but not limited to the Ningaloo Coast. This, and the potential for possible lower concentration exposure for dissolved aromatic hydrocarbons, have the potential to result in lethal and sub-lethal impacts to a certain portion of fish larvae in affected areas, depending on concentration and duration of exposure and the inherent toxicity of the hydrocarbon. Although there is the potential for spawning/nursery habitat to be impacted (e.g. mangroves and seagrass beds, discussed above), losses of fish larvae in worst affected areas are unlikely to be of major consequence to fish stocks compared with significantly larger losses through natural predation, and the likelihood that most nearshore areas would be exposed is low (i.e. not all areas in the region would be affected). This is consistent with a recent study in the Gulf of Mexico which used juvenile abundance data, from shallow-water seagrass meadows, as indices of the acute, population-level responses of young fishes to the Deepwater Horizon spill (Fodrie and Heck 2011). Results indicated that there was no change to the juvenile cohorts following the Deepwater Horizon spill. Additionally, there were no significant post-spill shifts in community composition and structure, nor were there changes in biodiversity measures (Fodrie and Heck 2011). Any impacts to spawning and nursery areas are expected to be minor and short term, as would flow on effects to adult fish stocks into which larvae are recruited.
	Reefs The reef communities fringing the offshore Ningaloo Coast may be exposed to entrained hydrocarbons (> 94 ppb) and consequently exhibit lethal or sub-lethal impacts resulting in partial or total mortality of keystone sessile benthos, particularly, hard corals and thus potential community structural changes to these shallow, nearshore benthic communities may occur. If these reefs are exposed to entrained hydrocarbons, impacts are expected to result in localised long-term effects.
	Filter Feeders Hydrocarbon exposure to offshore, filter-feeding communities (e.g. deepwater communities of Ningaloo Coast in 20–200 m) may occur depending on the depth of the entrained and dissolved aromatic hydrocarbons. See discussion above on potential impacts.
	Sandy Shores/Estuaries/Tributaries/Creeks (Including Mudflats)/Rocky Shores Potential impacts may occur due to hydrocarbon contact with intertidal areas, including sandy shores, mudflats and rocky shores, listed in **Table 12-17.** Hydrocarbons at sandy shores are incorporated into fine sediments through mixing in the surface layers from wave energy, penetration down worm burrows and root pores. Hydrocarbons in the intertidal zone can adhere to sand particles however high tide may remove some or most of the hydrocarbons back off the sediments. Typically, hydrocarbon is only incorporated into the surface layers to a maximum of 10 cm. Given the hydrocarbons are non-persistent, long-term impacts to shores are not expected. The impact of hydrocarbons on rocky shores will be largely dependent on the incline and energy environment. On steep/vertical rock faces on wave exposed coasts there is likely to be no impact from a spill event. However, a gradually sloping boulder shore in calm water can potentially trap large amounts of hydrocarbon (International Petroleum Industry Environmental Conservation Association 2000). The impact of the spill on marine organisms along the rocky coast will be dependent on the toxicity and weathering of the hydrocarbon however no shoreline accumulation is predicted. The

	location of rocky shores where impacts are predicted are at Barrow/Montebello/Lowendal Islands group. Intertidal mudflats are susceptible to potential impacts from hydrocarbons as they are typically low energy environments and therefore trap hydrocarbons. The extent of oiling is influenced by the neap and spring tidal cycle and seasonal highs and lows affecting mean sea level. Potential impacts to tidal flats include heavy accumulations covering the flat at low tide; however, it is unlikely that hydrocarbon will penetrate the water-saturated sediments except through animal burrows and root pores. It has been demonstrated that infaunal burrows allow hydrocarbons to travel down to subsurface sediments where it can be retained for months. Again, no floating or accumulated hydrocarbons are predicted along shorelines, therefore impacts are expected to be limited. Potential impacts may occur due to entrained contact with shallow, subtidal and intertidal zones of the Ningaloo Coast, Barrow Island, Montebello Islands and the Pilbara Southern Islands. In-water toxicity of the dissolved and entrained hydrocarbons reaching these shores will determine impacts to the marine biota such as sessile barnacle species and/or mobile gastropods and crustaceans such as amphipods. Lethal and sub-lethal impacts may be expected where the entrained hydrocarbon concentration threshold is > 94 ppb. Impacts may result in localised changes to the community structure of these shoreline habitats which would be expected to recover in the medium term (two to five years).
Key Ecological Features	***Key Ecological Features*** The KEFs potentially impacted by the hydrocarbon spill from a loss of well containment event are: • Ancient Coastline at 125 m Depth Contour • Glomar Shoals • Continental Slope Demersal Fish Communities • Exmouth Plateau • Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula • Commonwealth waters adjacent to Ningaloo Reef. Although these KEFs are primarily defined by seabed geomorphological features, they are described to identify the potential for increased biological productivity and, therefore, ecological significance. The consequences of a hydrocarbon spill from a loss of well containment may impact the values of the KEFs affected. Potential impacts include the contamination of sediments, impacts to benthic fauna/habitats and associated impacts to demersal fish populations and reduced biodiversity as described above and below. Most of the KEFs within the ZoC have relatively broad-scale distributions and are unlikely to be significantly impacted.
Summary of potential impacts to water quality	
Setting	***Aspect***
Offshore and Mainland and Islands (Nearshore waters)	***Open Water – Water Quality*** Water quality would be affected due to hydrocarbon contamination which is described in terms of the biological effect concentrations. These are defined by the ZoC descriptions for each of the entrained and dissolved hydrocarbon fates and their predicted extent. Furthermore, water quality is predicted to have minor long term and/or significant short-term hydrocarbon contamination above background compared to background water quality.

Summary of potential impacts to marine sediment quality	
Setting	***Receptor Group***
Offshore	***Marine Sediment Quality*** Studies of hydrocarbon concentrations in deep sea sediments in the vicinity of a catastrophic well blowout indicated hydrocarbon from the blowouts can be incorporated into sediments (Romero *et al.* 2015). Proposed mechanisms for hydrocarbon contamination of sediments include sedimentation of hydrocarbons and direct contact between submerged plumes and the seabed (Romero *et al.* 2015). In the event of a major hydrocarbon release at the seabed, modelling indicates that a pressurised release of condensate would generate a cone of rising gas that will entrain oil droplets and transported them to the surface. As a result, the extent of potential impacts to the seabed area at and surrounding the release site would be confined to a localised footprint. Marine sediment quality would be reduced as a consequence of hydrocarbon contamination for a small area within the immediate release site for a long to medium term.
Mainland and Islands (Nearshore waters)	***Marine Sediment Quality*** Entrained and dissolved hydrocarbons (at or above the defined thresholds) are predicted to potentially contact shallow, nearshore waters of identified islands and mainland coastlines and hydrocarbons may accumulate (at or above the ecological threshold) at a range of nearshore receptors (refer to **Table 12-17**). Such hydrocarbon contact may lead to reduced marine sediment quality by several processes, such as adherence to sediment and deposition shores or seabed habitat.
Summary of potential impacts to air quality	
A hydrocarbon release during a loss of well containment has the potential to result in localised, temporary reduction in air quality and contribution of greenhouse gases to the global concentration of these gases in the atmosphere. The ambient concentrations of methane and VOCs released from diffuse sources is difficult to accurately quantify, although the behaviour and fate is predictable in open offshore environments as it is dispersed rapidly by meteorological factors such as wind and temperature. Methane and VOC emissions from a hydrocarbon release in such environments are rapidly degraded in the atmosphere by reaction with photo chemically-produced hydroxyl radicals. Due to the unlikely occurrence of a loss of well containment; the temporary nature of any methane or VOC emissions (from either gas surfacing or weathering of liquid hydrocarbons from a loss of well containment); the predicted behaviour and fate of methane and VOCs in open offshore environments; and the significant distance from the Operational Area to the nearest sensitive air shed (town of Dampier approximately 135 km away), the potential impacts are expected to be minor and short-term.	
Summary of potential impacts to protected areas	
The quantitative spill risk assessment results indicate that the open water environment protected within the Commonwealth marine parks listed in refer to **Table 12-17** may be affected by the released hydrocarbons. In the unlikely event of a major spill, entrained hydrocarbons and/or dissolved hydrocarbons may contact the identified key receptor locations of islands and mainland coastlines, resulting in the actual or perceived contamination of protected areas as identified for the ZoC (refer to **Table 12-17**). Objectives in the Ningaloo Marine Park (Commonwealth Waters) Management Plan and the Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area require considerations to a number of physical, ecological and social values identified in these areas. Impact on the values of this protected area is discussed in the relevant sections above for ecological and physical (water quality) values and below for social (socio-economic) values. Additionally, such hydrocarbon contact may alter stakeholder understanding and/or perception of the protected marine environment, given these represent areas largely unaffected by anthropogenic influences and contain biological diverse environments.	

Summary of potential impacts to socio-economic values	
Setting	**Receptor Group**
Offshore	**Fisheries – Commercial** Spill scenarios modelled are unlikely to cause significant direct impacts on the target species of Commonwealth and offshore State fisheries within the defined ZoC. Further details are provided below (impact assessment relating to spawning is discussed above under 'Summary of potential impacts to other habitats and communities'). Fish exposure to hydrocarbon can result in 'tainting' of their tissues. Even very low levels of hydrocarbons can impart a taint or 'off' flavour or smell in seafood. Tainting is reversible through the process of depuration which removes hydrocarbons from tissues by metabolic processes, although it is dependent upon the magnitude of the hydrocarbon contamination. Fish have a high capacity to metabolise these hydrocarbons while crustaceans (such as prawns) have a reduced ability (Yender *et al.* 2002). Seafood safety is a major concern associated with spill incidents. Therefore, actual or potential contamination of seafood can affect commercial and recreational fishing and can impact seafood markets long after any actual risk to seafood from a spill has subsided (Yender *et al.* 2002). A major spill would result in the establishment of an exclusion zone around the spill affected area. There would be a temporary prohibition on fishing activities for a period of time and subsequent potential for economic impacts to affected commercial fishing operators.
	Tourism including Recreational Activities Recreational fishers predominantly target tropical species, such as emperor, snapper, grouper, mackerel, trevally and other game fish. Recreational angling activities include shore-based fishing, private boat and charter boat fishing, with the peak in activity between April and October (Smallwood *et al.* 2011). Limited recreational fishing takes place in the offshore waters of the Operational Area due to the distance from shore; however, fishing may take place at Glomar Shoals. Impacts on species that are recreationally fished are described above and under 'Summary of potential impacts to other species' above. A major loss of hydrocarbon from the Petroleum Activities Program may lead to exclusion of marine nature-based tourist activities, resulting in a loss of revenue for operators.
	Offshore Oil and Gas Infrastructure In the unlikely event of a major spill, surface hydrocarbons may affect production from existing petroleum facilities (platforms and FPSOs). For example, facility water intakes for cooling and fire hydrants could be shut off which could in turn lead to the temporary cessation of production activities. Spill exclusion zones established to manage the spill could also prohibit activity support vessel access as well as tankers approaching facilities on the NWS. The impact on ongoing operations of regional production facilities would be determined by the nature and scale of the spill and metocean conditions. Furthermore, decisions on the operation of production facilities in the event of a spill would be based primarily on health and safety considerations. The closest oil and gas operation is the GWA platform (operated by Woodside). Other nearby facilities include a Chevron-operated platform. Operation of these facilities is likely to be affected in the event of a worst-case loss of well containment.
Mainland and Islands (Nearshore Waters)	**Fisheries – Commercial** *Nearshore Fisheries and Aquaculture:* In the unlikely event of a loss of well containment, there is the possibility that target species in some areas utilised by a number of state fisheries in nearshore waters between Dampier and the Ningaloo Coast, and aquarium fisheries and aquaculture activities (**Table 12-17**) in the nearshore waters that are within the ZoC could be affected. Targeted fish resources could experience sub-lethal stress, or in some instances, mortality depending on the concentration and duration of hydrocarbon exposure and its inherent toxicity. *Prawn Managed Fisheries:* In the highly unlikely event of a major spill, the modelling indicated the entrained ZoC may extend to nearshore waters closest to the mainland coasts, including the areas that are utilised by the Nickol Bay and Onslow prawn fishery. However recent fishing effort, based on 2016 data, has been limited in these fisheries. Prawn habitat utilisation differs between species in the post-larval, juvenile and adult stages (Dall *et al.* 1990) and direct impacts to benthic habitat due to a major spill has the potential to impact prawn stocks. For example, juvenile banana prawns are found almost exclusively in mangrove-lined creeks, whereas juvenile tiger prawns are most abundant in areas of seagrass (Masel and Smallwood 2000). Adult prawns also inhabit coastline areas but tend to move to deeper waters to spawn. In the highly unlikely event of a major spill, the model predicted shallow subtidal habitats at the Ningaloo Coast, and mangrove and seagrass habitats of the Montebello/Barrow/Lowendal are located within the ZoC and could be exposed to hydrocarbon concentrations above threshold concentrations, depending on the trajectory of the plume. However, modelling indicated the Zoc will not extend to the intertidal areas along the Ningaloo coast. Localised loss of juvenile prawns in worse spill affected areas is possible.

	Whether lethal or sub-lethal effects occur will depend on duration of exposure, hydrocarbon concentration and weathering stage of the hydrocarbon and its inherent toxicity. Furthermore, seafood consumption safety concerns and a temporary prohibition on fishing activities may lead to subsequent potential for economic impacts to affected commercial fishing operators.
	Fisheries – Traditional Although no designated traditional fisheries have been identified it is recognised that Indigenous communities' fish in the shallow coastal and nearshore waters of Ningaloo Reef, and therefore, may be potentially impacted if a hydrocarbon spill from a loss of well containment were to occur. Impacts would be similar to those identified for commercial fishing in the form of a potential exclusion zone and contamination/tainting of fish stocks.
	Tourism and Recreation In the unlikely event of a major spill, the nearshore waters of the Murion Island and northern Ningaloo Coast (reaching just the tip of the North West Cape) could be reached by entrained hydrocarbon, depending on prevailing wind and current conditions. This location offers a number of amenities such as fishing, swimming and utilisation of beaches and surrounds have a recreational value for local residents and visitors (regional, national and international). In the event of a major spill, tourists and recreational users may also avoid areas due to perceived impacts, including after the hydrocarbon spill has dispersed. There is potential for stakeholder perception that this remote environment will be contaminated over a large area and for the longer term resulting in a prolonged period of tourism decline. Oxford Economics (2010) assessed the duration of hydrocarbon spill related tourism impacts and found that on average, it took 12 to 28 months to return to baseline visitor spending. There is likely to be, resulting in moderate, medium term impacts to the tourism industry, wider service industry (hotels, restaurants and their supply chain) and local communities in terms of economic loss as a result of spill impacts to tourism. Recovery and return of tourism to pre-spill levels will depend on the size of the spill, effectiveness of the spill clean-up and change in any public misconceptions regarding the spill (Oxford Economics 2010).
	Cultural Heritage There are a number of historic shipwrecks identified in the vicinity of the Operational Area. Shipwrecks occurring in the subtidal zone will be exposed to entrained and dissolved hydrocarbons and marine life that shelter and take refuge in and around these wrecks may be affected by in-water toxicity of dispersed hydrocarbons. The consequences of such hydrocarbon exposure may include all or some of the following: large fish species moving away and/or resident fish species and sessile benthos such as hard corals exhibiting sub-lethal and lethal impacts (which may range from physiological issues to mortality). Entrained hydrocarbons above threshold concentrations (> 500 g/m^2) are predicted at the Montebello/Barrow/Lowendal islands. Artefacts, scatter and rock shelters are located on land above the high-water mark on Barrow and Montebello islands, therefore no contact by surface or accumulated hydrocarbons are predicted for these areas. Additionally, within the wider ZoC a number of places are designated World, National and Commonwealth heritage places. These places are also covered by other designations such as WHA, marine parks, and listed shipwrecks. Potential impacts have, therefore been discussed in the sections above.

Summary of Control Measures

- Maintain well mechanical integrity to contain reservoir fluids within the well envelope to avoid a MEE
- Maintain availability of critical external and internal communication systems to facilitate prevention and response to accidents and emergencies
- Maintain Fire and Gas Detection and Alarm Systems on NRC to facilitate prevention and response to fire or gas hazards
- Maintain Safety Instrumented System (Safety Instrumented Functions and ESD actions) to detect and respond to pre-defined initiating conditions and/or initiate responses that put the process plant, equipment, and the wells in a safe condition so as to prevent or mitigate the effects of a MEE
- Maintain environmental incident response equipment to enact the NRC First Strike Plan
- Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011: Accepted WOMP
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC
- Incident reports are raised for unplanned releases within event reporting system.

Unplanned Hydrocarbon Release: Subsea Equipment Loss of Well Containment (MEE-02)

Impacts and Risks Evaluation Summary													
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Release of hydrocarbons resulting from subsea equipment loss of containment within the NRC exclusion zone.		X	X	X	X	X	X	B	B	1	M	LC S GP PJ RB A CV SV	Acceptable if ALARP
Release of hydrocarbons resulting from subsea equipment loss of containment outside the NRC exclusion zone.		X	X	X	X	X	X	B	B	0	M		

Description of Source of Risk

The North Rankin Complex is connected to the following facilities: (1) Goodwyn Alpha Platform (GWA) via a 23 km, 30" inter-field pipeline (IFL); (2) KGP via two 130 km, 40" (1TL) and 42" (2TL) trunklines; (3) Angel Platform via a 50 km, 30" pipeline; (4) Okha Floating Production Storage and Offloading Vessel via a 33 km, 12" pipeline; and (5) two subsea Persephone production wells via an approximately 6.8 km, 12" flexible flowline. The 40" 1TL, 30" IFL and Persephone flexible flowline are connected to NRA topside though risers. All other pipelines are connected to either 1TL or 2TL via various different subsea tie-in assemblies for export to shore. NRC has full remote-control capability over Angel and remote monitoring capability over the other interconnecting facilities.

The hazard associated with this Major Environment Event (MEE) is hydrocarbons conveyed in NRC platform subsea equipment (pipelines, flowlines, risers and associated equipment) within the 500 m exclusion zone, via the 1TL and 2TL from the NRC 500 m exclusion zone to KGP and for the Persephone subsea infrastructure and flowline.

The MEE associated with this hazard is loss of containment from the subsea equipment of 1TL, IFL or 2TL resulting in a hydrocarbon release to the environment. A loss of containment from Persephone subsea infrastructure and flowline does not result in a MEE due to a significantly lower uncontained volume in the event of a spill. The Persephone flowline release scenario is included in the bowtie for this MEE to demonstrate which controls apply for this infrastructure.

A decision type 'B' has been applied to this risk under the Oil and Gas UK Decision Support Framework. This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie Methodology and oil trajectory spill modelling. Company and societal values were also considered in the demonstration of ALARP and acceptability, through peer review, benchmarking and stakeholder consultation.

The pipeline, flowline and riser design include a range of measures that specifically aid in minimising the risk of external damage; these include:

- material selection for strength and corrosion resistant properties
- subsea and surface valves to isolate pipelines from the facility and vice versa
- subsea shutdown system closes on loss of hydraulic pressure
- construction and installation techniques such as stabilisation and self-burial
- design of subsea equipment which takes into consideration snag potential and, where practicable, is snag
- resistant
- installation of flowline low pressure alarms (set above minimum operating pressure)

- flowline specifications upgraded in line with changing technologies.

The potential hazard sources that could instigate a loss of containment from the NRC pipelines and risers are:

- internal corrosion
- external corrosion
- erosion (Persephone)
- overpressure
- under pressure
- high temperature
- equipment fatigue (risers and structural supports)
- pipeline stability and free spans
- anchor impact / dragging
- loss of control of suspended load from visiting vessel.

Escalation from other MEEs can cause Subsea Equipment Loss of Containment:

- loss of Structural Integrity (MEE-04)
- loss of Marine Vessel Separation (MEE-05)
- loss of Control of Suspended Load from NRC platform(s) (MEE-06).

Although anchor impact / dragging are potential hazard sources, typical commercial trawling practices are not considered credible to result in pipeline loss of containment, given structural protection frames are in place for key subsea infrastructure (e.g. manifolds) according to design risk-based analysis. The NRC/PSP development area is located outside of the two demersal trawl fishing areas within proximity of the North West Shelf. Maintenance of subsea infrastructure structural protection frames are included in mechanical integrity controls set out for pipeline, integrity performance standard P09-Pipeline System.

Subsea Equipment Loss of Containment – Credible Scenarios

The worst-case credible hydrocarbon release scenario is the rupture of the 1TL subsea hydrocarbon export trunkline which holds the largest hydrocarbon inventory within the NRC subsea system. This could result in a 12-hour subsea release of up to 9,228 m^3 of Angel Condensate and associated gas, based on an instantaneous full bore release, with activation of the emergency shutdown systems within 10 seconds. This scenario assumes 1TL is being fully supplied by Angel wells (Angel Condensate) which are more condensate rich than NRC wells. The modelling case presented is a rupture of the mid-point of 1TL based on proximity to sensitive receptors (Montebello Islands) and the influence of prevailing currents at this location. The scenario of a subsea equipment release at the sea surface from the 1TL or IFL riser at the NRC platform was also identified but deemed to be of lesser consequence due to the smaller volume of isolatable hydrocarbon inventory and greater distance from sensitive receptors. The subsea loss of containment scenario parameters are summarised in **Table 12-18**.

Table 12-18: Summary of worst-case subsea loss of containment hydrocarbon release scenario

Scenario	***Hydrocarbon***	***Duration (hrs)***	***Depth (m)***	***Latitude (D° M'S'' S)***	***Longitude (D° M'S'' E)***	***Total Condensate Release Volume***
Scenario 3 – Rupture of 1TL at the mid-point	Angel Condensate	12	56.5	20°5'41.19"S	116°28'45.6708"E	9,228 m^3

Decision Type, Risk Analysis and ALARP Tools

Woodside has a good history of implementing industry standard practice in subsea system design and construction. The NRC has never experienced a worst-case subsea loss of containment in its operational history.

Decision Type

A decision type 'B' has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie methodology and hydrocarbon spill trajectory modelling. Company were also considered in the demonstration of ALARP and acceptability.

The release of hydrocarbons as a result of subsea equipment loss of containment is considered a Major Environment Event (MEE-02). The hazard associated with this MEE is hydrocarbons in subsea infrastructure (pipelines, flowlines, manifolds etc.) tied to or originating from the NRC.

Quantitative Spill Risk Assessment

Spill modelling of each of the subsea loss of containment credible spill scenarios was undertaken by RPS APASA, on

behalf of Woodside, to determine the fate of hydrocarbon released in Scenario 3 based on the assumptions in **Table 12-18**. Modelling was undertaken over all seasons to address year-round operations. This is considered to provide a conservative estimate of the ZoC and the potential impacts from the identified worst-case credible release volumes for all subsea loss containment scenarios.

Likelihood

In accordance with the Woodside Risk Matrix, given prevention and mitigation measures in place (i.e. design, inspection and maintenance, pipeline marked on marine charts), the likelihood for the worst-case credible scenario presented has been assessed as 0 (Remote). For the scenario of a release at the sea surface from subsea equipment near the NRC platforms, a higher likelihood of 1 (Highly Unlikely) is applied due to the potential for dropped objects within the NRC 500m exclusion zone.

Consequence

The spatial extent and fate (incl. weathering) of the spilled hydrocarbon were considered during the impact assessment for a worst-case subsea or riser loss of containment (presented in the following section). These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS, available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.

Consequence Assessment

Potential Impacts to Marine Sediment, Water Quality, Air Quality, Ecosystems/Habitats, Species and Socio-Economic Environment

Zone of Consequence

Surface Hydrocarbons

Quantitative spill modelling indicated the potential for floating oil > 10 g/m^2 extending up to 50 km from the release location. Therefore, only offshore receptors are predicted to be contacted by floating hydrocarbons.

Entrained Hydrocarbons

Quantitative hydrocarbon spill modelling results for entrained hydrocarbons are summarized in **Table 12-19.** Modelling results indicated only two sensitive receptors may be contacted by entrained hydrocarbons above impact thresholds, with time to contact approximately 4 days (Montebello Islands; Glomar Shoals). In the highly unlikely event of a worst-case subsea loss of containment scenario occurring, entrained hydrocarbons at or above 94 ppb are forecast to potentially extend up to 468 km from the release site. The most likely direction of drift is south-westerly towards the Ningaloo Coast, reflecting the prevailing current patterns. Results also indicate that entrained oil may also be likely to drift towards the northeast and in the offshore directions at lower probabilities.

Dissolved Hydrocarbons

Modelling results indicated only two sensitive receptors may be contacted by dissolved hydrocarbons above impact thresholds, Montebello Islands and Glomar Shoals. In the highly unlikely event of a subsea loss of containment scenario occurring, dissolved hydrocarbons at or above 94 ppb are forecast to potentially occur up to 303 km from the release site.

Accumulated Hydrocarbons

Though there is no predicted shoreline contact, above impact thresholds for surface, entrained and dissolved hydrocarbons, modelling has indicated that there is the potential for shoreline accumulation above impact thresholds at a number of receptors (**Table 12-19**). Modelling indicated that hydrocarbons may be stranded on shorelines from the Kimberley to the Pilbara Islands (Southern Island Group).

Consequence Assessment Summary

The credible worst-case hydrocarbon spill scenarios that may arise from MEE-02 may impact upon a range of environmental receptors; refer to **Table 12-19** for a summary of receptors identified by the stochastic spill modelling studies. Potential impacts of a hydrocarbon spill to these receptors are considered in MEE-01. Further details are provided below on the potential impacts from hydrocarbon shoreline accumulation.

The credible worst-case hydrocarbon volumes that can credibly be released by MEE-02 are significantly smaller than the credible worst-case loss of well containment volumes considered in MEE-01. Additionally, the credible release durations are significantly shorter.

Table 12-19: Key receptor locations and sensitivities potentially contacted above impact thresholds by the loss of well containment scenario with summary hydrocarbon spill contact

Environmental setting	Location / name	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions																													Hydrocarbon contact and fate (Condensate)			
		Physical		Biological																														
				Marine Primary Producers			Other habitats / Communities								Protected Species									Other Species		Socio-economic								
		Openwater – (prisitine)	Marine Sediment (pristine)	Coral reef	Seagrass beds / Macroalgae	Mangroves	Spawning/nursery areas	Open water – Productivity/upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries / tributaries / creeks / lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and interesting areas and significant nesting	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident /Demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and Recreation	Protected Areas / Heritage – European and Indigenous / Shipwrecks	Offshore Oil and Gas Infrastructure (topside and subsea)	Surface hydrocarbon (≥10g/m2)	Entrained hydrocarbon (≥94 ppb)	Dissolved hydrocarbon (≥94 ppb)	Accumulated hydrocarbon (≥10g/m2)
Offshore	Commonwealth waters	✓	✓				✓								✓	✓					✓	✓	✓	✓		✓		✓		✓	x	x	x	
	Montebello AMP	✓	✓	✓			✓	✓							✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			x	x	
Submerged Shoals	Glomar Shoals	✓	✓	✓			✓	✓		✓						✓					✓	✓		✓	✓	✓		✓				x	X	
Oceanic Reefs and Offshore Islands	Rowley Shoals (including Sate Maine Park)	✓	✓	✓			✓	✓				✓				✓			✓	✓		✓	✓	✓	✓			✓	✓					X
Islands	Lacapede Islands	✓	✓	✓	✓							✓							✓			✓	✓	✓	✓				✓					X
	Montebello Islands (including State Marine Park)	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			x	X	x
	Barrow Island (including State Nature Reserves, State Marine Park and Marine Management Area)	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			x	X
	Lowendal Islands (including State Nature Reserve)	✓	✓	✓	✓		✓	✓				✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					X
	Pilbara Islands – Southern Island Group (Serrurier, Thevenard and Bessieres Islands – State Nature Reserves)	✓	✓		✓		✓		✓			✓		✓		✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓					X

Environmental setting	Location / name	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions																														Hydrocarbon contact and fate (Condensate)			
		Physical		Biological																															
				Marine Primary Producers			Other habitats / Communities								Protected Species									Other Species		Socio-economic								
		Openwater – (prisitine)	Marine Sediment (pristine)	Coral reef	Seagrass beds / Macroalgae	Mangroves	Spawning/nursery areas	Open water – Productivity/upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries / tributaries / creeks / lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and interesting areas and significant nesting	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident /Demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and Recreation	Protected Areas / Heritage – European and Indigenous / Shipwrecks	Offshore Oil and Gas Infrastructure (topside and subsea)	Surface hydrocarbon (≥10g/m2)	Entrained hydrocarbon (≥94 ppb)	Dissolved hydrocarbon (≥94 ppb)	Accumulated hydrocarbon (≥10g/m2)
	Pilbara Islands – Northern Island Group (Sandy Island Passage Islands – State Nature Reserves)	✓	✓		✓		✓		✓			✓		✓		✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓	✓				X
Mainland (nearshore waters)	Dampier Archipelago	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓					X
	Kimberly Coast	✓	✓		✓	✓			✓			✓	✓			✓	✓		✓	✓		✓	✓	✓	✓			✓						X
	Eighty Mile Beach (including Marine Park and Ramsar site)	✓	✓		✓	✓						✓	✓				✓		✓	✓		✓	✓	✓	✓			✓	✓					X
	Northern Pilbara Shoreline	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓								X

Summary of Potential Impacts to Environmental Values(s)	
Summary of Potential Impacts to protected species	
Setting	***Receptor Group***
Islands and Mainland (nearshore waters)	***Marine Turtles*** Several marine turtle species utilise nearshore waters and shorelines for foraging and breeding (including internesting), with significant nesting beaches along the mainland coast and islands in potentially impacted locations such as the Kimberley Coast, Montebello/Barrow/Lowendal Islands group and Pilbara Islands (Southern Island Group). Many of these locations have been identified as BIA and/or critical habitats. Nesting beaches of these turtle habitat areas may be exposed to accumulated hydrocarbons exceeding impact threshold concentrations. The potential impacts of exposure are as discussed previously in Offshore – Marine Turtles. Hydrocarbon exposure can impact on turtles during the breeding season at nesting beaches. Contact with gravid adult females or hatchlings may occur on nesting beaches (accumulated hydrocarbons) Results from studies of nesting beaches subject to extensive oil pollution from the Deepwater Horizon spill indicated a significant reduction (approximately 44%) in turtle nest density during the nesting season immediately following the spill (Lauritsen et al. 2017). Lauritsen et al. (2017) partially attributed this reduction to direct (e.g. direct mortality of adults due to oiling or toxicity) and indirect (e.g. shoreline disturbance from response activities) impacts from the spill. There was a significant increase in nesting density in the years immediately following the spill, with nesting density returning to levels comparable to pre-spill densities within two nesting seasons (Lauritsen et al. 2017). This indicates that adult female turtles that avoided mortality may have deferred nesting during the spill until subsequent years. The significant decline in nesting density observed following the Deepwater Horizon spill represents a decline of approximately 36% of reproductive output of the turtle population in the study area (Lauritsen et al. 2017); given turtles may take over a decade to reach sexual maturity, the effects of such a reduction in reproductive output may take over a decade to appear in nesting related metrics (which are commonly used to monitor turtle populations). Based on the potential for impact and recovery of turtles, a worst-case hydrocarbon spill from a loss of containment from subsea equipment may result in reduced turtle numbers and nesting density; however, it would not be expected to result in elimination of a population. Impacts and subsequent recovery may take decades to occur. To date, no oil spills have been demonstrated to have resulted in elimination of a turtle population at any scale (Yender and Mearns 2010). Disastrous spills impacting important turtle habitat (including nesting areas) have not been shown to eliminate turtle populations, although direct and indirect impacts have been documented (e.g. Lauritsen et al. 2017, McDonald et al. 2017, Stacy et al. 2017, Vander Zanden et al. 2016). Turtle populations have been shown to be able to recover, even when populations have been reduced to small sizes after experiencing significant declines (Mazaris et al. 2017).

	Seabirds and/or Migratory Shorebirds In the event of a subsea equipment loss of containment, there is the potential for seabirds, and resident/non-breeding overwintering shorebirds that use the beaches for foraging and resting, to be exposed to accumulated hydrocarbons. This could result in lethal or sub-lethal effects. Pathways of biological exposure that can result in impact may occur through ingestion of contaminated invertebrates (intertidal foraging grounds such as beaches, mudflats and reefs). Ingestion can also lead to internal injury to sensitive membranes and organs (International Petroleum Industry Environmental Conservation Association 2004). Whether the toxicity of ingested hydrocarbons is lethal or sub-lethal will depend on the weathering stage and its inherent toxicity (note the shortest entrained hydrocarbon time to contact with a shoreline is four days (Montebello Islands)). Exposure to hydrocarbons may have longer term effects, with impacts to population numbers due to decline in reproductive performance and malformed eggs and chicks, affecting survivorship and loss of adult birds. Refer to Table 5-16 for locations within the predicted extent of the ZoC that are identified as habitat for seabirds/migratory shorebirds. Suitable habitat or seabirds and shorebirds are broadly distributed along the mainland and nearshore island coasts within the ZoC. Of note are important nesting areas including: • Eighty Mile Beach • Montebello/Barrow/Lowendal Islands group (including known nesting habitats on Boodie, Double and Middle Islands) • Pilbara Islands North and South Island Group. Therefore, a hydrocarbon spill may result in impacts on key feeding habitat and a disruption to a significant portion of the habitat; however, this is not expected to result in a threat to the overall population viability of seabirds or shorebirds.
Summary of potential impacts to other habitats and communities	
Setting	***Receptor Group***
	Sandy Shores/Estuaries/Tributaries/Creeks (including Mudflats)/Rocky Shores Shoreline exposure for the upper and lower areas differ. The upper shore has the potential to be exposed to surface slicks, while the lower shore is subjected to dissolved or entrained oil. Potential impacts may occur due to surface hydrocarbon contact with intertidal areas, including sandy shores, mudflats and rocky shores, listed in **Table 12-19**. Hydrocarbons at sandy shores are incorporated into fine sediments through mixing in the surface layers from wave energy, penetration down worm burrows and root pores (International Petroleum Industry Environmental Conservation Association 2000). Hydrocarbons in the intertidal zone can adhere to sand particles; however, high tide may remove some or most of the hydrocarbons back out of the sediments. Typically, hydrocarbons are only incorporated into the surface layers to a maximum of 10 cm (International Petroleum Industry Environmental Conservation Association 2000). It is predicted that a number of sandy shores along the coastline may have accumulated hydrocarbons ≥100 g/m^2 (see **Table 12-19**). As described earlier, accumulated hydrocarbons ≥100 g/m^2 could impact the survival and reproductive capacity of benthic epifaunal invertebrates living in intertidal habitat. The persistence of the hydrocarbons will be dependent on the wave exposure but can be months to years. The impact of oil on rocky shores is largely dependent on the incline and energy environment. On steep/vertical rock faces on wave exposed coasts, there is likely to be no impact from a spill event. However, a gradually sloping boulder shore in calm water can potentially trap large amounts of oil (International Petroleum Industry Environmental Conservation Association 2000). The impact of the spill on marine organisms along the rocky coast will be dependent on the toxicity and weathering of the hydrocarbon. Similar to sandy shores, accumulated hydrocarbons ≥100 g/m^2 could coat the epifauna along rocky coasts and impact the reproductive capacity and survival. The location of rocky shores where impacts are predicted are listed in Table 5-16. Intertidal mudflats are susceptible to potential impacts from hydrocarbons, as they are typically low energy environments and therefore trap oils. Intertidal mudflats have been identified in the ZoC along the Dampier Archipelago and the Pilbara coastline as well as Eighty Mile Beach (see Table 5-16). The extent of oiling is influenced by the neap and spring tidal cycle, and seasonal highs and lows affecting mean sea level. Potential impacts to tidal flats include heavy accumulations covering the flat at low tide; however, it is unlikely that oil will penetrate the water-saturated sediments. However, oil can penetrate fine sediments through animal burrows and root pores. It has been demonstrated that infaunal burrows allow hydrocarbons to enter subsurface sediments, where it can be retained for months. The toxicity of stranded surface hydrocarbons identified in Table 5-16 will determine impacts to marine biota such as sessile barnacle species and/or mobile gastropods and crustaceans such as

	amphipods. Impacts may result in localised changes to the community structure of these shoreline habitats, which would be expected to recover in the medium term (2–5 years).
Summary of potential impacts to protected areas	
The quantitative spill risk assessment results indicate shorelines protected within the State marine parks listed in refer to **Table 12-18** may be affected by the released hydrocarbons. In the unlikely event of a spill, hydrocarbons may become stranded on shorelines along identified key receptor locations of islands and mainland coastlines, resulting in the actual or perceived contamination of protected areas as identified for the ZoC (refer to **Table 12-18**). Additionally, such hydrocarbon contact may alter stakeholder understanding and/or perception of the protected marine environment, given these represent areas largely unaffected by anthropogenic influences and contain biological diverse environments.	

Summary of Control Measures

- Maintain pipeline, riser and hydrocarbon-containing infrastructure integrity to avoid a MEE.
- Maintain Fire and Gas Detection and Alarm Systems on NRC to facilitate prevention and response to fire or gas hazards
- Maintain availability of critical external and internal communication systems to facilitate prevention and response to accidents and emergencies
- Maintain Safety Instrumented System (Safety Instrumented Functions and ESD actions) to detect and respond to pre-defined initiating conditions and/or initiate responses that put the process plant, equipment, and the wells in a safe condition (e.g. through appropriate isolation of hazardous inventories) so as to prevent or mitigate the effects of a MEE
- Maintain environmental incident response equipment to enact the NRC First Strike Plan
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for NWS Pipelines
- Incident reports are raised for unplanned releases within event reporting system.

Unplanned Hydrocarbon Release: Topsides Loss of Containment (MEE-03)

Impacts and Risks Evaluation Summary													
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Hydrocarbon release from topside process equipment to the marine environment and atmosphere.			X	X	X	X	X	B	C	1	M	LCS GP PJ RBA CV SV	Acceptable if ALARP
Hydrocarbon release from topsides non-process equipment to the marine environment.			X	X	X	X	X	B	D	1	M		

Description of Source of Risk

The hydrocarbon processing equipment on the NRC contains a considerable volume of hydrocarbons. The hydrocarbon inventory of this processing equipment may be released, potentially resulting in hydrocarbons being released to the marine environment. Due to the potential consequences of a worst-case topsides loss of containment, this risk is a MEE (MEE-03).

The following events could lead to loss of containment from the topsides:

- internal corrosion
- external corrosion
- erosion
- overpressure
- low temperature
- equipment fatigue/ overstress
- rotating equipment failure/ uncontrolled transfer (including overflow)
- rotating equipment failure
- overheating of hot oil system
- tubing failure of hot oil system.

Escalation from other MEEs can also potentially lead to cause Topsides Loss of Containment:

- Loss of Structural Integrity (MEE-04)
- Loss of Marine Vessel Separation (MEE-05)
- Loss of Control of Suspended Load from NRC platform(s) (MEE-06)
- Loss of Controlled Flight is considered as a potential escalation cause, and is described in the NRC Safety Case [5] (MAE-09).

The largest isolatable topsides process inventory is the NRB Separation System which contains 78 m^3 of condensate and 290 m^3 of hydrocarbon gas. For NRA, the largest hydrocarbon liquid inventory is from the dewatering system (32 m^3) and hot oil (12 m^2).
The largest topsides non-process inventory is 440 m^3 from the Diesel Storage Leg B-2 on NRA and 180 m^3 on NRB.

Topsides Loss of Containment – Credible Hydrocarbon Spill Scenario

The following hydrocarbon inventories were considered as the worst-case topsides loss of containment scenario:

Scenario 4 – Instantaneous release from the NRC of:

- Topsides process: 78 m^3 NWS Condensate
- Topsides non-process: 440 m^3 Marine Diesel

The locations, hydrocarbon types and volumes for Scenario 4 are provided in **Table 12-20.**

Table 12-20: Summary of worst-case topsides loss of containment hydrocarbon release scenario

Scenario	Hydrocarbon	Duration (hrs)	Depth (m)	Latitude (D°M'S'' S)	Longitude (D°M'S'' E)	Total Release Volume (m^3)
Scenario 4 – Topsides loss of containment	NWS Condensate	Instantaneous	Surface	19°35'08.02"	116°08'12.28"	78
	Marine Diesel	Instantaneous	Surface	19°35'08.02"	116°08'12.28"	440

Decision Type, Risk Analysis and ALARP Tools

Woodside has a good history of implementing industry standard practice in topsides design and construction. The NRC has never experienced a worst-case topsides loss of containment in its operational history.

Decision Type

A decision type 'B' has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie Methodology and hydrocarbon spill trajectory modelling. Company values were also considered in the demonstration of ALARP and acceptability.

The release of hydrocarbons as a result of topsides loss of containment is considered a Major Environment Event (MEE-03). The hazard associated with this MEE is hydrocarbon inventory on the NRC in process and non-process equipment.

Quantitative Spill Risk Assessment

Spill modelling of the marine diesel component of Scenario 4 was undertaken by RPS, on behalf of Woodside, to determine the fate of hydrocarbon based on the assumptions in **Table 12-20**. Note that modelling of the topsides process condensate loss of containment was not undertaken; the modelling used to inform the diesel loss of containment has been considered as a worst-case analogue. For the diesel scenario, a conservative surrogate modelling scenario has been used to inform the consequence. The surrogate scenario applied is a modelled 500 m^3 marine diesel loss of containment from the GWF-1 project which is in near proximity and in similar conditions to the NRC.

Modelling was undertaken over all seasons to address year-round operations. This is considered to provide a conservative estimate of the ZoC and the potential impacts from the identified worst-case credible release from a topsides loss of containment.

Likelihood

In accordance with the Woodside Risk Matrix, a worst-case topsides loss of containment has been defined as a 'Highly Unlikely' event as it is 'has occurred once or twice in the industry' (experience-based likelihood) and aligns with a frequency of a '1 in 10,000 to 1 in 100,000 year' event.

Consequence

The spatial extent and fate (incl. weathering) of the spilled hydrocarbon were considered during the impact assessment for a worst-case topsides loss of containment (presented in the following section). These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS, available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.

Consequence Assessment

Potential Impacts Overview

Zone of Consequence

Surface Hydrocarbons

The gas and condensate components of a worst-case topsides loss of containment are not expected to result in surface hydrocarbons above impact thresholds (> 10 g/m^2). The diesel component may result in floating hydrocarbons beyond the immediate vicinity of the release location. No contact of floating hydrocarbons above impact thresholds with key receptor locations was indicated by the modelling.

Entrained Hydrocarbons

The diesel component of a topside release has the potential to become entrained and may extend beyond the release location. Entrained hydrocarbons from the condensate component of a topsides release may become entrained and hence, extend beyond the vicinity of the release location however it is expected to be within the diesel modelled scenario due to the considerably smaller volumes. No contact of entrained hydrocarbons above impact thresholds with key receptor locations was indicated by the modelling.

Dissolved Hydrocarbons

Dissolved hydrocarbons above impact thresholds from a topsides loss of containment are expected to be localised to the immediate area around the release location. Modelling of the diesel component of a topside release did not indicate dissolved hydrocarbons above impact thresholds would occur. No contact with key receptor locations above impact thresholds is expected to occur.

Accumulated Hydrocarbons

No accumulated hydrocarbons above impact thresholds were predicted by modelling for the release scenarios considered in MEE-03.

Consequence Assessment Summary

The credible worst-case hydrocarbon spill scenario that may arise from MEE-03 may impact upon the open water environment in the vicinity of the NRC platforms. Hydrocarbon spill modelling of the marine diesel component of the credible worst-case scenario did not indicate contact above impact thresholds for any sensitive environmental receptors. As such, potential environmental impacts are expected to be restricted to open water sensitivities such as marine fauna.

The credible worst-case hydrocarbon volumes that can credibly be released by MEE-03 are significantly smaller than the credible worst-case loss of well containment volumes considered in MEE-01. Additionally, the credible release durations are instantaneous rather than protracted. These considerations are pertinent when considering the potential environmental impacts in relation to MEE-03.

Summary of Control Measures

- Maintain topsides hydrocarbon-containing infrastructure integrity
- Maintain Safety Instrumented Systems and relief system to prevent hydrocarbon loss of containment in order to prevent a MEE
- Maintain availability of critical external and internal communication systems to facilitate prevention and response to accidents and emergencies
- Maintain Fire and Gas Detection and Alarm Systems on NRC to facilitate prevention and response to fire or gas hazards
- Maintain Safety Instrumented Systems (e.g. ESD and safety instrumented functions) system, Blowdown and Open Hazardous Drains system to isolate, remove and control hazardous inventories so as to mitigate the effects of a MEE/ prevent escalation to a MEE
- Maintain environmental incident response equipment to enact the NRC First Strike Plan
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC
- Incident reports are raised for unplanned releases within event reporting system.

Unplanned Hydrocarbon Release: Loss of Structural Integrity (MEE-04)

Impacts and Risks Evaluation Summary													
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***					
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Hydrocarbon release from platform well to the marine environment and atmosphere		X	X	X	X	X	X	B	B	1	M	LCS GP PJ RBA CV SV	Acceptable if ALARP
Hydrocarbon release from subsea equipment to the marine environment and atmosphere		X	X	X	X	X	X	B	B	1	M		
Hydrocarbon release from topsides equipment to the marine environment and atmosphere			X	X	X	X	X	B	C	1	M		
Marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC		X	X	X	X	X	X	B	B	1	M		

Description of Source of Risk

Extreme environmental conditions or other causes which result in an exceedance of the design criteria and a catastrophic failure of the facility and individual equipment (e.g., cranes, flare tower, etc.) has been identified as a potential MEE (MEE-04). Catastrophic structural failure of the NRC could lead to the release of hydrocarbons from platform wells, topsides process and non-process hydrocarbon inventories, and pipeline inventories. A platform collapse includes the potential risk of the release of inventory above the SSSV for each platform well, riser inventory above SSIV and topsides inventories.

The following causes of structural failure of NRC were identified:

- Internal corrosion (e.g. of caissons)
- External Corrosion
- Fatigue
- Impact from a vessel collision (refer to MEE-05)
- Extreme weather (cyclone, high waves)
- Seismic events / seabed instability
- Fire / Overpressure event.

There is a possibility of platform collapse ('slow' or 'rapid') caused by the extreme loads induced by strong winds and extreme waves. Extreme weather may induce fracture of pipework due to vibration/fatigue and loosen/dislodge objects/projectiles causing impact to equipment/pipework and subsequently result in a loss of containment.

Structural damage to the platform resulting from the causes listed above could be minor or could in the most extreme situation result in total loss of the platform. The type of structural failure considered is restricted to major structural damage e.g. catastrophic collapse of the jacket or release of hydrocarbons on or adjacent to the platform. Such events are, by definition, beyond the design basis for the platform. Structural damage can affect any area of the platform.

Loss of Structural Integrity – Credible Hydrocarbon Spill Scenario

A loss of structural integrity could result in a significant release of hydrocarbons. Hydrocarbon releases may result in a spill to the marine environment, (MEE-01 - Well Loss of Containment), (MEE-02 – Subsea Equipment Loss of Containment) and (MEE-03 - Topsides Loss of Containment). In addition, vessel cargo, including diesel inventory could be spilled if the cause of the loss of platform integrity was a collision from a support vessel as per (MEE-05 - Loss of Marine Vessel Separation).

Worst case hydrocarbon release scenarios for platform well loss of containment, subsea loss of containment, topsides loss of containment that could result from loss of structural integrity of the NRC facility are discussed in the relevant sections referenced above. Relevant trajectory modelling as applicable to these scenarios is also discussed in the above-mentioned sections.

Decision Type, Risk Analysis and ALARP Tools

Woodside has a good history of implementing industry standard practice in structural design and construction. The NRC has never experienced a worst-case loss of containment due to structural failure in its operational history.

Decision Type

A decision type 'B' has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie Methodology and hydrocarbon spill trajectory modelling. Company and societal values were also considered in the demonstration of ALARP and acceptability, through peer review, benchmarking and stakeholder consultation.

The loss of structural integrity is considered a Major Environment Event (MEE-04). The hazards associated with this MEE is hydrocarbons in platform wells, pipelines, process and non-process inventories and potentially vessels, wellheads, and the NRC structure itself.

Quantitative Spill Risk Assessment

Credible worst-case hydrocarbon scenarios 1, 3, and 4 are considered to apply to a loss of structural integrity (MEE-4). Refer to the (Scenario 1), (Scenarios 3) and (Scenario 4) for a discussion of these credible worst-case spill scenarios.

Likelihood

In accordance with the Woodside Risk Matrix, the following likelihoods have been assigned to the sources of risk:

- Hydrocarbon release from platform well to the marine environment and atmosphere / Hydrocarbon release from topsides equipment to the marine environment and atmosphere
  - 'highly unlikely' event as it 'has occurred once or twice in the industry' (experience-based likelihood) and aligns with a frequency of a '1 in 10,000 to 1 in 100,000 year' event
- Marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC
  - 'highly unlikely' event as it 'has occurred once or twice in the industry' (experience-based likelihood) and aligns with a frequency of a '1 in 10,000 to 1 in 100,000 year' event.

Consequence

The spatial extent and fate (incl. weathering) of the spilled hydrocarbon and the potential seabed disturbance footprint from the NRC were considered during the impact assessment for a worst-case loss of structural integrity. These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS, available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.

Consequence Assessment

Potential Impacts Overview

Zone of Consequence

As discussed under Description of Source of Risk, the potential impacts from hydrocarbon release caused by a loss of structural integrity are those which would result from:

- well Loss of Containment, (MEE-01)
- subsea Equipment Loss of Containment, (MEE-02)
- topsides Loss of Containment, (MEE-03)
- loss of Marine Vessel Separation, (MEE-05).

The potential impacts are therefore discussed in the above-mentioned sections.

Seabed Disturbance

In the event of loss of structural integrity there is the potential for collapse of the platform leading to an incremental increase of the facility's footprint on the seabed. The potential area that would be affected can conservatively be defined as the existing NRC footprint plus 100 m in all directions, that is approximately 300 m by 350 m (0.105 km^2). The benthic habitats surrounding NRC have been subject to historical disturbance (e.g. NRC construction, discharge of drill cuttings) and are considered to be of low ecological value (although it is acknowledged that NRC provides artificial hard substrate, which has formed the basis of relatively high biodiversity communities when compared to the surrounding seabed). The physical disturbance to the seabed resulting from the collapse of NRC would be localised but result in long-term disturbance to benthic communities.

NRC could act as a source of environmental contaminants due to material onboard the platform (e.g. chemical / hydrocarbon inventories, corrosion of structural materials, debris etc.). The potential for contamination will diminish over time as the structure degrades. Depending on the nature of the loss of structural integrity, complete or partial salvage of the NRC structures may not be feasible. Any structures not able to be recovered will be left on the seabed indefinitely. These structures are expected to be colonized by marine organisms, and a reef habitat will develop over time on the structures.

Summary of Control Measures

- Maintain structural integrity to ensure availability of critical systems during a major accident or environment event and prevent structural failures from contributing to escalation of a MEE
- Maintain control of ignition sources and fire protection to prevent loss of structural integrity
- Maintain environmental incident response equipment to enact the NRC First Strike Plan
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC
- Incident reports are raised for unplanned releases within event reporting system.

Unplanned Hydrocarbon Release: Loss of Marine Vessel Separation (MEE-05)

Impacts and Risks Evaluation Summary													
Source of Risk	*Environmental Value Potentially Impacted*							*Evaluation*					
	Soil and Groundwater	Marine Sediment	Water Quality	Air Quality (incl. Odour)	Ecosystems/Habitat	Species	Socio-Economic	Decision Type	Consequence/Impact	Likelihood	Risk Rating	ALARP Tools	Acceptability
Hydrocarbon release from platform well to the marine environment and atmosphere		X	X	X	X	X	X	B	B	1	M	LCS GP PJ RBA CV SV	Acceptable if ALARP
Hydrocarbon release from subsea equipment near the NRC to the marine environment and atmosphere		X	X	X	X	X	X	B	B	1	M		
Hydrocarbon release from topsides equipment to the marine environment and atmosphere			X	X	X	X	X	B	C	1	M		
Marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC.		X	X	X	X	X	X	B	B	1	M		

Description of Source of Risk

A loss of marine vessel separation between a vessel and the NRC may result in a loss of hydrocarbon containment from the NRC and / or the release of fuel from the vessel. A vessel collision with the NRC has been identified as a potential MEE (MEE-05). Vessel collisions can arise from:

- Visiting vessel collisions associated with platform support vessels - ships which are visiting the platform can accidentally collide with the platform during approach to, or manoeuvring alongside, the platform.
- Errant passing vessel collision - ships which are not visiting the platform (i.e. passing vessels) can, for one reason or another, move off-course and collide with the platform.

The different collision hazards involve significantly different sized vessels and collision speeds, hence, differing impact energies and consequences, and have been assessed.

Visiting Vessels

Visiting vessels are defined as those which are routinely used to service the NRC. Operating procedures will dictate how vessels are operated, loaded and unloaded, but it will generally occur so that the prevailing winds move the vessel away from the facility. The primary causes of visiting vessel collisions are failure to follow safe procedures and communication errors between the marine vessels and platform operations. These errors could be worsened by the following:

- vessel station keeping failures
- vessel operations in adverse weather conditions.

A number of common failure causes due to human error and Safety Critical Equipment (SCE) failures are presented in the generic Human Error and SCE failure bowties.

Errant Passing Vessels

Errant passing vessels are defined as third-party vessels that enter the platform's 500 m Petroleum Safety Zone, but do not call at NRC or other installations (i.e. not platform or subsea support vessels). The collision can be powered or drifting. Either has the potential to cause significant damage to NRC.

The causes of errant passing vessel collisions include:

- failure of propulsion or steering systems
- adverse weather conditions resulting in poor visibility
- rough seas
- human error.

Woodside implements a range of control measures to mitigate the risk of errant vessel collision.

In addition to the potential for large hydrocarbon releases following impact by a vessel with the NRC structure, powered collisions from large passing vessels or tankers could have sufficient impact energy to breach both skins of the vessel to the extent that there is a loss of containment of cargo or fuel oil with the potential for significant loss of inventory and consequent environmental impact.

Loss of Vessel Separation – Credible Hydrocarbon Spill Scenario

The loss of marine vessel separation is considered a Major Environment Event (MEE-05). The hazards associated with this MEE is hydrocarbons in platform wells, pipelines, process and non-process inventories and potentially vessels, wellheads, and fuel onboard platform support vessels. A loss of marine vessel separation could result in a significant release of hydrocarbons. Hydrocarbon releases will result in a spill to the marine environment as described in (MEE-01 - Well Loss of Containment), (MEE-02 - Subsea Equipment Loss of Containment) and (MEE-03 - Topsides Loss of Containment). In addition, vessel cargo, including diesel inventory, could be spilled if the cause of the loss of platform integrity was a collision from a support vessel.

Worst case hydrocarbon release scenarios for platform loss of well containment (MEE-01), subsea equipment loss of containment (MEE-02) and topsides loss of containment (MEE-03) that could result from loss of marine vessel separation are discussed in the relevant sections referenced above. Relevant trajectory modelling as applicable to these scenarios is also discussed above.

A loss of vessel separation may lead to the accidental release of marine diesel from the fuel tanks on the vessel(s) involved. For a vessel collision to result in the worst-case scenario of a hydrocarbon spill potentially impacting an environmental receptor, several factors must align as follows:

- vessel interaction must result in a collision
- the collision must have enough force to penetrate the vessel hull
- the collision must be in the exact location of the fuel tank
- the fuel tank must be full, or at least of volume which is higher than the point of penetration.

The probability of the chain of events described above aligning, to result in a breach of fuel tanks resulting in a spill that could potentially affect the marine environment is considered highly unlikely. Given the offshore location of the Offshore Facility Operational Area, vessel grounding in relation to the Petroleum Activities Program is not considered a credible risk.

A collision between a platform, subsea support vessel, ASV or HLV with a third-party vessel (i.e. commercial shipping, other petroleum related vessels and commercial fishing vessels) was considered the only credible event that could release a significant quantity of marine diesel to the environment. This was assessed as being credible but highly unlikely given the platform support vessels typically operate in the Offshore Facility Operational Area, the presence of subsea vessels in the Offshore Facility Operational Area is typically temporary (e.g. while undertaking IMMR activities), vessels undertaking the Petroleum Activities Program typically operate of low speeds or are stationary, the standard vessel operations and equipment in place to prevent collision at sea, and the construction and placement of storage tanks. The largest tank of a platform support or subsea support vessel is unlikely to exceed 105 m^3. However, an HLV or ASV may have in the order of 1000 m^3 in an individual tank. Therefore, for the purposes of understanding the characteristics of a marine diesel release from a HLV or ASV, an instantaneous loss of 1000 m^3 has been selected as being representative of a worst-case spill scenario. Modelling of a 1000 m^3 was undertaken at the Pluto platform and used as a surrogate for a spill at the NRC location. The Pluto platform is approximately 90 km south west of NRC and therefore given the offshore location and proximity to the Offshore Facility Operational Area, likely to have similar metocean influences.

Decision Type, Risk Analysis and ALARP Tools

Woodside has not experienced any loss of marine vessel separation events that have resulted in significant environmental impacts. The NRC has never experienced a worst-case loss of containment due to loss of vessel separation in its operational history.

Decision Type

A decision type 'B' has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie Methodology and hydrocarbon spill trajectory modelling. Company and societal values were also considered in the demonstration of ALARP and acceptability, through peer review, benchmarking and stakeholder consultation.

Quantitative Spill Risk Assessment

Credible worst-case hydrocarbon spill scenarios 1, 3 and 4 are considered to apply to a loss of structural integrity (MEE-4). Refer to the (Scenario 1), (Scenarios 3) and (Scenario 4) for a discussion of these credible worst-case spill scenarios.

Likelihood

In accordance with the Woodside Risk Matrix, a likelihood of 'highly unlikely' event as it 'has occurred once or twice in the industry' (experience-based likelihood) and aligns with a frequency of a '1 in 10,000 to 1 in 100,000 years' has been assigned to each of the following events:

- hydrocarbon release from platform well to the marine environment and atmosphere
- hydrocarbon release from subsea equipment to the marine environment and atmosphere
- hydrocarbon release from topsides equipment to the marine environment and atmosphere.

In addition, a 'highly unlikely' likelihood with a frequency of a '1 in 10,000 to 1 in 100,000 year' has been assigned for:

- marine environment footprint and associated hydrocarbon and chemical release associated with structural collapse of NRC.

Consequence

The spatial extent and fate (incl. weathering) of the spilled hydrocarbon from the NRC and platform support vessels were considered during the impact assessment for a worst-case loss of marine vessel separation. These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS**,** available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.

Consequence Assessment

Potential Impacts Overview

Zone of Consequence

As discussed under Description of Source of Risk, the potential impacts from hydrocarbon release caused by a loss of marine separation are those which would result from:

- well Loss of Containment, (MEE-01)
- subsea Equipment Loss of Containment, (MEE-02)
- topsides Loss of Containment, (MEE-03).

The potential impacts are therefore discussed in the above-mentioned sections.

Zone of Consequence

Surface Hydrocarbons

The surface hydrocarbon spill is forecast to drift in all directions, reflecting the competing influence of both surface currents and winds across the wide area in which a large and persistent slick could travel over the long duration of the release. At the surface threshold of 10 g/m^2, floating oil is forecast to potentially occur up to 110 km from the release site. No contact with sensitive receptors, other than open water sensitivities and marine fauna, are predicted.

Entrained Hydrocarbons

Modelling results indicated the only environmental sensitivities that may be contacted by entrained hydrocarbons above impact thresholds is Rankin Bank. In the event of a worst-case loss of well containment scenario occurring, entrained hydrocarbons at or above 500 ppb are forecast to potentially extend up to 120 km from the release site

Dissolved Hydrocarbons

In the event of a loss of well containment scenario occurring, dissolved hydrocarbons at or above 500 ppb (environmental impact threshold) are not predicted within the model.

Summary of Potential Impacts to Environmental Values(s)

Rankin Bank, open ocean and the Montebello AMP are the only sensitive receptor locations expected to be contacted by hydrocarbons above impact thresholds. The credible worst-case hydrocarbon volumes that can credibly be released by MEE-05 are significantly smaller than the credible worst-case loss of well containment volumes considered in MEE-01 and MEE-02. Additionally, the credible release durations are significantly shorter.

Summary of Control Measures

- Maintain collision warning systems and navigational aids to alert facility of a potential collision with marine vessels, and to alert marine vessels of facility location so that they may take timely action to avoid the facility and hence reduce likelihood of collision
- Maintain availability of critical external and internal communication systems to facilitate prevention and response to accidents and emergencies
- Maintain environmental incident response equipment to enact the NRC First Strike Plan
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC
- Incident reports are raised for unplanned releases within event reporting system.

Unplanned Hydrocarbon Release: Loss of Control of Suspended Load from NRC Platform(s) Lifting Operations (MEE-06)

Impacts and Risks Evaluation Summary														
Source of Risk	***Environmental Value Potentially Impacted***							***Evaluation***						
	Soil and Groundwater	**Marine Sediment**	**Water Quality**	**Air Quality (incl. Odour)**	**Ecosystems/Habitat**	**Species**	**Socio-Economic**	**Decision Type**	**Consequence/Impact**	**Likelihood**	**Risk Rating**	**ALARP Tools**	**Acceptability**
Hydrocarbon release from subsea equipment to the marine environment and atmosphere.		X	X	X	X	X	X	B	B	1	M	LCS GP PJ RBA CV	Acceptable if ALARP
Hydrocarbon release from topsides equipment to the marine environment and atmosphere.		X	X	X	X	X	X	B	C	1	M		

Description of Source of Risk

Lifting activities on the NRC can take place on NRA or NRB from one of a number of platform cranes between supply vessels and laydown areas or between laydown areas. There are three cranes on NRA and two on NRB.
The sources of hazard associated with MEE-06 are lifting operations performed using the NRA, NRB or visiting vessel cranes that could potentially lead to dropped objects impacting assets (NRA, NRB, bridges, subsea infrastructures) inside the NRC 500m zone.

Loss of suspended load has been identified as a MEE (MEE-06). A loss of suspended load may arise from:

- collision of cranes
- lifting equipment failure
- facility lifting operations.

A number of common failure causes due to human error and Safety Critical Equipment (SCE) failures are presented in the generic Human Error and SCE failure bowties.

Loss of Suspended Load – Credible Hydrocarbon Spill Scenario

The identified outcome of this MEE is a loss of containment of hydrocarbons due to impact of a dropped object on topsides equipment or subsea pipelines resulting in a release of the hydrocarbon inventory to the atmosphere or the marine environment; **(**MEE-02 – Subsea Equipment Loss of Containment) and (MEE-03 - Topsides Loss of Containment) for a description of these credible loss of containment scenarios. It is not considered credible that loss of control of suspended load during topsides lifting operations will result in a MEE from the platform wells or pipeline loss of containment.

Decision Type

A decision type ‘B’ has been applied to this risk under the Guidance on Risk Related Decision Making (Oil and Gas UK 2014). This reflects the complexity of the risk, the higher potential consequence and stakeholder implications should the event be realised. To align with this decision type, a further level of analysis has been applied using risk-based tools including the Bowtie methodology and hydrocarbon spill trajectory modelling. Company values were also considered in the demonstration of ALARP and acceptability.

The release of hydrocarbons as a result of subsea loss of containment is considered a Major Environment Event (MEE-02). The hazard associated with this MEE is hydrocarbons in subsea infrastructure (flowlines, manifolds etc.) tied to, or originating from, the NRC.

Quantitative Spill Risk Assessment

Credible worst-case hydrocarbon Scenarios 3 (MEE-02) and 4 (MEE-03) are considered to apply to the potential loss of containment that may occur in the event of a loss of a suspended load.

Likelihood

In accordance with the Woodside Risk Matrix, a likelihood of 'highly unlikely' event as it 'has occurred once or twice in the industry' (experience-based likelihood) and aligns with a frequency of a '1 in 10,000 to 1 in 100,000 year' has been assigned to each of the following events: • hydrocarbon release from subsea equipment to the marine environment and atmosphere • hydrocarbon release from topsides equipment to the marine environment and atmosphere. ***Consequence*** The spatial extent and fate (incl. weathering) of the spilled hydrocarbon were considered during the impact assessment for a worst-case loss of suspended load. These considerations were informed primarily by the outputs from the numerical modelling studies undertaken by RPS, available information on environmental sensitivities that may credibly be impacted in the event of a worst-case spill and relevant literature and studies considering the effects of hydrocarbon exposure.
Consequence Assessment
As discussed under Description of Source of Risk, the potential impacts from hydrocarbon release caused by a loss of structural integrity are those which would result from: • subsea Equipment Loss of Containment, (MEE-02) • topsides Loss of Containment, (MEE-03). The potential impacts are therefore discussed in the above-mentioned sections.
Summary of Control Measures
• Maintain platform lifting equipment to prevent platform lifting equipment failure or dropped/swinging loads that could result in a MEE • Maintain structural integrity (impact protection) to ensure availability of critical systems during a major accident or environment event and prevent structural failures from contributing to escalation of a MEE • Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC • Incident reports are raised for unplanned releases within event reporting system.

MEE Common Cause Event failure mechanisms: SCE Failure CCE-01 and Human Error CCE-02

This section presents common mode failure causes and controls applicable across MEEs, which are also observed within the bowties of the MEEs discussed within sections above. Controls, EPSs and MCs presented within this section are also considered relevant to MEE-01 to MEE-06.

NRC: Major Environmental Event Datasheet	
MEE Number	ALL
Hazard Description	Generic Safety Critical Equipment failure (CCE-01)

HAZARD DESCRIPTION

Hazard Overview and Scope

There are a number of causes which contribute to failures of SCEs and other systems which might protect against an MEE. These include:

- maintenance errors
- defects
- electrical supply failure
- hydraulic supply failure
- adverse environmental conditions.

The generic SCE failure bowties illustrates the causes, outcomes and the controls in place to manage these failure mechanisms.

Summary of Control Measures

- Maintaining hydraulic supplies (e.g. to support Safety Instrumented Systems and actuation of SCE valves/isolations). Integrity will be managed in accordance with SCE Management Procedure and SCE Technical Performance Standard(s) to prevent environment risk related Damage to SCEs for:
  - F06 – Safety Instrumented System
- Maintaining protection from environmental conditions. Integrity will be managed in accordance with SCE Management Procedure and SCE Technical Performance Standard(s) to prevent environment risk related Damage to SCEs for:
  - P01 – Pressure Vessels
  - P02 – Heat Exchanger
  - P03 – Rotating Equipment
  - P07 – Topsides/Surface Structures
  - P08 – Piping Systems
  - P09 – Pipeline Systems
  - P10 – Wells
  - P21 – Substructures
- Maintaining UPS/emergency power system to supply essential safety systems. Integrity will be managed in accordance with SCE Management Procedure and SCE Technical Performance Standard(s) to prevent environment risk related Damage to SCEs for:
  - F25 – UPS/Emergency Power
- Maintaining climate-controlled enclosures to protect essential equipment from adverse environmental conditions. Integrity will be managed in accordance with SCE Management Procedure and SCE Technical Performance Standard(s) to prevent environment risk related Damage to SCEs for:
  - E02 – Safety Critical Buildings
- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009: Accepted Safety Case for the NRC facility.

NRC: Major Environmental Event Datasheet	
MEE Number	ALL
Hazard Description	Generic Safety Critical Equipment failure (CCE-01)
There are a number of causes of human errors which contribute to MEEs, or which can result in failure or degradation of the barriers in place to protect against MEEs. These are presented in the following bowtie pages and include: • task issues (e.g. poor task design; time pressures, task complexity) • poor physical interfaces/working environment • provision of inappropriate tools for the task • communication errors (i.e. poor quality information, lack of clarity in instructions) • operator failings (e.g. competence, fitness, impairment or fatigue) • organisational issues (e.g. peer pressure, poor safety culture, inadequate supervision, lack of clarity on roles and expectations). The Generic Human Errors bowtie illustrates the causes, outcomes and the barriers in place for these failure mechanisms. Human Errors are managed solely via the WMS (no SCEs) and the bowtie is included in this section for completeness.	

APPENDIX B: CONTROL MITIGATION MEASURES FOR POTENTIAL ENVIRONMENTAL IMPACTS ASSOCIATED WITH SPILL RESPONSE ACTIVITIES

Response activities can introduce new impacts and risks. Therefore, it is necessary to complete an environmental risk assessment process to ensure impacts and risks from response activities have been considered, practical control measures are in place to minimise impacts and risks to ALARP. A simplified assessment process has been used to complete this task which covers the identification, analysis, evaluation and treatment of impacts and risks introduced by responding to the event.

Identification of impacts and risks from implementing response strategies

Each of the control measures can modify the impacts and risks identified in the EP. These impacts and risks have been previously assessed within the scope of the EP. Refer to the EP for details regarding how these risks are being managed. They are not discussed further in this document.

- *atmospheric emissions*
- *routine and non-routine discharges*
- *physical presence, proximity to other vessels (shipping and fisheries)*
- *routine acoustic emissions vessels*
- *lighting for night work/navigational safety*
- *invasive marine species*
- *collision with marine fauna*
- *disturbance to seabed.*

Additional impacts and risks associated with the control measures not included within the scope of the EP but discussed below include:

- *vessel operations and anchoring*
- *presence of personnel on the shoreline*
- *human presence (manual cleaning)*
- *vegetation cutting*
- *additional stress or injury caused to wildlife*
- *secondary contamination from the management of waste.*

Analysis of impacts and risks from implementing response strategies

The table below compares the adopted control measures for this oil spill response activity against the environmental values that can be affected when they are implemented.

Table 12-21: Analysis of risks and impacts

	Environmental Value						
	Soil & Groundwater	Marine Sediment Quality	Water Quality	Air Quality	Ecosystems/ Habitat	Species	Socio-Economic
Monitor and evaluate		✓	✓		✓	✓	
Source control		✓	✓		✓	✓	✓
Containment and Recovery			✓	✓	✓	✓	✓
Shoreline Protection & Deflection	✓	✓	✓		✓	✓	✓

Shoreline Clean-up	✓	✓	✓		✓	✓	✓
Oiled Wildlife					✓	✓	
Scientific Monitoring	✓	✓	✓	✓	✓	✓	✓
Waste Management	✓			✓	✓	✓	✓

Evaluation of impacts and risks from implementing response strategies

Vessel operations and anchoring

Typical booms used in containment and recovery operations are designed to float, meaning that fauna capable of diving, such as cetaceans, marine turtles and sea snakes can readily avoid contact with the boom. Impacts to species that inhabit the water column such as sharks, rays and fish are not expected. Additionally, some fauna, such as cetaceans, are likely to detect and avoid the spill area, and are not expected to be present in the proximity of containment and recovery operations.

During the implementation of response strategies, where water depths allow, it is possible that response vessels will be required to anchor (e.g. during shoreline surveys). The use of vessel anchoring will be minimal and likely to occur when the impacted shoreline is inaccessible via road. Anchoring in the nearshore environment of sensitive receptor locations will have the potential to impact coral reef, seagrass beds and other benthic communities in these areas. Recovery of benthic communities from anchor damage depends on the size of anchor and frequency of anchoring. Impacts would be highly localised (restricted to the footprint of the vessel anchor and chain) and temporary, with full recovery expected.

Presence of personnel on the shoreline

Presence of personnel on the shoreline during shoreline operations could potentially result in disturbance to wildlife and habitats. During the implementation of response strategies, it is possible that personnel may have minimal, localised impacts on habitats, wildlife and coastlines. The impacts associated with human presence on shorelines during shoreline surveys may include:

- damage to vegetation/habitat to gain access to areas of shoreline oiling
- damage or disturbance to wildlife during shoreline surveys
- removal of surface layers of intertidal sediments (potential habitat depletion)
- excessive removal of substrate causing erosion and instability of localised areas of the shoreline.

Human presence

Human presence for manual clean-up operations may lead to the compaction of sediments and damage to the existing environment especially in sensitive locations such as mangroves and turtle nesting beaches. However, any impacts are expected to be localised with full recovery expected.

Waste generation

Implementing the selected response strategies will result in the generation of the following waste streams that will require management and disposal:

- Liquids (recovered oil/water mixture), recovered from containment and recovery and shoreline cleanup operations
- Semi-solids/solids (oily solids), collected during containment and recovery and shoreline cleanup operations
- Debris (e.g. seaweed, sand, woods, plastics), collected during containment and recovery and shoreline cleanup operations and oiled wildlife response.

If not managed and disposed of correctly, wastes generated during the response have the potential for secondary contamination similar to that described above, impacts to wildlife through contact with or ingestion of waste materials and contamination risks if not disposed of correctly onshore. Woodside's waste management strategy to manage the potential volumes of waste generated by the selected response strategies

Cutting back vegetation could allow additional oil to penetrate the substrate and may also lead to localised habitat loss. However, any loss is expected to be localised in nature and lead to an overall net environmental benefit associated with the response by reducing exposure of wildlife to oiling.

Additional stress or injury caused to wildlife

Additional stress or injury to wildlife could be caused through the following phases of a response:

- capturing wildlife
- transporting wildlife
- stabilisation of wildlife
- cleaning and rinsing of oiled wildlife
- rehabilitation (e.g. diet, cage size, housing density)
- release of treated wildlife.

Inefficient capture techniques have the potential to cause undue stress, exhaustion or injury to wildlife, additionally pre-emptive capture could cause undue stress and impacts to wildlife when there are uncertainties in the forecast trajectory of the spill. During the transportation and stabilisation phases there is the potential for additional thermoregulation stress on captured wildlife. Additionally, during the cleaning process, it is important personnel undertaking the tasks are familiar with the relevant techniques to ensure that further injury and the removal of water proofing feathers are managed and mitigated. Finally, during the release phase it's important that wildlife is not released back into a contaminated environment.

Treatment of impacts and risks from implementing response strategies

In respect of the impacts and risks assessed the following treatment measures have been adopted. It must be recognised that this environmental assessment is seeking to identify how to maintain the level of impact and risks at levels that are ALARP and of an acceptable level rather than exploring further impact and risk reduction. It is for this reason that the treatment measures identified in this assessment will be captured in Operational Plans, Tactical Response Plans, and/or First Strike Response Plans.

Vessel operations and access in the nearshore environment

- personnel on watch for wildlife during containment and recovery operations
- existing mooring points would be used for anchoring
- where existing fixed anchoring points are not available, locations will be selected to minimise impact to nearshore benthic environments with a preference for areas of sandy seabed where they can be identified
- shallow draft vessels will be used to access remote shorelines to minimise the impacts associated with seabed disturbance on approach to the shorelines.

Presence of personnel on the shoreline

- oversight by trained personnel who are aware of the risks
- trained unit leader's brief personnel of the risks prior to operations.

Human Presence

- shoreline access route (foot, car, vessel and helicopter) with the least environmental impact identified will be selected by a specialist in SCAT operations
- vehicular access will be restricted on dunes, turtle nesting beaches and in mangroves.

Waste generation

- zoning of response locations to prevent secondary contamination and minimize the mixing of clean and oiled sediment and shoreline substrates
- limiting vegetation removal to only that vegetation that has been moderately or heavily oiled.

Additional stress or injury caused to wildlife

- operations conducted with advice from the DBCA Oiled Wildlife Advisor and in accordance with the processes and methodologies described in the WA OWRP and the relevant regional plan.

APPENDIX C: SUMMARY OF STAKEHOLDER FEEDBACK AND WOODSIDE'S RESPONSE

Relevant Stakeholder feedback for the Petroleum Activities Program

Organisation	Method	Feedback	Woodside assessment	Woodside's response
Department of Industry, Innovation and Science	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Department of Mines, Industry Regulation and Safety	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Australian Maritime Safety Authority	Email with vessel traffic map and Information Sheet sent on 9 January 2019.	**Date:** 14 January 2019 **Feedback summary:** AMSA advised it had no comment on the revision to the Environment Plan for the North Rankin Complex operations. AMSA also provided AIS spatial data from September to November 2018 and noted heavy traffic around the shipping fairways.	The stakeholder raised no claims or objections.	**Response/Action:** No further action.
Australian Hydrographic Office	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.

Organisation	Method	Feedback	Woodside assessment	Woodside's response
Department of Primary Industries and Regional Development	Email with State fisheries map and Information Sheet sent on 9 January 2019.	**Date:** 17 January 2019 **Feedback summary:** The Department advised it had no comment on the revision to the Environment Plan for the North Rankin Complex operations.	The stakeholder raised no claims or objections.	**Response/Action:** No further action.
Commonwealth Fisheries Association	Email with Commonwealth fisheries map and Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Western Australian Fishing Industry Council (WAFIC)	Email with State fisheries map and Information Sheet sent on 9 January 2019.	**Date:** 9 January 2019 **Feedback summary:** WAFIC referenced advice to previous consultation by Woodside for the drilling of production well PLA07 in WA-34-L and advised it could not comment on the activity as the stakeholder covering email and information sheet did not contain information relevant to commercial fishers. WAFIC also sought a response for NRC as per points it raised as part of consultation by Woodside for the drilling of production well PLA07 in WA-34-L.	Woodside acknowledged WAFIC's requirement with respect to content and presentation of consultation material to commercial fishers. On 14 March 2019, Woodside emailed WAFIC, providing specific information relevant to commercial fishers in line with WAFIC's request. Woodside provided 32 days for WAFIC to provide feedback on the updated consultation information. Woodside acknowledges WAFIC's claim that four weeks is insufficient time for	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.

Organisation	Method	Feedback	Woodside assessment	Woodside's response
		WAFIC provided guidance on content and presentation of consultation material to commercial fishers. WAFIC advised that a four-week consultation period was insufficient to allow responses from stakeholders.	commercial fishers to provide feedback. Woodside believes that the consultation time provided to be appropriate given the unchanged nature of operational activities since the Environment Plan was revised and accepted by NOPSEMA in April 2017.	
Department of Transport	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
	Email with First Strike Plan sent 16 April 2019.	**Feedback summary:** No response received at time of EP submission	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Department of Agriculture and Water Resources	Email with information sheet and fisheries map send on 19 June 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 29 June 2019.	The stakeholder raised no claims or objectives	**Response/Action** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Director National Parks	Email with Information Sheet sent on 20 March 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 18 April 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the

Organisation	Method	Feedback	Woodside assessment	Woodside's response
				assessment of this EP and throughout the duration of the accepted EP.
Vermilion Oil and Gas Australia	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Carnarvon Petroleum	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Quadrant North West	Email with Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.

Organisation	Method	Feedback	Woodside assessment	Woodside's response
Western Australian Fisheries (licence holders) - Mackerel Fishery - Pearl Oyster - Specimen Shell - Marine Aquarium Fish - Onslow Prawn - Pilbara Fish Trawl - Pilbara Fish Trap - Pilbara Line Fishery	Letter with State fisheries map and Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.
Commonwealth Fisheries - Western Skipjack Fishery - Western Tune and Billfish Fishery - Southern Bluefin Tuna Fishery	Email sent to Commonwealth Fisheries Association with Commonwealth fisheries map and Information Sheet sent on 9 January 2019.	**Feedback summary:** No response at the closing time for stakeholder feedback on 7 February 2019.	The stakeholder raised no claims or objections.	**Response/Action:** Woodside will continue to accept feedback from all stakeholders during the assessment of this EP and throughout the duration of the accepted EP.